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— JENDL-3 —

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Japanese Evaluated Nuclear Data Library, Version-3 — JENDL-3

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Abstract

The general purpose file of the third version of Japanese Evaluated Nuclear Data Library, JENDL-3, has been compiled by the JAERI Nuclear Data Center in cooperation with the Japanese Nuclear Data Committee. It contains neutron nuclear data for 171 nuclides which are needed for design of fission and fusion reactors and for shielding calculation. In the JENDL-3 evaluation, much effort was devoted to improve reliability of high-energy data for fusion application and to include gamma-ray production data. Theoretical calculations played an important role in achieving these purposes. A special method called simultaneous evaluation was adopted to determine important cross sections of fissile and fertile nuclides. This report presents a general description for the evaluation of light, medium-heavy and heavy nuclide data. Also given are the descriptive data for each nuclide contained in the File 1 part of JENDL-3.

Keywords: JENDL-3, Neutron Nuclear Data, Nuclear Data Library, Evaluation, Data Compilation, Cross Section, Calculation, Fission Reactors, Fusion Reactors, Shielding

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* Nuclear Energy Data Center

日本の評価済み核データライブラリー，第3版
－JENDL-3－

日本原子力研究所シグマ研究委員会
JENDL－3編集グループ

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日本の評価済み核データライブラリーの第3版JENDL－3の汎用ファイルがシグマ研究委員会の協力の基に原研核データセンターにより編集された。この汎用ファイルは，核分裂炉，核融合炉の設計や遮蔽計算に必要な171核種の中性子核データを収納している。JENDL－3作成に於いては，核融合への適応を考慮して高エネルギーデータの精度改善及びガンマ線生成データの評価に注意を払った。その際，理論計算は重要な役割を果たした。また，重要な核分裂性核種及び親物質の断面積の決定には，同時評価と呼ばれる評価手法を用いた。本報告書では，軽核，中重核，重核の評価方法の概要が記述されている。また，付録には，JENDL－3のFile 1にあるコメント・データを核種毎に掲げた。

*（財）原子力データセンター

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1. Introduction

Evaluated nuclear data libraries are requisite for nuclear engineering such as design of nuclear reactors and shielding calculation. The first version of Japanese Evaluated Nuclear Data Library, JENDL-1[1,2], was compiled in 1977 in cooperation with the Japanese Nuclear Data Committee (JNDC). It contained 72 nuclides required for fast reactor calculation. The second version, JENDL-2[3], made in 1982 was applicable not only to fast reactor but also to thermal reactor and shielding calculation. However, it was pointed out that applicability of JENDL-2 to fusion neutronics was unsatisfactory.

Under such a situation, the JAERI Nuclear Data Center and JNDC started evaluation and compilation work for the third version, JENDL-3, in April 1982. Main purpose for making JENDL-3 is to remedy the defects of JENDL-2 as pointed out in benchmark tests, to add gamma-ray production cross sections, to evaluate nuclear data in higher energy region as precisely as possible, and to make it a large general purpose nuclear data library which is applicable to fusion neutronics calculation as well as the fast reactor, thermal reactor and shielding calculations. In 1987, a temporary version, JENDL-3T, was offered for use in the various benchmark tests to check its applicability. The defects pointed out in the benchmark tests were carefully examined and a slight modification was made. The results of the benchmark tests are reviewed in Ref. 4. The general purpose file (GPF) of JENDL-3 was finally compiled in October 1989 within the framework of the ENDF-5 format[5]. The GPF of JENDL-3 includes 171 nuclides, 59 out of which have gamma-ray production data, as given in **Table 1**.

Several computer codes were made ready for the JENDL-3 evaluation. To calculate cross sections for direct, preequilibrium and multi-step compound nuclear processes, some existing nuclear model codes such as ECIS[6], DWUCK4[7], GNASH[8] and TNG[9] were made available in JAERI. A preequilibrium and multi-step evaporation model code, PEGASUS[10], was developed for calculating multi-particle emission cross sections. For the evaluation of resonance cross sections for light nuclide, a code based on the R-matrix theory, RESCAL[11], was made. Double differential cross sections (DDXs) are important for fusion neutronics calculation. To generate and/or analyze DDX, two computer codes, FAIRDDX[12] and DDXPLOT[13], were developed. With these tools, the evaluation for JENDL-3 was made efficiently and precisely.

This report presents a brief description of the evaluation methods for making the GPF of JENDL-3. In Chapter 2, a general description is given for light nuclide, medium-heavy nuclide and heavy nuclide data. Appendix deals with the descriptive data for each nuclide contained in the File 1 part of JENDL-3.

Table 1 Nuclides contained in the general purpose file of JENDL-3.

Tape No.	No.	Nuclide	MAT No.	Records
301	1	$^{1}H^{*}$	3011	277
	2	^{2}H	3012	1103
	3	^{3}He	3021	456
	4	^{4}He	3022	1272
	5	$^{6}Li^{*}$	3031	2297
	6	$^{7}Li^{*}$	3032	3523
	7	$^{9}Be^{*}$	3041	2702
	8	$^{10}B^{*}$	3051	3705
	9	$^{11}B^{*}$	3052	5136
	10	$^{12}C^{*}$	3061	2026
	11	$^{14}N^{*}$	3071	4302
	12	$^{15}N^{*}$	3072	2970
	13	$^{16}O^{*}$	3081	5475
	14	^{19}F	3091	1455
	15	$^{23}Na^{*}$	3111	4709
	16	Mg^{*}	3120	4252
	17	^{24}Mg	3121	1584
	18	^{25}Mg	3122	2046
	19	^{26}Mg	3123	1677
	20	$^{27}Al^{*}$	3131	4982
	21	Si^{*}	3140	8719
	22	$^{28}Si^{*}$	3141	4184
	23	$^{29}Si^{*}$	3142	5018
	24	$^{30}Si^{*}$	3143	3824
	25	^{31}P	3151	1326
	26	S	3160	3955
	27	^{32}S	3161	1470
	28	^{33}S	3162	1231
	29	^{34}S	3163	1239
	30	^{36}S	3164	1034
	31	K	3190	2887

Table 1 (continued)

Tape No.	No.	Nuclide	MAT No.	Records
301	32	^{39}K	3191	1233
	33	^{40}K	3192	1190
	34	^{41}K	3193	1088
	35	Ca*	3200	5639
	36	^{40}Ca*	3201	3757
	37	^{42}Ca	3202	1784
	38	^{43}Ca	3203	1758
	39	^{44}Ca	3204	1781
	40	^{46}Ca	3205	632
	41	^{48}Ca	3206	1528
	42	^{45}Sc	3211	2204
	43	Ti*	3220	5250
	44	^{46}Ti	3221	2083
	45	^{47}Ti	3222	1672
	46	^{48}Ti	3223	2441
	47	^{49}Ti	3224	1582
	48	^{50}Ti	3225	1700
	49	^{51}V	3231	3007
			(Total	131165)
302	1	Cr*	3240	9164
	2	^{50}Cr	3241	2378
	3	^{52}Cr	3242	3740
	4	^{53}Cr	3243	3454
	5	^{54}Cr	3244	2287
	6	^{55}Mn*	3251	20461
	7	Fe*	3260	8817
	8	^{54}Fe*	3261	4878
	9	^{56}Fe*	3262	6033
	10	^{57}Fe*	3263	5176
	11	^{58}Fe*	3264	4090

Table 1 (continued)

Tape No.	No.	Nuclide	MAT No.	Records
302	12	^{59}Co	3271	3663
	13	Ni*	3280	8004
	14	^{58}Ni*	3281	3526
	15	^{60}Ni*	3282	3732
	16	^{61}Ni	3283	2119
	17	^{62}Ni	3284	2247
	18	^{64}Ni	3285	2137
			(Total	95906)
303	1	Cu*	3290	5827
	2	^{63}Cu*	3291	5977
	3	^{65}Cu*	3292	5766
	4	Zr*	3400	8530
	5	^{90}Zr	3401	1781
	6	^{91}Zr	3402	1950
	7	^{92}Zr	3403	2091
	8	^{94}Zr	3405	1818
	9	^{96}Zr	3407	1410
	10	^{93}Nb*	3411	6482
	11	Mo*	3420	8745
	12	^{92}Mo	3421	1516
	13	^{94}Mo	3422	1838
	14	^{95}Mo	3423	2426
	15	^{96}Mo	3424	1960
	16	^{97}Mo	3425	2499
	17	^{98}Mo	3426	2225
	18	^{100}Mo	3428	2073
	19	Ag*	3470	9276
	20	^{107}Ag*	3471	6927
	21	^{109}Ag*	3472	6646
	22	Cd*	3480	9487

Table 1 (continued)

Tape No.	No.	Nuclide	MAT No.	Records
303	23	Sb	3510	3575
	24	^{121}Sb	3511	2216
	25	^{123}Sb	3512	2035
	26	Eu*	3630	7746
	27	^{151}Eu	3631	4558
	28	^{153}Eu	3633	4647
			(Total	122027)
304	1	Hf*	3720	6645
	2	^{174}Hf*	3721	4208
	3	^{176}Hf*	3722	5185
	4	^{177}Hf*	3723	4990
	5	^{178}Hf*	3724	4855
	6	^{179}Hf*	3725	4404
	7	^{180}Hf*	3726	3935
	8	^{181}Ta*	3731	4615
	9	W*	3740	8044
	10	^{182}W	3741	3024
	11	^{183}W	3742	3409
	12	^{184}W	3743	3239
	13	^{186}W	3744	3400
	14	Pb*	3820	6595
	15	^{204}Pb*	3821	2709
	16	^{206}Pb*	3822	4030
	17	^{207}Pb*	3823	3891
	18	^{208}Pb*	3824	3959
	19	^{209}Bi*	3831	4225
			(Total	85362)
305	1	^{223}Ra	3881	1273
	2	^{224}Ra	3882	1065

Table 1 (continued)

Tape No.	No.	Nuclide	MAT No	Records
305	3	^{225}Ra	3883	843
	4	^{226}Ra	3884	1383
	5	^{225}Ac	3891	608
	6	^{226}Ac	3892	564
	7	^{227}Ac	3893	986
	8	^{227}Th	3901	627
	9	^{228}Th	3902	1557
	10	^{229}Th	3903	817
	11	^{230}Th	3904	1511
	12	^{232}Th	3905	6264
	13	^{233}Th	3906	1806
	14	^{234}Th	3907	1877
	15	^{231}Pa	3911	1752
	16	^{232}Pa	3912	678
	17	^{233}Pa	3913	1666
	18	^{232}U	3921	1329
	19	^{233}U	3922	9216
	20	^{234}U	3923	2829
	21	$^{235}U^{*}$	3924	11021
	22	^{236}U	3925	4432
	23	$^{238}U^{*}$	3926	9794
	24	^{237}Np	3931	4748
	25	^{239}Np	3932	900
			(Total	69546)
306	1	^{236}Pu	3941	1018
	2	^{238}Pu	3942	2416
	3	$^{239}Pu^{*}$	3943	10073
	4	^{240}Pu	3944	7452
	5	^{241}Pu	3945	5635
	6	^{242}Pu	3946	4102

Table 1 (continued)

Tape No.	No.	Nuclide	MAT No.	Records
306	7	^{241}Am	3951	1937
	8	^{242}Am	3952	1594
	9	^{242m}Am	3953	2193
	10	^{243}Am	3954	1590
	11	^{244}Am	3955	2219
	12	^{244m}Am	3956	2233
	13	^{241}Cm	3961	862
	14	^{242}Cm	3962	950
	15	^{243}Cm	3963	1811
	16	^{244}Cm	3964	1444
	17	^{245}Cm	3965	2898
	18	^{246}Cm	3966	2316
	19	^{247}Cm	3967	1873
	20	^{248}Cm	3968	1121
	21	^{249}Cm	3969	1227
	22	^{250}Cm	3970	808
	23	^{249}Bk	3971	1868
	24	^{250}Bk	3972	1932
	25	^{249}Cf	3981	1671
	26	^{250}Cf	3982	2225
	27	^{251}Cf	3983	2144
	28	^{252}Cf	3984	1294
	29	^{254}Cf	3985	765
	30	^{254}Es	3991	755
	31	^{255}Es	3992	868
	32	^{255}Fm	3995	751
			(Total	72045)

*) Gamma-ray production data are included.

2. General Description for Evaluation

2.1 Light nuclide data

The nuclides with mass number less than 20 are considered as light nuclides. In JENDL-3, included are 14 nuclides from ^{1}H to ^{19}F in this region. The evaluation method is briefly described in this section.

Hydrogen

The elastic scattering cross section of ^{1}H was evaluated on the basis of the effective range theory using the parameters of Poenitz and Whalen[14] below 100 keV, and in the energy region above 100 keV the JENDL-2 data[3] were adopted. As for ^{2}H, the JENDL-2 data[15] were recommended without any modifications.

Helium

The total, elastic scattering and (n,p) reaction cross sections of ^{3}He in the energy region below 1 MeV were calculated[16] by the RESCAL code based on the R-matrix theory. The evaluated (n,p) reaction cross section of ^{3}He, which is considered as a standard below 50 keV, was found to be consistent with the latest measurements of Borzakov et al.[17] The total and elastic scattering cross sections of ^{4}He were also analyzed[16] with the R-matrix theory in the energy region from 10^{-5} eV to 20 MeV.

Lithium

Lithium is a candidate for the fusion-blanket material and thus its tritium-production cross section is important. The (n,t) reaction cross section of ^{6}Li was evaluated[18] with the R-matrix theory below 1 MeV, and the cross sections above 1 MeV were obtained by the spline-function fitting to experimental data with the least-squares method.

The tritium-production cross section of ^{7}Li was evaluated[19] in 1984. After that, however, some modifications were made[20] because the new measurements[21-24] were made available. The 14-MeV cross section of JENDL-3 is by 10% smaller than that of ENDF/B-IV, as seen in **Fig. 2.1.1**.

Energy distributions of continuum neutrons for both isotopes were calculated[20] with the phase-space model, and they were given by about 30 pseudo levels in actual data-file. It is found from **Fig. 2.1.2** that the DDXs of natural lithium calculated from JENDL-3 are in good agreement with the measurements of Takahashi et al.[25]

Beryllium

The (n,2n) reaction cross section of ^{9}Be, which is important for neutron multiplication in the fusion reactors, was evaluated on the basis of available experimental data. Its 14-MeV cross section was based on the measurement of Takahashi et al.[26] and Baba et al.[27], and found to be by 4% smaller than that of JENDL-2. This result is consistent with the data of ENDF/B-VI. According to the analyses[28] of the integral measurements using 14 MeV neutrons, however, it was pointed out that existing nuclear data libraries overestimated the measured neutron multiplication. This inconsistency would still remain even though the JENDL-3 data were used for the analyses. At the present time it is unlikely that the 14-MeV cross section for the $^{9}Be(n,2n)$ reaction lowers.

Carbon

The total cross section of ^{12}C below 4.8 MeV calculated[29] using the RESCAL code, and was evaluated on the basis of available experimental data above 4.8 MeV. Three discrete levels up to an excitation energy of 9.6 MeV were taken into account for the inelastic scattering.

Fluorine

The JENDL-2 data[3] were adopted for JENDL-3 except that the total cross section above 100 keV was modified on the basis of the measurements of Larson et al.[30]

Boron, Nitrogen and Oxygen

The cross sections of these nuclides were evaluated[31-33] with the R-matrix theory, statistical model and direct reaction theory. The (n,α_0) and (n,α_1) channels were separately considered for the $^{10}B(n,\alpha)$ reaction cross section which is regarded as a standard below 100 keV.

2.2 Medium-heavy nuclide data

The nuclides between Na and Bi are regarded as medium-heavy nuclides. This region includes the nuclides which are constituents of structural materials for the fission and fusion reactors.

Theoretical Calculation

Theoretical calculations[34-36] play the important role in the evaluation of medium-heavy nuclides. In the JENDL-3 evaluation, the nuclear-model codes mentioned in Chapter 1 were employed, together with the statistical-model code CASTHY[37]. The preequilibrium and direct reaction processes were taken into account in order to raise the reliability of the evaluated data in the MeV region. As an example, the DDXs for natural iron calculated at 14 MeV are illustrated in **Fig. 2.2.1**, together with the measurements of Takahashi et al.[26] It is found from the figure that the DDXs calculated from JENDL-3 are in good agreement with the experimental data, whereas those of JENDL-2 underestimate the inelastic scattering above 6 MeV.

In the theoretical calculation, various parameters are required as input to the computer codes; optical-model potential parameters, level density parameters and information on nuclear level scheme. These parameters were determined on the basis of experimental data. In most cases, the formula of Gilbert and Cameron[38] was employed for the level density. In the evaluation of lead, however, the formula of Ignatyuk et al.[39] was used in order to consider the shell effects on the Fermi-gas parameter.

Total Cross Section

Resonance structures are found up to several MeV in the total cross sections of structural materials. It is required to reproduce these structures for the shielding calculation. Thus, the high resolution experimental data were traced by using the Neutron Data Evaluation System (NDES)[40]. Normalization was made[35] for Cr, Fe and Ni by using the energy-average experimental data. ***Figure* 2.2.2** shows the total cross section of natural iron averaged over 0.5 MeV.

Threshold Reaction Cross Section

The threshold-reaction cross sections are important as the nuclear data for fusion and dosimetry applications. In most cases, they were calculated with the statistical model including preequilibrium effects, and normalized to reliable experimental data if it was necessary.

The (n,2n) reaction cross section of lead is important for neutron multiplication in the fusion blanket. A discrepancy in the measurements still exists by as much as 20% at 14 MeV. In the JENDL-3 evaluation, the cross sections were calculated by the GNASH code and normalized to 2.184 barns at 14 MeV, which is the average value of several measurements[41-44]. **Figure 2.2.3** shows the evaluated results.

Helium-production cross sections are needed for the neutron damage study. **Figure 2.2.4** shows the helium-production cross sections of Cr, Fe and Ni. The JENDL-3 data agree well with the experimental data.

Gamma-Ray Production Cross Section

The gamma-ray production cross sections and spectra for medium-heavy nuclides were calculated by the statistical-model codes such as GNASH and TNG, whereas those for light nuclides were mainly obtained from the experimental data on discrete gamma-ray intensities. In the nuclear-model calculation, three types of transitions were considered, i.e., E1, E2 and M1. The calculated spectra were found to be very sensitive to the discrete levels and level density parameters required as input to the codes. In the MeV region, the calculations are almost consistent with the measurements performed at the Oak Ridge Electron Linear Accelerator Laboratory, as seen in **Fig. 2.2.5**. At the thermal neutron energy, however, the calculated results for several nuclides disagreed with the data measured by Maerker[45] using the Oak Ridge Tower Shielding Facility. Thus, the thermal cross sections and spectra were evaluated by adopting available experimental data. **Figure 2.2.6** shows the evaluated thermal gamma-ray spectrum for iron which was based on the gamma-ray intensity data contained in Evaluated Nuclear Structure Data File (ENSDF)[46], together with the measurements of Maerker.

2.3 Heavy nuclide data

Fifty-seven nuclides between ^{223}Ra and ^{225}Fm are contained in JENDL-3 as heavy nuclides.

Simultaneous Evaluation

Important cross sections of fissile and fertile nuclides were simultaneously evaluated[47] by taking account of the ratio measurements such as $\sigma_f(^{239}\text{Pu})/\sigma_f(^{235}\text{U})$ as well as the absolute measurements in the energy region above 50 keV. The cross sections obtained in the simultaneous evaluation are the fission cross sections of ^{235}U, ^{238}U, ^{239}Pu, ^{240}Pu and ^{241}Pu and the capture cross section of ^{238}U, together with the capture cross section of ^{197}Au which was used as a standard. These cross sections were determined by the generalized least-squares method using the B-spline function. The measurements after 1970 were mainly considered for the spline-function fitting. Covariance data required for this method were estimated from the experimental conditions. The evaluated results of ^{235}U and ^{239}Pu are shown in **Fig. 2.3.1**.

Capture Cross Section of ^{238}U

The capture cross section of ^{238}U was obtained by the simultaneous evaluation mentioned above. It was found, however, that the latest measurements of Kazakov et al.[48] were smaller than the results of the simultaneous evaluation in the energy region from 50 keV to 300 keV. The results of the benchmark tests also favored the smaller cross section. Thus, the capture cross section was re-evaluated with much weight on the data of Kazakov et al. It should be noted that the present evaluated data are by 10% smaller than the JENDL-2 data around 100 keV, as seen in **Fig. 2.3.2**.

Resonance Parameters for ^{238}U and ^{239}Pu

Large modification was made for the resonance parameters of ^{238}U and ^{239}Pu.

Concerning ^{238}U, the resolved resonance parameters were determined on the basis of the JENDL-2 data[3] up to 4 keV and of the analyses of Olsen[49] up to 10 keV. As a result, the upper limit of the resolved resonance region was extended to 9.5 keV. Above 1.5 keV, smooth background cross sections were added to the capture cross sections in order to take account of the contribution from the missing p-wave resonances.

As for ^{239}Pu, the resolved resonance parameters were obtained from the analyses of

Derrien and de Saussure[50]. The upper limit of the resolved resonance region is 1 keV, while that of JENDL-2 is 598 eV.

Fission Neutron and Gamma-Ray Spectra

The prompt fission neutron spectra obtained by Madland and Nix[51] were adopted for ^{233}U, ^{234}U, ^{235}U, ^{238}U, ^{239}Pu and ^{240}Pu. This type of spectrum has larger average neutron energy than the Maxwellian and Watt spectra adopted in JENDL-2. The spectra for ^{239}Pu are shown in **Fig. 2.3.3**. The Maxwellian spectra were adopted for the other nuclides.

The prompt fission gamma-ray spectra and multiplicities were obtained from the measurements of Verbinski et al.[52] for ^{235}U, ^{238}U and ^{239}Pu. The non-elastic gamma-ray spectra from the reactions other than fission were calculated by the GNASH code.

Transplutonium Data

In general, the experimental data on transplutonium nuclides are very scarce, and only available are the resonance parameters, the fission and capture cross sections. Therefore, the optical and statistical model code CASTHY was unexceptionally used[53-58] to evaluate the cross sections. The optical-model potential parameters for neutrons were determined[59] so as to reproduce the total cross section of ^{241}Am, and they were used for other transplutonium nuclides with slight modifications.

The fission cross sections were evaluated on the basis of available experimental data, because it was difficult to predict them theoretically. If no measurements are available for fission, the cross section is obtained by considering the systematics of the experimental data for the neighbonng nuclides.

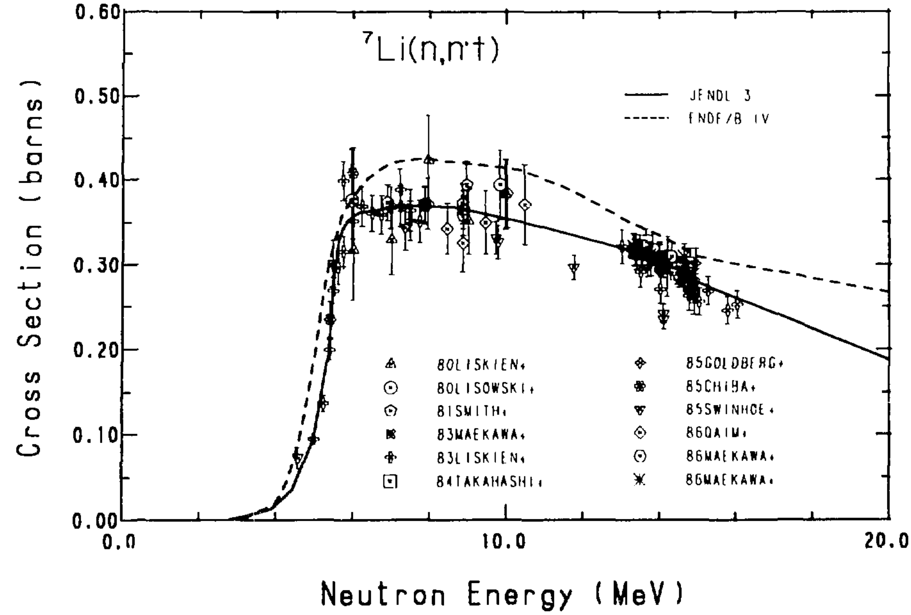

Fig. 2.1.1 ^{7}Li(n,n't)α reaction cross sections.

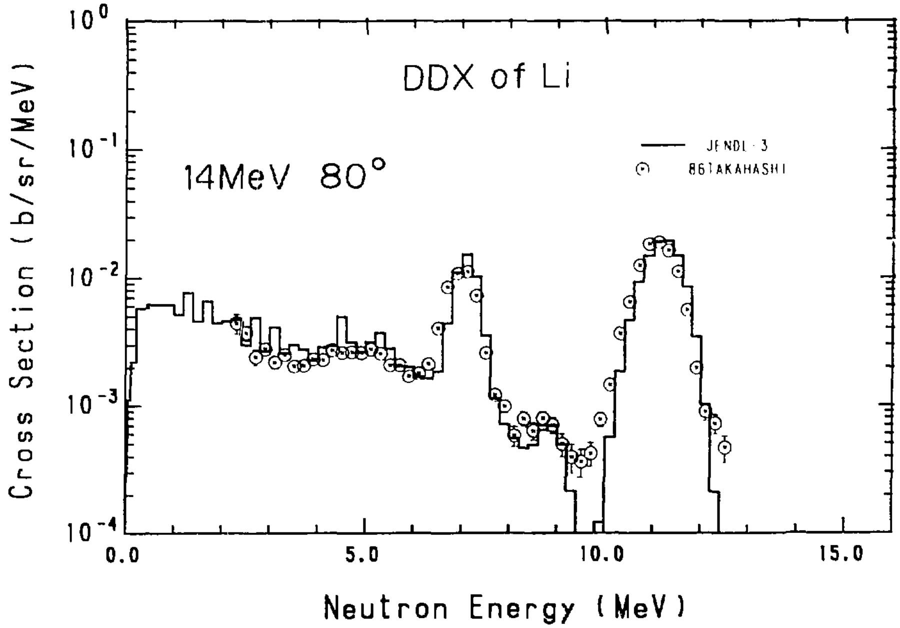

Fig. 2.1.2 Double differential cross sections of natural lithium at 14 MeV.

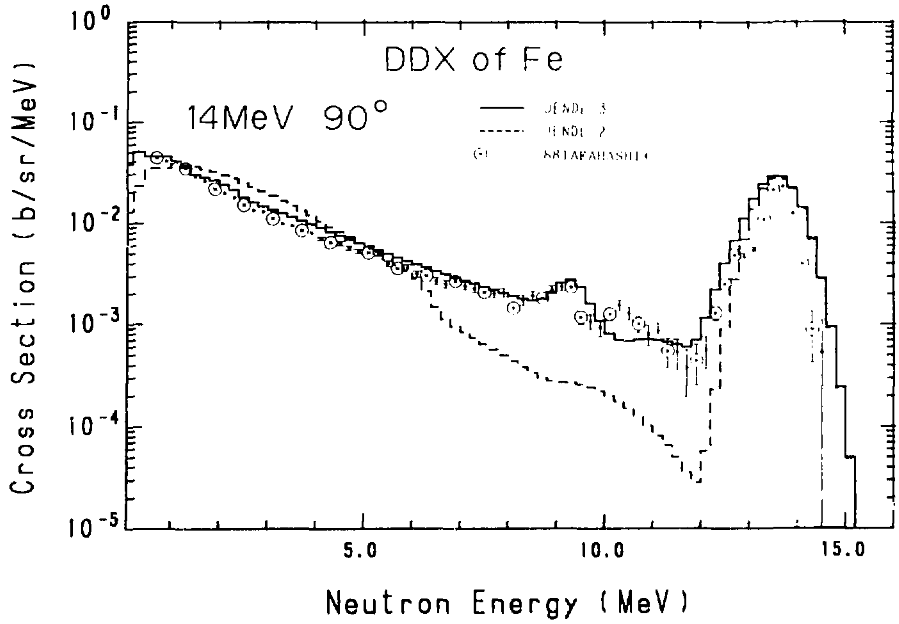

Fig. 2.2.1 Double differential cross sections of natural iron at 14 MeV

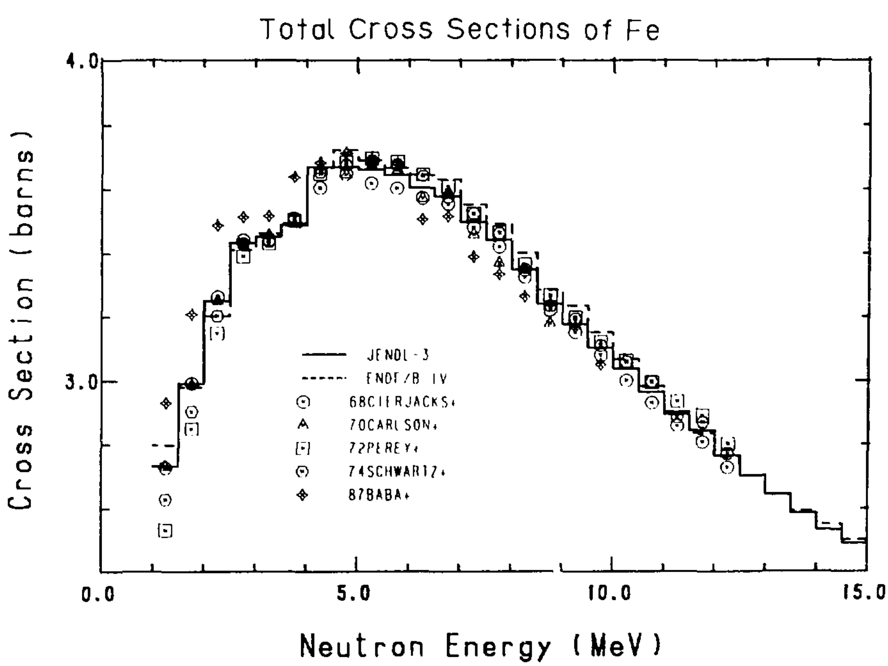

Fig. 2.2.2 Total cross sections of natural iron averaged over 0.5 MeV.

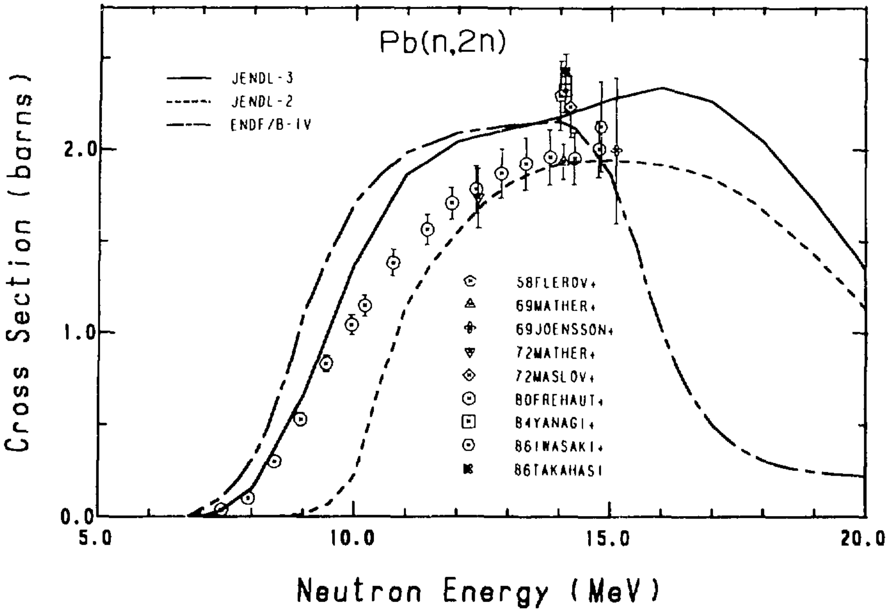

Fig. 2.2.3 (n,2n) reaction cross section of natural lead.

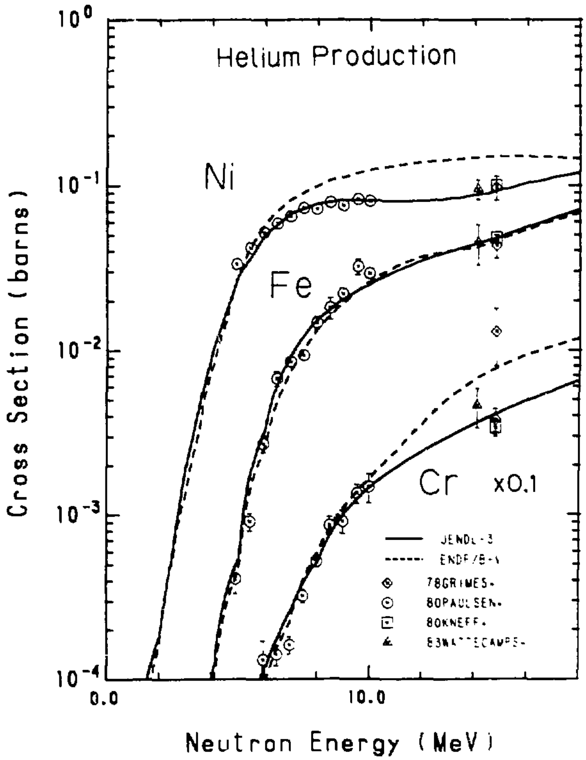

Fig. 2.2.4 Helium-production cross sections of natural chromium, iron and nickel.

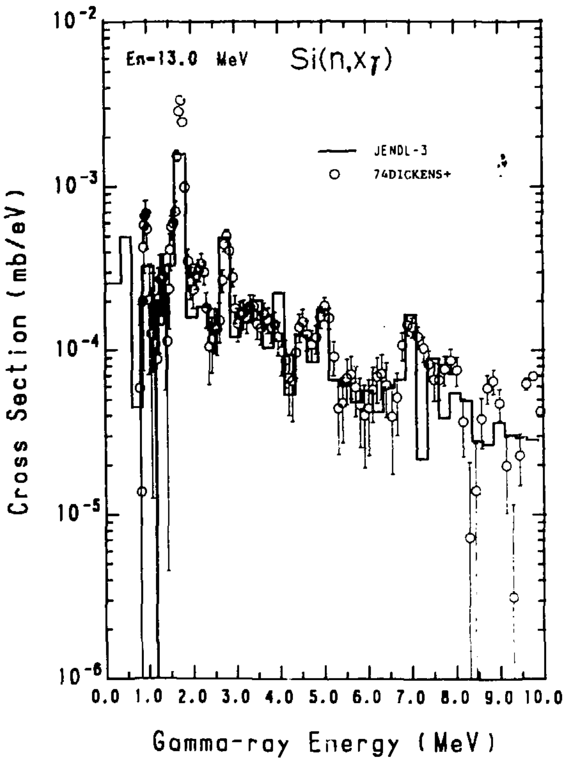

Fig. 2.2.5 Gamma-ray spectra from natural silicon at 13 MeV.

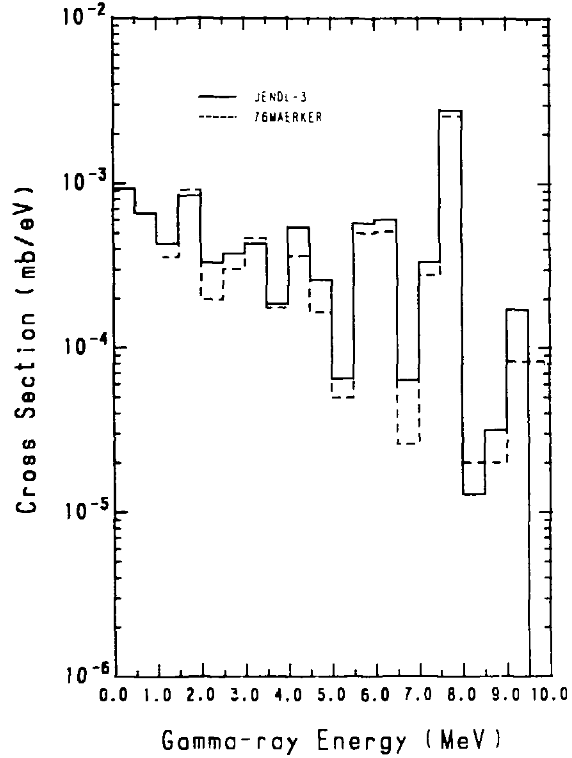

Fig. 2.2.6 Gamma-ray spectra from natural iron at 0.0253 eV.

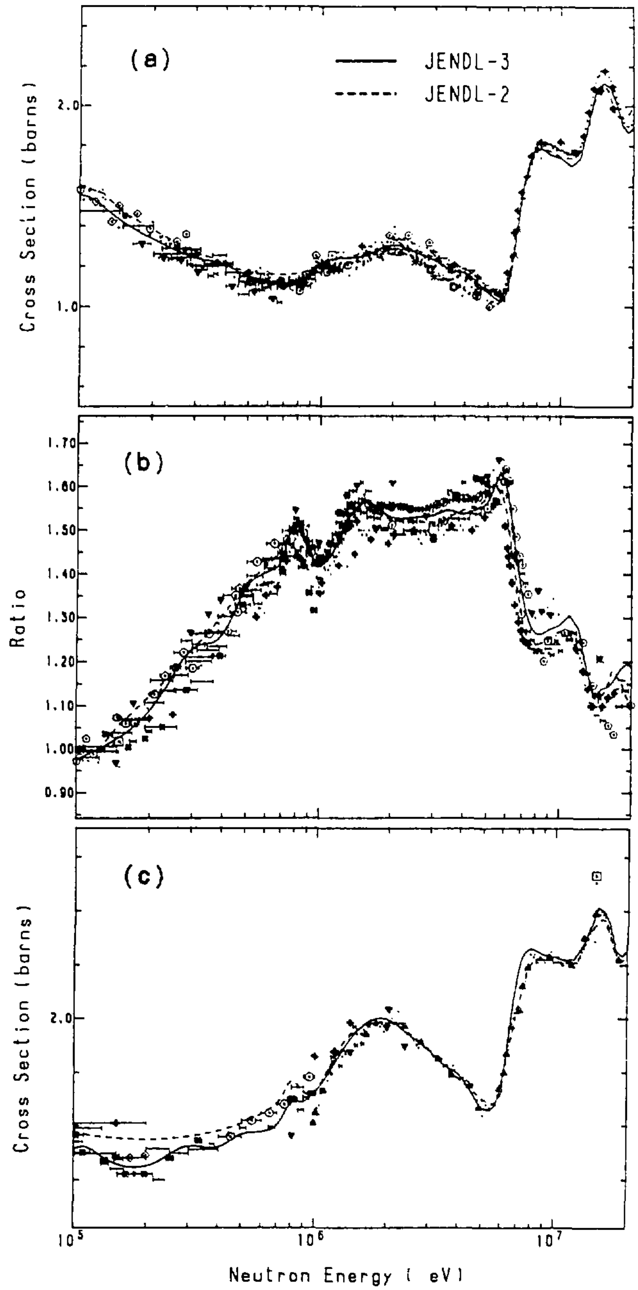

Fig. 2.3.1 Fission cross sections of ^{235}U and ^{239}Pu.
(a) $^{235}U(n,f)$, (b) $^{239}Pu(n,f)/^{235}U(n,f)$ and (c) $^{239}Pu(n,f)$.

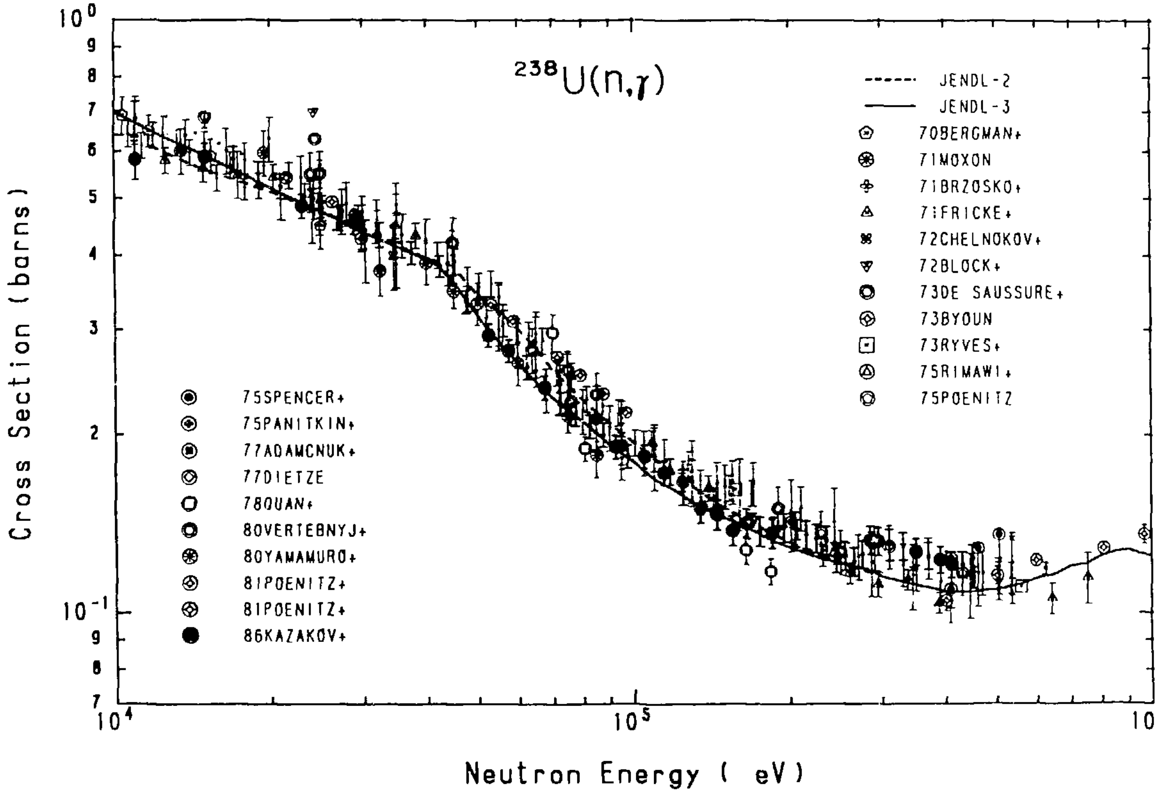

Fig. 2.3.2 Capture cross sections of ^{238}U.

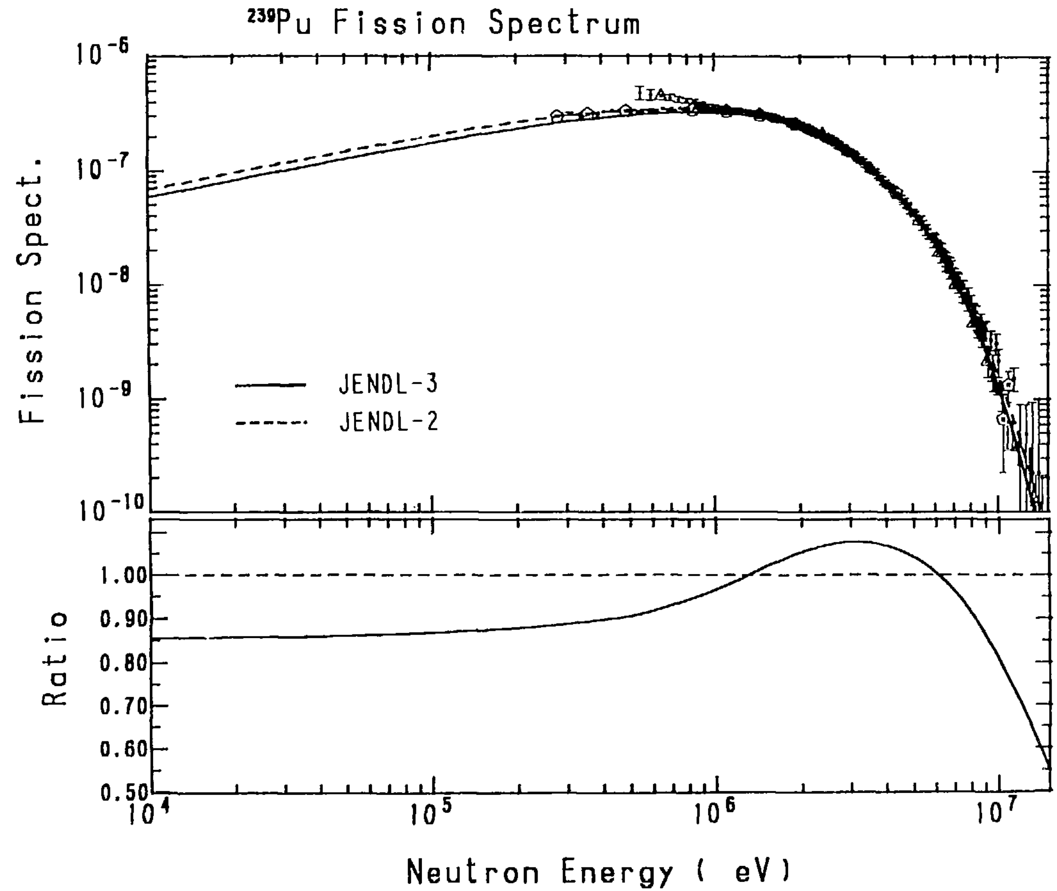

Fig. 2.3.3 Fission neutron spectra for ^{239}Pu at 200 keV. The lower part shows the ratio of JENDL-3 to JENDL-2, which is illustrated by the solid line.

3. Conclusions

The third version of Japanese Evaluated Nuclear Data Library, JENDL-3, has been made available. Its evaluation methods were briefly described in this report.

Much effort was made to improve the reliability of high-energy data and to include the gamma-ray production data. The theoretical calculations were rigorously carried out to meet these purposes. Moreover, the simultaneous evaluation method has been established to determine important cross sections of fissile and fertile nuclides. The quality and quantity of the evaluated data have considerably increased as compared with JENDL-2. In fact, the results of the benchmark tests[4,60] were found to be quite satisfactory.

The Compilation Group expects JENDL-3 to be used in the various fields of nuclear engineering, and also welcomes any comments and suggestions on the basis of experience in the practical use of JENDL-3.

Acknowledgments

The present work was performed under constant encouragement and interest of the members of JNDC. The authors would like to thank them for their invaluable help. They are very much indebted to Drs. N. Shikazono and M. Ishii of JAERI for their support during the course of this work. They also acknowledge Miss M. Mori for her aid in preparing the print-outs for the appendix. Careful typewriting by Miss S. Ishibashi is much appreciated.

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Appendix Descriptive Data for Each Nuclide

The File 1 part of JENDL-3 contains the descriptive data which give information on how the evaluation was performed for each nuclide. The descriptive data are given in this appendix, where characters are converted from capital letters to a normal style of mixture of capital and small letters.

MAT number = 3011

```
  1-H -  1 JAERI        Eval-Dec84 K.Shibata
JAERI-1261              Dist-Sep89
History
83-03 Compiled by K.Shibata for JENDL-2
      Main part was carried over from JENDL-1 data evaluated by
      M.Y: namoto.  Details are given in ref. /1/.
83-11 MF=2 was added. The transformation matrix given for MT=2 of
      MF=4.
84-12 Re-evaluated by K.Shibata (JAERI) for JENDL-3
      Elastic scattering cross section was re-calculated below
      100 keV.
      Mu-bar was also re-calculated.
      Photon-production cross section was added.

MF=1  General Information
  MT=451  Descriptive data and dictionary

MF=2  Resonance Parameters
  MT=151  Scattering radius only


MF=3  Neutron Cross Sections
      Calculated 2200m/s cross sections and res. integrals
                    2200m/s (b)   res. integ. (b)
       total        20.806            -
       elastic      20.474            -
       capture      0.332          0.1491

  MT=1     Total cross section
        Sum of elastic and capture cross sections
  MT=2     Elastic scattering cross section
        Below 100 keV, calculated by using effective range and
        scattering length parameters of Poenitz and Whalen /2/.
        Above 100 keV, the data of Hopkins and Breit/3/ were
        recommended.
  MT=102  Capture cross section
        The data of Horsley/4/ were recommended.
  MT=251  Mu-bar
        Calculated from the data in MF=4.

MF=4  Angular Distributions of Secondary Neutrons
  MT=2
        Below 100 keV, isotropic in the center of mass system was
        assumed.  Above 100 keV, the data of Hopkins and Breit/3/
        were recommended.

MF=12  Photon Production Multiplicity
  MT=102
        m=1.0

MF=14  Photon Angular Distribution
  MT=102
        Assumed to be isotropic.

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```

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MAT number = 3012

```
  1-H -  2 JAERI       Eval-Jul82 K.Shibata,T.Narita,S.Igarasi
 JAERI-M 83-006        Dist-Mar83
History
83-01 New evaluation for JENDL-2.  Details are given in ref. /1/.
      Data were compiled by the authors.
8?-11 MF=2 was added.
87-05 Carried over from JENDL-2.

MF=1  General Information
  Mt=451   Descriptive data and dictionary

MF=2  Resonance Parameters
  MT=151   Scattering radius only

MF=3  Neutron Cross Sections
      2200-m/s cross sections and calculated res. integrals.
                   2200-m/s        res. integ.
         elastic    3.389   b          -
         capture    0.00055 b      0.000286 b
         total      3.390   b          -

  MT=1      Total
         Based on a least-squares fit to the experimental data of
         /2/-/8/.
  MT=2      Elastic
         elastic = total - (n,2n) - capture.
  MT=16     (n,2n)
         Based on a least-squares fit.
         Data listed in /9/-/11/ were used.
  MT=102   Capture
         Below 1 keV, 1/v form normalized to the data of
                       Ishikawa /12/.
         Above 1 keV, evaluated on the basis of the inverse
                       reaction /13/.
  Mt=251   Mu-bar
         Calculated from the data in MF=4.

MF=4  Angular Distributions of Secondary Neutrons
  MT=2,16
         Calculated from the three-body model based on
         the Faddeev equation /14/.

MF=5     Energy Distributions of Secondary
         Neutrons
  MT=16 The three-body model calculation.
```

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MAT number = 3021

```
  2-He-  3 JAERI        Eval-Jun87 K.Shibata
                        Dist-Sep89
History
87-06  Newly evaluated by K.Shibata

MF=1          General Information
  MT=451   Descriptive data

MF=2          Resonance Parameters
  MT=151   Scattering radius only

MF=3          Neutron Cross Sections
      Calculated 2200m/s cross sections and res. integrals
                2200m/s (b)      res.integ (b)
     total      5331.1              -
     elastic    3.135               -
     (n,p)      5328.0              -

  MT=1     Total
       Below 1 MeV, the experimental data /1/ were analyzed using
       the R-matrix theory.
       Above 1 MeV, based on experimental data /2-4/.
  MT=2     Elastic
       Below 1 MeV, the experimental data /1/ were analyzed using
       the R-matrix theory.
       Above 1 MeV, (elastic) = (total) - (reaction)
  MT=103   (n,p)
       Below 1 MeV, the experimental data /5/ were analyzed using
       the R-matrix theory.
       Above 1 MeV, based on experimental data /6,7/.
  MT=104   (n,d)
       Evaluation was performed on the basis of experimental
       data /6,7/.
  MT=251   MU-BAR
       Calculated from the data in file-4.

MF=4          Angular Distributions of Secondary Neutrons
  MT=2     Elastic
       Based on the following experimental data:
         1.0E-5 eV to 500 keV : isotropic in c.m.
         1.0, 2.0, 3.5 MeV    : Seagrave et al. /8/
         5 to 20 MeV          : Haesner /6/
```

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MAT number = 3022

```
  2-He- 4 JAERI        Eval-Feb87 K.Shibata
                       Dist-Sep89
History
87-02  Newly evaluated by K.Shibata

MF=1          General Information
  MT=451    Descriptive data

MF=2          Resonance Parameters
  MT=151    Scattering radius only

MF=3          Cross Sections
        Calculated 2200m/s cross sections
              total    0.7593 barn
              elastic 0.7593 barn

  MT=1,2    Sig-t, Sig-el
        Experimental data /1/-/6/ were analyzed using
        the R-matrix theory.
  MT=251    Mu-bar
        Calculated from the data in file-4

MF=4          Angular Distributions of Secondary Neutrons
  MT=2      Elastic
        R-matrix calculations
```

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MAT number = 3031

```
  3-Li-  6 JAERI       Eval-Mar85 S.Chiba and K.Shibata
JAERI-M 88-164         Dist-Sep89
History
83-12  Newly evaluated by K.Shibata
84-07  Data of MF=4 (MT=16,91) and MF=5 (MT=16,91) were revised
       Comment was also modified.
85-03  Modified by S. Chiba
       Data of MF=3 (MT=59,63) and MF=4 (MT=59,63) were added.
       Data of MF=3 (MT=16), MF=4 (MT=2,16,53), MF=5 (MT=16)
       were revised.
       Pseudo-level representation was adopted for the
       (n,n')alpha-d continuum (MT=51,52,54-56,58,60-62,64-86).

MF=1          General Information
  MT=451    Descriptive data

MF=2          Resonance Parameters
  MT=151    Scattering radius only

MF=3          Cross Sections
        Calculated 2200m/s cross sections and res  integrals
                   2200m/s (b)      res. integ. (b)
        total      94.11              -
        elastic    0.735              -
        capture    0.039             0.017
        (n,t)      94.03              -

  MT=1      Sig-t
        Below 1 MeV based on the R-matrix calculation.  Sig-cap
        was added to the calculated cross section.
        Above 1 MeV, based on the experimental data /1/-/3/.
  MT=2      Sig-el
        Below 1 MeV, based on the R-matrix calculation.
        Above 1 MeV, the cross section was obtained by subtracting
        the reaction cross section from the total cross section.
  MT=3      Non-elastic
        Sum of MT=4, 16, 102, 103 and 107.
  MT=4      Total inelastic
        Sum of MT=51, 52, 53, 54 and 91.
  MT=16     (n,2n)Li5
        Based on the experimental data /4/,/5/,/12/.
  MT=53     Sig-in    2.185 MeV
        Based on the experimental data /3/,/6/-/9/.
  MT=57     Sig-in    3.562 MeV
        Based on the experimental data /10/,/11/.
  MT=59     Sig-in    4.31 MeV
        Based on a coupled-channel calculation. The symmetric
        rotational model was assumed. The coupling scheme was
        1+(g.s.) - 3+(2.185) - 2+(4.31) - 1+(5.7).
        The potential parameters were;
        V  = 45.0766 MeV,           r = 1.1875 fm,  a  = 0.57335 fm
        Ws = 0.4432*El-1.1631 MeV, ri= 1.6113 fm,  ai = 0.26735 fm
        Vso= 5.5 MeV,               rso=1.15 fm,    aso= 0.5 fm
        beta(2)=1.1395,
        where El means the incident neutron energy in the lab.
```

system (MeV).

MT=63 Sig-in 5.7 MeV

Based on the CC calculation normalized to the experimental data /12/.

MT=51,52,54-56,58,60-62,64-86 (n,n')alpha-d continuum

Represented by pseudo-levels, binned in 0.5 MeV intervals. The (n,n')alpha-d cross section was based on the measurement of Rosen and Stewart /13/. The contribution from MT=53, 59 and 63 was subtracted so that Sig-t might be equal to the sum of partial cross sections. The cross section for each level was calculated by the 3-body phase-space distribution with a correction of the Coulomb interaction in the final state, assuming isotropic center-of-mass distributions

MT=102 Capture

Below 100 keV, 1/v curve normalized to the thermal data of Jurney /14/.
Above 100 keV, the inverse reaction data of Ferdinande et al./15/ were added.

MT=103 (n,p)

Based on the experimental data /10/,/16/

MT=105 (n,t)alpha

Below 1 MeV, R-matrix calculation.
Above 1 MeV, based on the experimental data /17/,/18/.

MT=251 Mu-bar

Calculated from the data in file4.

MF=4 Angular Distributions of Secondary Neutrons

MT=2

Below 500 keV, R-matrix calculation.
Between 500 keV and 14 MeV, based on the experimental data /1/,/6/,/19/.
Above 15 MeV, based on the CC calculation.

MT=16

Based on the experimental data /12/ at 14.2 MeV.
Angular distributions are given in the laboratory system.

MT=53

Below 4.8 MeV, assumed to be isotropic in CM.
Between 4.8 and 14 MeV, based on the experimental data /6/,/20/.
Above 15 MeV, the CC calculation.

MT=57

Assumed to be isotropic in CM.

MT=59

Based on the CC calculation.

MT=63

Assumed to be isotropic in CM.

MT=51,52,54-56,58,60-62,64-86

Assumed to be isotropic in CM.

MF=5 Energy Distribution of Secondary Neutrons

MT=16

The evaporation model was assumed. The evaporation temperature of Ref. 12 was adopted. It was extrapolated as
T = 0.176497*sqrt(El) MeV,
where El means the incident neutron energy in the lab. system (MeV).

MF=12 Photon-Production Multiplicities

MT=57

m=1.0

MT=102

Based on the thermal measurement of Jurney /13/

MF=14 Photon Angular Distributions

MT=57

Isotropic

MT=102

Assumed to be isotropic.

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MAT number = 3032

```
  3-Li- 7 JAERI        Eval-Dec84 S.Chiba and K.Shibata
 JAERI-M 88-164        Dist-Sep89
History
83-12  Newly evaluated by K.Shibata
84-07  Data of MF=4 (MT=16,91) and MF=5 (MT=16,91) were revised
       Comment was also modified.
84-12  Modified by S. Chiba
       Data of MT=62 and 64(MF=3,4) were added. Data of MF=4
       (MT=2,51,57,16) and MF=5 (MT=16,91) were modified.
       Pseudo-level representation was adopted for the
       (n,n')alpha-t continuum (MT=52-56,58-61,63,65-84).
       Comment was also modified.
87-02  Li7(n,nt) cross section was modified
88-02  Li7(n,n2) cross section and ang. dist. were modified.
       Li7(n,n0) was also modified so as to give the total cross
       section which is equal to JENDL-3PR1.  The Li7(n,n1) ang
       dist. was also modified.  Li7(n,nt) cross section was
       fixed to 87-02 version by modifying the pseudo level
       cross sections. Comment was also modified

MF=1          General Information
  MT=451     Descriptive data

MF=2          Resonance Parameters
  MT=151     Scattering radius only.

MF=3          Cross Sections
        Calculated 2200m/s cross sections and res  integrals
                 2200 m/s (b)          res. integ. (b)
        total     1.015                    -
        elastic   0.97                     -
        capture   0.045                  0.020

  MT=1       Sig-t
        Below 100 keV, Sig-t = 0.97 + Sig-cap (barns)
        Above 100 keV, based on the experimental date /1/-/4/.
  MT=2       Sig-el
        Below 100 keV, Sig-el = 0.97 (barns).
        Above 100 keV, Sig-el = Sig-t - Sig-react.
  MT=3       Non-elastic
        Sum of MT=4, 16, 102 and 104.
  MT=4       Total inelastic
        Sum of MT=51 to 84.
  MT=16      (n,2n)
        Based on the experimental data /5/,/6/.
  MT=51      Sig-in    0.478 MeV
        Based on the (n,n'gamma) data of Morgan /7/.
  MT=57      Sig-in    4.63 MeV
        Based on the experimental data /8/-/10/.
  MT=62      Sig-in    6.68 MeV
        Based on a coupled-channel calculation normalized to the
        experimental data /13,14/. The symmetric rotational model
        was assumed.  The coupling scheme was
        3/2-(g.s.) - 1/2-(0.478) - 7/2-(4.63) - 5/2-(6.68).
        The potential parameters were as follows:
```

V= 49.6 - 0.362•El MeV, r= 1.28 fm, a= 0.620 fm
Ws= -13.2 + 1.88•El MeV, ri= 1.34 fm, ai= 0.104 fm
Vso= 5.500 MeV, rso=1.150 fm, aso=0.50 fm
beta(2)= 0.952,
where El means laboratory incident energy in MeV.

MT=64 Sig-in 7.467 MeV
Assumed to have the same excitation function as MT=53, normalized to the experimental data /13,14/.

MT=52-56,58-61,63,65-84, (n,n')alpha-t continuum
Represented by pseudo-levels, binned in 0.5 MeV intervals. The cross section was obtained by subtracting the contribution of MT=57,62 and 64 from the (n,n')alpha-t cross section (MT=205). The cross section for each level was calculated by the 3-body phase-space distribution with a correction of the Coulomb interaction in the final state.

MT=102 Capture
1/v normalized to the thermal measurement /15/.

MT=104 (n,d)
The (n,d) cross section was calculated with DWBA. Normalization was taken so that the calculated cross section might be consistent with the activation data /16/.

MT=205 (n,n')alpha-t
Based on the experimental data /17/-/22/.

MT=251 Mu-bar
Calculated from the data in file4.

MF=4 Angular Distributions of Secondary Neutrons

MT=2
Below 4 MeV, an R-matrix calculation with the parameters of Knox and Lane/23/.
Between 4 MeV and 14 MeV, based on the experimental data /8/,/24/.
Above 15 MeV, the coupled-channel calculation.

MT=16
Based on the experimental data /13/ at 14.2 MeV.
Angular distributions are given in the laboratory system.

MT=51
Below 4 MeV, the R-matrix calculation.
4 to 10 MeV, evaluation of Liskien/25/ was adopted.
Above 10 MeV, the coupled-channel calculation.

MT=57
Below 8 MeV, the R-matrix calculation.
Between 8 MeV and 14 MeV, based on the experimental data /10/-/12/.
Above 15 MeV, the coupled-channel calculation.

MT=62
At the threshold, an isotropic distribution was assumed.
Above 10 MeV, the coupled-channel calculation.

MT=64
Isotropic distributions were assumed in the center-of-mass system.

MT=52-56,58-61,63,65-84
Experimental data/13/ were adopted.

MF=5 Energy Distribution of Secondary Neutrons

MT=16

The evaporation model was assumed, with the temperature deduced experimentally/13/ at 14.2 MeV The temperature was extrapolated as
t = 0.229*sqrt(El) MeV,
where El means laboratory incident energy in MeV.

MF=12 Photon-Production Multiplicities
MT=51
m=1.0
MT=102
Multiplicities were obtained from ref./26/.

MF=14 Photon Angular Distributions
MT=51
Isotropic
MT=102
Assumed to be isotropic.

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MAT number = 3041

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  4-Be- 9 JAERI        Eval-Aug84 K.Shibata
 JAERI-M 84-226        Dist-Sep89
History
84-08   Reevaluated for JENDL-3 by K.Shibata.
        Details of the evaluation are given in ref/1/.
89-01   Modified by considering neutron emission spectra

MF=1           General Information
  MT=451   Descriptive data

MF=2           Resonance Parameter
  MT=151   Scattering radius only.

MF=3           Cross Sections
        Calculated 2200m/s cross sections and res. integrals
                       2200m/s (b)      res. integ. (b)
          total        6.1586               -
          elastic      6.1510               -
          capture      0.0076            0.0034

  MT=1      Sig-t
        Below 1 eV, sum of sig-el and sig-cap.  Between 1 eV and
        830 keV, the cross section was calculated on the basis of
        the R-matrix theory.  The R-matrix parameters were
        obtained so as to give the best fit to the experimental
        data /2/-/6/.  Above 830 keV, based on the measurements
        /5/,/7/,/8/.
  MT=2      Sig-el
        Below 1 eV, sig-el = 6.151 barns.
        Above 1 ev, the cross section was obtained by subtracting
        the reaction cross section from the total cross section.
  MT=3      Non-elastic
        Sum of MT=4,16,24,102,103,103,105,107
  MT=4      Total inelastic
        Sum of MT=51 and 52.
  MT=6, 7, 16, 51, 52
        The shape of the inelastic scattering cross section was
        obtained from the statistical model calculation.  The
        absolute value was determined so that a sum of the
        inelastic scattering and (n,a1) reaction cross sections
        might be equal to the (n,2n) reaction cross section in
        JENDL-2.  Optical potential parameters of Agee and Rosen
        /9/ were used.
           V = 49.3 - 0.33E, Ws = 5.75    , Vso = 5.5     (MeV)
           r = 1.25         , rs = 1.25   , rso = 1.25    (fm)
           a = 0.65         , b  = 0.70   , aso = 0.65    (fm)
        Level scheme
           no          energy(MeV)     spin-parity
          g.s.           0.0              3/2-
            1            1.68             1/2+
            2            2.429            5/2-
            3            2.800            1/2+
            4            3.06             5/2+
            5            4.7              3/2+
            6            6.8              7/2-
```

7	7.9	5/2- •)
8	11.28	9/2- •)
9	11.81	7/2- •)
10	13.79	5/2- •)
11	14.396	3/2- •)

•) Spin-parity value was tentatively assigned.
All the excited levels except 7.9 and 13.79 MeV ones decay by emitting neutrons, contributing to the (n,2n) cross section. Within the framework of the current ENDF/B format, different MT numbers were assigned to these levels.

MT no.	level
6	2nd+3rd+4th
7	6th
16	1st+5th+8th+9th+11th+cont
51	7th
52	10th

••
• The (n,2n) cross sections is given as a sum of MT=6, 7, •
• 16, and 24. •
••

MT=24 (n,2n alpha)
This is the cross section for the (n,a1) reaction. The 1st excited level of He-6 decays by emitting 2 neutrons. the (n,a1) cross section was calculated with the statistical model.
Alpha potential parameters are the following /10/:
V = 125.0 , Ws = 15.0 , Vso = 0.0 (MeV)
r = 1.56 , rs = 1.56 , rc = 1.22 (fm)
a = 0.50 , b = 0.11 (fm)
The cross section was normalized to the data of Perroud and Sellem /11/ at 14 MeV.

MT=46, 47 Sig-in
Same as MT=6, 7, respectively.

MT=102 Capture
Thermal cross section of 7.6E-3 barn was obtained from the recommendation by Mughabghab et al./12/
1/v curve was assumed over the whole energy range.

MT=103 (n,p)
Calculated with the statistical model.
Proton potential parameters are the following /13/:
V = 59.5 - 0.36e, Ws = 12.0 + 0.07E, Vso = 4.9 (MeV)
r = 1.24 , rs = 1.36 , rso = 1.2 (fm)
rc= 1.3 (fm)
a = 0.63 , b = 0.35 , aso = 0.31 (fm)
The cross section was normalized to the experimental data of Augustson and Menlove /14/, who measured delayed neutros, by taking account of the branching ratio of 49.5% for Li-9 => Be-9• => 2a + n.

MT=104 (n,d)
Based on the experimental data of Scobel /15/.

MT=105 (n,t)
Sum of MT=740 and 741.

MT=107 (n,a0)
Based on the experimental data /10/,/11/,/16/-/19/.

MT=251 Mu-bar
Calculated from the data in file4.

MT=740, 741 (n,t0),(n,t1)

Calculated with the statistical model.
Triton potential parameters are the following /20/:

V = 140.0	, Ws = 7.5	, Vso = 6.0		(MeV)
r = 1.20	, rs = 2.69	, rso = 1.20	, rc = 1.30	(fm)
a = 0.45	, b = 0.36	, aso = 0.7		(fm)

Normalization was taken so that the total (n,t) cross section might be consistent with the experimental data of Boedy et al./21/

MF=4 Angular Distributions

MT=2

1.0E-5 eV to 50 keV	Isotropic in CM.
50 keV to 14 MeV	Based on the experimental data /22/-/27/.
14 MeV to 20 MeV	Optical-model calculations using the potential parameters of Agee and Rosen /9/.

MT=6

Legendre coefficients were derived from the experimental data /27/,/28/.

MT=7

Statistical model calculation

MT=16

Kalbach-Mann systematics/31/

MT=24, 46, 47

Calculated by assuming the two-step sequential reaction /29/.

MF=5 Energy Distribution

MT=16

Evaporation plus 3-body phase space

MT=24, 46, 47

Calculated by assuming the two-step sequential reaction /29/.

MF=12 Photon-Production Multiplicities

MT=102

Based on the measurement of Jurney /30/.

MT=741

m=1.0

MF=14 Photon Angular Distributions

MT=102

Assumed to be isotropic.

MT=741

Isotropic

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MAT number = 3051

5-B - 10 JAERI Eval-Mar87 S.Chiba
Dist-Sep89

History
87-03 Newly evaluated by S.Chiba (JAERI) for JENDL-3.
88-11 Data for MF=3(MT=1,2,3,4,51,103,107,113,780,781) were modified. Data for MF=12(MT=102,781), MF=13(MT=4,103), MF=14(MT=4,102,103,781) were added. Comment was also modified.

MF=1 General Information
MT=451 Descriptive data and dictionary

MF=2 Resonance Parameters
MT=151 Scattering radius only.
The 2200m/s and 14 MeV cross sections are in Table 1.

MF=3 Neutron Cross Sections
MT=1 Total
Below 1.2 MeV, sum of the partial cross sections
1.2 to 17 MeV, based on the experimental data /1/-/9/.
Above 17MeV, optical model calculation was normalized at 17 MeV. The spherical optical potential parameters/10/ are listed in Table 2.
MT=2 Elastic scattering
Below 10 keV, based on the R-matrix calculation. The R-matrix parameters are mainly based on ref./11/.
10 keV to 1.2 MeV, based on the experimental data /12/-/14/.
Above 1.2 MeV, calculated by subtracting all the other partial cross sections from the total cross section.
MT=3 Non-elastic
Sum of MT=4, 16, 102, 103, 104, 107 and 113.
MT=4 Total inelastic
Sum of MT=51 to 89.
MT=16 (n,2n)
Based on the experimental data /15/. Cross section was extrapolated as 0.0120*sqrt(E-Eth), where E is incident neutron energy and Eth threshold energy in MeV. Note that this reaction produces 1 proton and 2 alpha particles, i.e. (n,2np)2alpha.
MT=51-59, 61, 62, 64-66. Inelastic scattering to real levels
Cross sections were calculated by the collective model DWBA and normalized to the experimental data/16/ at 14 MeV. Calculated levels and assumed orbital angular momentum transfers (l) are summarized in Table 3.
Data for MT=51 was normalized to the experimental data/17/ below 6MeV. Above 6MeV, the deformation parameter deduced from (p,p') reaction/18/ was used.
MT=60,63,67-89 (n,n'd)2alpha continuum.
Represented by pseudo-levels, binned in 0.5 MeV intervals. The (n,n'd)2alpha cross section was based on the measurement of Frye+ /19/. The cross section for each level was calculated by the 3-body phase space distribution, assuming isotropic center-of-mass

angular distributions.

MT=102 Capture
1/v shape was normalized to the experimental data /20/.

MT=103 (n,p)
Sum of MT = 700 to 705.

MT=104 (n,d)
Sum of MT = 720 and 721.

MT=107 (n,alpha)
Sum of MT = 780 and 781. The thermal cross section of 3837 barns was adopted/21/.

MT=113 (n,t)2alpha
Based on the experimental data /19/,/22/-/29/

MT=251 Mu-bar
Calculated from the data in file4.

MT=700 (n,p) to the ground state of Be-10
Below 100 keV, assumed to be 1/v. The thermal cross section was assumed to be 3mb/30/.
From 100 keV to 500 keV, assumed to be constant.
From 500 kev to 1 MeV, linearly interpolated.
Above 1 MeV, the statistical model calculation was normalized by a factor of 0.704. The optical potential, level schemes and level density parameters used in the calculation are summarized in Tables 2, 3 and 4.

MT=701-705 (n,p) to the low lying excited states of Be-10.
The statistical model calculation was normalized to the experimental data/26/ at 14 MeV.

MT=720 (n,d0)
Below 7.6 MeV, the inverse reaction cross sections/31/-/32/ were converted by the principle of detailed balance.
From 7.6 to 14 MeV, interpolated linearly.
Above 14 MeV, DWBA calculation with the proton pickup mechanism was normalized to the experimental data, /33/-/34/ at 14 MeV. The d + Be-9 and bound proton potentials of Valkovic+/34/ were used. Depth of the proton potential was searched by the separation energy method. The potential parameters are listed in Table 2.

MT=721 (n,d2)
DWBA calculation with the proton pickup mechanism was normalized to the experimental data/26/,/33/-/34/ at 14 MeV. This is really the (n,d) reaction to the second level of Be-9.

MT=780, (n,alpha0)
Below 10 keV, R-matrix calculation.
From 10 keV to 800 keV, based on the experimental data /35/-/36/.
From 800 keV to 7.5 MeV, the experimental data/37/ were normalized by a factor of 1.38 and fitted by the spline function.
Above 7 MeV, the experimental data/26/ were adopted.

MT=781 (n,alpha1)
Below 10 keV, the R-matrix calculation.
From 10 keV to 100 keV, based on the experimental data/36/ /38/.
From 100 keV to 2 MeV, recommendation by Liskien and Wattecamps/39/ was adopted
From 2 to 7.5 MeV, the experimental data/37-40/ were

normalized by a factor of 1.38 and fitted by the spline function.
Above 7 MeV, the experimental data/40/ was adopted.

MF=4 Angular Distributions of Secondary Neutrons
MT=2
Below 100 keV, the R-matrix calculation.
From 100 keV to 6 MeV, ENDF/B-V was adopted.
Above 6 MeV, based on the optical model calculation.
MT=16
Calculated by the method of Nakagawa/41/.
Angular distributions are given in the laboratory system.
MT=51-59, 61, 62, 64-66.
DWBA calculation.
MT=60, 63, 67-89
Assumed to be isotropic in CM

MF=5 Energy Distribution of Secondary Neutrons
MT=16
The evaporation model was assumed. The evaporation temperature was assumed to be 1 MeV at 14 MeV. It was extrapolated as
$$t = 0.2673 \cdot \mathrm{sqrt}(En) \text{ MeV},$$
where En means the incident neutron energy in the laboratory system in MeV.

MF=12 Photon Multiplicities
MT=102
Multiplicities were given according to a compilation of Ajzenberg et al./43/. However, they were normalized for the total secondary gamma-ray energy to match the available energy in the final state.
MT=781
Multiplicity for the 0.478-MeV gamma-ray was given as 1.0.

MF=13 Photon Production Cross Sections
MT=4
Experimental data/41,44/ were adopted for 0.4138-, 0.7183- and 1.0219-MeV gamma-rays. For 1.44- and 2.15-MeV gamma-rays, excitation function of the 0.4138-MeV gamma-ray production was normalized to the data/41/ at 14.8MeV. For 2.87-, 3.01-, 4.44- and 6.03-MeV gamma-rays, shapes of the corresponding (n,n') excitation functions in MF=3 were normalized to the data/41/ at 14.8MeV.
MT=103
For 3.368- and 2.592-MeV gamma-rays, shapes of the corresponding (n.p) excitation functions in MF=3 were normalized to the experimental data/41/ at 14.8MeV.

MF=14 Angular Distribution of Secondary Photons
MT=4,102,103,113
Assumed to be isotropic.

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Table 1 The 2200-m/s and 14 MeV cross sections

	2200-m/s (b)	14 MeV (b)
elastic	2.144	0.943
(n,n')	-----	0.269
(n,p)	0.003	0.038
(n,d)	-----	0.047

(n,t)	0.012	0.095
(n,alpha)	3837.0	0.049
(n,2n)	-----	0.027
capture	0.50	0.000
total	3839.7	1.467

Table 2 Optical potential parameters

B-10 + n /10/

V= 47.91 - 0.346En, Ws= 0.657 + 0.810En, Vso=5.5 (MeV)
r= 1.387 , rs= 1.336 , rso=1.15 (fm)
a= 0.464 , as= 0.278 , aso=0.5 (fm)

Be-10 + p /45/

V = 60.0 + 27.0(N-Z)/A -0.3Ecm (MeV)
Ws = 0.64Ecm + 10.0(N-Z)/A ,(Ecm < 13.8 MeV) (MeV)
= 9.60-0.06Ecm + 10.0(N-Z)/A ,(Ecm > 13.8 MeV) (MeV)
Vso= 5.5 (MeV)
r = rs = rso = 1.15 (fm)
a = aso = 0.57, as= 0.5 (fm)

Be-9 + d /34/

V= 80.0 , Wv= 30.0 , Vso=6.0 (MeV)
r= 1.0 , rv= 1.0 , rso=1.0 ,rc= 1.3 (fm)
a= 1.0 , av= 0.8 , aso=1.0 (fm)

Table 3 Level schemes used in the DWBA or statistical model calculation

B-10				Be-10		
MT	Energy (MeV)	JP	l	MT	Energy (MeV)	JP
2	0.0	3+		700	0.0	0+
51	0.7183	1+	2	701	3.368	2+
52	1.7402	0+	4	702	5.958	2+
53	2.154	1+	2	703	5.960	1-
54	3.587	2+	2	704	6.179	0+
55	4.774	3+	2	705	6.263	2-
56	5.110	2-	3			
57	5.163	2+	2			
58	5.18	1+	2			
59	5.920	2+	2			
61	6.025	4+	2			
62	6.127	3-	3			
64	6.561	3+	2			
65	6.881	1-	3			
66	7.00	1+	2			
	7.430	1-				
	7.470	1+				
	7.477	2-				
	7.560	0+				
	7.670	1+				
	7.840	1-				
	8.070	2-				

8.650	1+
8.890	3-
8.894	2+

Table 4 Level density parameters used in the statistical model calculation

	a(1/MeV)	t(MeV)	c(1/MeV)	pair.(MeV)	ex(MeV)
B-10	1.196	5.581	0.066	0.0	16.17
Be-10	1.088	5.866	0.021	5.13	19.63

MAT number = 3057

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  5-B - 11 JAERI        Eval-May88 T.Fukahori
JAERI-M 89-046          Dist-Sep89
History
87-03  Newly evaluated by T.Fukahori (JAERI)
88-05  Revised by T.Fukahori (JAERI)
       (n,d),(n,nd),(n,t),(n,nt) and (n,n2a) added

MF=1          General Information
  MT=451    Descriptive data and dictionary

MF=2          Resonance Parameters
  MT=151    Only scattering radius is given.

MF=3          Cross Sections
  2200 m/sec cross sections and resonance integrals
                        2200 m/sec        res. integ.
          total           5.050 b            -
          elastic         5.045 b            -
          capture         5.075 mb         2.542 mb

  MT=1        Total cross section
       Below 1 MeV, calculated with the multi-level Breit-Wigner
       formula and the resonance parameters taken from ref. /1/.
       In the range of 1 to 4 MeV, based on the R-matrix
       calculation which was performed by using Koehler et al.'s
       parameters /2/. Above 4 MeV, smooth curve was obtained by
       fitting to the experimental data of Auchampaugh et al./3/.
  MT=2        Elastic scattering cross section
       Below 1 MeV based on the multi-level Breit-Wigner formula.
       In the range of 1 to 2.2 MeV, the R-matrix calculation was
       adopted. Above 2.2 MeV, the cross section was obtained by
       subtracting the reaction cross sections from the total
       cross section.
  MT=4        Total inelastic scattering cross section
       Sum of MT=51-57 and 91.
  MT=16       (n,2n)B-10 cross section
       Calculated with GNASH /4/. The optical potential
       parameters, the level density parameters and the level
       scheme are shown in Tables 1-3, respectively.
  MT=22       (n,n'alpha)Li-7 cross section
       Calculated with GNASH. The optical potential parameters,
       the level density parameters and the level scheme are
       shown in Tables 1-3, respectively.
  MT=28       (n,n'p)Be-10 cross section
       Based on the GNASH calculation. The parameters used are
       listed in Tables 1-3.
  MT=29       (n,n'2alpha)t cross section
       Based on (n,n't) cross section of the GNASH calculation
       and normalized to He production cross section of Kneff
       et al. /5/.
  MT=32       (n,n'd)Be-9 cross section
       Based on the GNASH calculation. The parameters used are
       listed in Tables 1-3.
  MT=33       (n,n't)Be-8 cross section
       Based on the GNASH calculation. The parameters used are
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listed in Tables 1-3.
MT=51 Inelastic scattering
The R-matrix calculation with Koehler et al.'s parameters was adopted below 7 MeV. Above 7 MeV, the GNASH and DWBA calculations were performed. The sum of both results was adopted, and normalized to the experimental data of Koehler et al. /2/ and Glendinning et al. /6/.
MT=52,53 Inelastic scattering
Below 7 MeV, based on the R-matrix calculation with the searched parameters. Above 7 MeV, the sum of the GNASH and DWBA calculations was adopted, and fitted to the experimental data of Glendinning et al..
MT=54-57 Inelastic scattering
The sum of results of the GNASH and DWBA calculations was normalized to the result of OKTAVIAN's DDX data /7/.
MT=91 Continuum inelastic scattering
Above 7.2 MeV, continuum levels were adopted.
Based on the GNASH calculation.
MT=102 Capture cross section
Calculated from the multi-level Breit-Wigner formula.
The direct capture /1/ is also considered.
MT=103 (n,p)Be-11 cross section
Based on the GNASH calculation with being normalized to the experimental data of Stepancic et al. /8/. The parameters used are shown in Tables 1-3.
MT=104 (n,d)Be-10 cross section
Based on the GNASH calculation.
MT=105 (n,t)Be-9 cross section
Based on the GNASH calculation.
MT=107 (n,alpha)Li-8 cross section
The GNASH calculation was performed, and normalized to the experimental data of Antolkovic et al. /9/ and Scobel et al. /10/. The parameters used are shown in Tables 1-3.
MT=251 Mu-bar
Calculated from the data in MF=4.

MF=4 Angular Distributions of Secondary Neutrons
MT=2
The R-matrix and DWBA calculations were adopted below 8 MeV and above 8 MeV, respectively.
MT=16,22,28,29,32,33,91
Assumed to be isotropic in the center of mass system.
MT=51,52,53
Below 8 MeV based on R-matrix calculation. Above 8 MeV, based on the DWBA and the GNASH calculations.
MT=54,55,56,57
Based on the DWBA and the GNASH calculations.

MF=5 Energy Distributions of Secondary Neutrons
MT=16,22,28,29,32,33,91
Based on the GNASH calculation.

MF=12-15 Gamma-ray Data
Based on the GNASH calculation.

Table 1 The optical potential parameters

neutron	V = 41.8-0.005E MeV•	r0= 1.40 fm	a0= 0.35 fm	ref.12
	Ws= 1.01E MeV•	ri= 1.15 fm•	ai= 0.50 fm	
proton	V = 66.1-0.273E MeV	r0= 1.15 fm	a0= 0.57 fm	ref.13
	Ws= 1.50+0.581E MeV	ri= 1.15 fm	ai= 0.5 fm	
	Vsym = 5.5 MeV	r0= 1.15 fm	a0= 0.57 fm	
deuteron	V = 80.0 MeV•	r0= 1.0 fm•	a0= 1.0 fm•	ref.14
	Wv= 30.0 MeV	ri= 1.0 fm•	ai= 0.8 fm•	
	Vsym = 6.0 MeV•	r0= 1.0 fm•	a0= 1.0 fm•	
triton	V = 103.0+20.0E MeV•	r0= 0.85 fm	a0= 0.70 fm	ref.15
	Wv= 1.49E MeV•	ri= 2.06 fm	ai= 0.72 fm	
	Vsym = 8.55 MeV•	r0= 0.85 fm	a0= 0.70 fm	
alpha	V = 285.2-2.40E MeV•	r0= 1.61 fm•	a0= 0.55 fm•	ref.16
	Ws= 16.16-0.70E MeV•	ri= 1.81 fm	ai= 0.65 fm	

Note : E is incident neutron energy in lab. system
• means that parameter is modified from original one.

Table 2 The level density parameters

	a(1/MeV)	T(MeV)	pair.(MeV)
B-10	1.196	7.990	0.0
B-11	1.431	6.112	2.67
B-12	1.491	6.201	0.0
Be-8	1.115	9.187	5.13
Be-9	1.125	8.248	2.46
Be-10	1.088	10.029	5.13
Be-11	1.419	7.277	2.46
Li-7	1.138	7.197	2.67
Li-8	1.115	8.170	0.0

Table 3 The level scheme (energy(MeV), spin and parity) /17-18/

	B-10		B-11		Be-10		Be-11		Li-7		Li-8	
gs	0.0	3+	0.0	3/2-	0.0	0+	0.0	1/2+	0.0	3/2-	0.0	2+
1	0.718	1+	2.125	1/2-	3.368	2+	0.320	1/2-	0.478	1/2-	0.981	1+
2	1.740	0+	4.445	5/2-	5.958	2+			4.630	7/2-		
3	2.154	1+	5.020	3/2-	5.960	1-			6.680	5/2-		
4	3.587	2+	6.743	7/2-	6.179	0+			7.460	5/2-		
5	4.774	3+	6.792	1/2+	6.263	2-			9.670	7/2-		
6	5.110	2-	9.120	7/2+	7.371	3-			9.850	3/2-		
7	5.164	2+	10.60	7/2+	7.452	2+			11.240	3/2-		
8	5.180	1+			9.270	4-						
9	5.926	2+			9.400	2+						
10	6.025	4+										
11	6.127	3-										
12	6.561	4-										
13	6.873	1-										
14	7.002	2+										
15	7.430	2-										

16	7.467	1+
17	7.479	2+
18	7.561	0+
19	7.670	1+
20	7.819	1-
21	8.070	2+
22	8.700	2+
23	8.889	3-
24	8.895	2+

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MAT number = 3061

6-C - 12 JAERI Eval-Aug83 K.Shibata
JAERI-M 83-221 Dist-Sep89

history
83-08 Newly evaluated by K.Shibata
Details of the evaluation are given in ref./1/.
84-07 Data of MF=4 MT=91 were revised.
Comment was also modified.
85-02 Data of MT=2, 3, 4, 53 of MF=3 were revised above 10.45 MeV. Angular distributions for MT=52, 53 were also revised.
88-07 Data of MT=1, 3, 4, 52 of MF=3 were revised above 8.3 MeV.

MF=1 General Information
MT=451 Descriptive data

MF=2 Resonance Parameters
MT=151 Scattering radius only.

MF=3 Cross Sections
Calculated 2200m/s cross sections and res integrals

	2200m/s (b)	res.integ. (b)
total	4.750	-
elastic	4.746	-
capture	0.0035	0.0017

MT=1 Sig-t
Below 10 eV, sum of Sig-el and Sig-cap.
Between 10 eV and 4.8 MeV, the cross section was calculated on the basis of the R-matrix theory. The R-matrix parameters were obtained so as to give the best fit to the experimental data /2/-/7/.
Above 4.8 MeV, based on the measurements /8/-/10/.

MT=2 Sig-el
Below 10 eV, Sig-el = 4.746 barns.
Above 10 eV, the cross section was obtained by subtracting the reaction cross section from the total cross section.

MT=3 Non-elastic
Sum of MT=4, 102, 103, 104 and 107.

MT=4 Total inelastic
Sum of MT=51, 52, 53 and 91.

MT=51 Sig-in 4.44 MeV level
Based on the experimental data of Morgan et al./11/.

MT=52 Sig-in 7.65 MeV level
The cross section was estimated so that the elastic scattering cross section given as the difference between the total and reaction cross sections might be consistent with experimental data. Taking account of the measurement /33/, the cross section was modified by multiplying a factor of 0.5.

MT=53 Sig-in 9.63 MeV level
Based on the experimental data of Antolkovic et al./12/.
Taking account of the measurement of Ono et al./31/, the cross section was modified by a factor 0f 0.8.

MT=91 (n,n')3a
Based on the experimental data of Antolkovic et al./12/.

Total (n,n')3a cross section is the sum of MT=52, 53 and 91.

MT=102 Capture
Below 100 keV, 1/v curve.
Above 100 keV, the inverse reaction data of Cook /13/ were added.

MT=103 (n,p)
Based on the measurement of Rimmer and Fisher /14/.

MT=104 (n,d)
Calculated with DWBA.

MT=107 (n,a)
Based on the experimental data /15/-/23/

MT=251 Mu-bar
Calculated from the data in file4.

MF=4 Angular Distributions of Secondary Neutrons

MT=2
Below 10 eV, isotropic in the center-of-mass system (CM).
Between 10 eV and 4.8 MeV, calculated with the R-matrix theory.
Above 4.8 MeV, based on the experimental data /24/-/28/.

MT=51
Based on the experimental data /24/-/28/.

MT=52, 53
Based on the experimental data /31//32/.

MT=91
Isotropic distributions in CM were transformed into the ones in the laboratory system. The formula is given in ref /30/.

MF=5 Energy Distribution of Secondary Neutrons

MT=91
Evaporation spectrum.

MF=12 Photon-Production Multiplicities

MT=51 (n,n')gamma
m=1.0

MT=102 (n,gamma)
Based on the measurement of Spilling et al./29/.

MF=14 Photon Angular Distributions

MT=51
Based on the experimental data of Morgan et al./11/.

MT=102
Assumed to be isotropic.

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MAT number = 3071

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  7-N - 14 JNDC       Eval-Jun89 Y.Kanda(KYU) T.Murata(NAIG)+
                      Dist-Sep89
History
89-06  New evaluation for JENDL-3
        Sub-working group on evaluation of N-14,
        working group on nuclear data for fusion,
        Japanese Nuclear Data Committee
       In charge
        Sig-t        K.Shibata (JAERI)
        Sig-el       T.Asami (JAERI), T.Murata (NAIG)
        Sig-in       T.Asami, T.Murata
        (n,2n),(n,p),(n,t),(n,a)
                     Y.Kanda(KYU)
        (n,na),(n,np),(n,nd),(n,d)
                     T.Asami
        Capture      T.Asami
        Photon production
                     T.Asami
       Compilation
        Evaluated data were compiled by T.Fukahori.

MF=1           General Information
  MT=451   Descriptive data

MF=2           Resonance Parameters
  MT=151   Scattering radius only.

MF=3           Cross Sections
          Calculated 2200m/s cross sections and res. integ.
                   2200m/s (b)        res. integ. (b)
       total        11.851                -
       elastic      10.007                -
       capture      0.075               0.0034

  MT=1       Sig-t
         Below 1 eV, a sum of partial cross sections.
         Above 1 eV, based on the experimental data /1,2,3,4/.
  MT=2       Sig-el
         Below 1 eV, sig-el = 10 barns.
         Above 1 eV, the elastic scattering cross section was
         obtained by subtracting the reaction cross sections from
         the total cross section.
  MT=4       Total inelastic
         Sum of MT=51 to 91.
  MT=16      (n,2n)
         Based on experimental data/5/-/7/.
  MT=22      (n,n alpha)
         Calculated with the GNASH code/8/.
  MT=28      (n,np)
         Calculated with the GNASH code/8/, and normalized
         to the experimental data/9/.
  MT=32      (n,nd)
         Calculated with the GNASH code/8/.
  MT=51-64,91  Sig-in
         The cross sections were calculated with the statistical
```

model The low-energy portion was analyzed with the resonance theory/10/. For MT=51 to 59, the direct interaction was considered by using DWBA.
The optical potential parameters used are the following: /11/

V = 50.08-0.01E , Ws = 9.0 + 0.62E, Vso = 5.5 (MeV)
r = 1.22 , rs = 1.45 , rso = 1.15 (.m)
a = 0.66 , b = 0.13 , aso = 0.50 (fm).

level scheme

no	energy(MeV)	spin-parity
g.s.	0.0	1 +
1.	2.3129	0 +
2.	3.9478	1 +
3.	4.9150	0 -
4.	5.1059	2 -
5.	5.6900	1 -
6.	5.8320	3 -
7.	6.2040	1 +
8.	6.4440	3 +
9.	7.0280	2 +
10.	7.9670	2 -
11.	8.0620	1 -
12.	8.4880	4 -
13.	8.6180	0 +
14.	8.7900	0 -

Continuum levels were assumed above 8.91 MeV.

MT=102 Capture
Calculated with the CASTHY code/12/.

MT=103 (n,p)
Below 7 MeV, based on experimental data/13/-/18/.
Above 7 MeV, based on the calculations with GNASH.

MT=104 (n,d)
Below 8.5 MeV, based on the experimental data/19/.
Above 8.5 MeV, calculated with GNASH.

MT=105 (n,t)
Below 9 MeV, based on the experimental data/20/.
Above 9 MeV, calculated with GNASH and normalized at 9 MeV.

MT=107 (n,alpha)
Based on the experimental data/17//20/.

MT=108 (n,2alpha)
Calculated with GNASH and normalized at 14.1 MeV to an average value among the experimental data/21//22/.

MT=251 Mu-bar
Calculated from angular distributions in MF=4.

MT=780 (n, alpha0)
Based on experimental data.

MT=781 (n, alpha1)
Based on experimental data.

MT=798 (n, alpha) continuum
Based on experimental data.

MF=4 Angular Distributions of Secondary Neutrons

MT=2
10E-5 eV to 8 MeV Calculated with the resonance theory.
8 MeV to 20 MeV Calculated with CASTHY.

MT=16,22,28,32

Assumed to be isotropic in the laboratory system.

MT=51-64

Calculated with CASTHY.
For MT=51,52,59, the direct interaction was considered by using DWBA.

MT=91

Symmetric distributions in the lab.system.

MF=5 Energy Distribution for Secondary Neutrons

MT=16,22,28,32,91

Calculated with GNASH.

MF=12 Photon Production Multiplicities

MT=102,103

Calculated with GNASH.
For MT=102, modified by using the level scheme data of N-15/23/ at thermal energy.

MF=13 Photon Production Cross Sections

MT=3

Calculated with GNASH.

MF=14 Photon Angular Distributions

MT=3,102,103

Isotropic

MF=15 Photon Energy Distributions

MT=3,102,103

Calculated with GNASH.
For MT=102, modified by using the experimental data/24/ at thermal energy.

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MAT number = 3072

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  7-N - 15             Eval-Dec88 T.Fukahori
JAERI-M 89-047         Dist-Sep89
HISTORY
88-12  Newly Evaluated by T.Fukahori (JAERI)

MF=1           General Information
  MT=451     Descriptive Data and Dictionary

MF=2           Resonance Parameters
  MT=151     MLBW parameters are given.
        Below 5.5 MeV, parameters of the multi-level Breit-Wigner
        formula /1,2/ are adjusted to reproduce the experimental
        data of B.Zeitnitz et al./3/.

  2200 m/sec cross sections and resonance integrals
                        2200 m/sec        Res. Integ.
           total         4.590 b             -
           elastic       4.590 b             -
           capture       0.024 mb          0.016 mb

MF=3           Cross Sections
  MT=1       Total Cross Section
        Below 5.5 MeV, background cross section for MLBW
        calculation is given. Above 5.5 MeV, smooth curve was
        obtained by fit*ing to the experimental data of
        B.Zeitnitz et al./3/.
  MT=2       Elastic Scattering Cross Section
        Below 5.5 MeV, background cross section for MLBW
        calculation is given. Above 5.5 MeV, the cross section
        was obtained by subtracting the reaction cross sections
        from the total cross section.
  MT=4       Total Inelastic scattering Cross Section
        Sum of MT=51-66 and 91.
  MT=16,22,28,32,33,103,104,105,107
        Calculated with GNASH /4/. The optical potential
        potential parameters, the level density parameters and
        the level scheme are shown in Tables 1-3, respectively.
  MT=51-91  Inelastic Scattering
        Calculated with CASTHY /5/. The parameters are also
        shown in Tables 1-3.
  MT=102    Capture Cross Section
        Above 5.5 MeV, the cross section was obtained by
        CASTHY calculation.
  MT=251    Mu-Bar
        Calculated from the data in MF=4.

MF=4           Angular Distributions of Secondary Neutrons
  MT=2,51-66
        Based on the CASTHY calculation.
  MT=16,22,28,32,33,91
        Assumed to be isotropic in the center of mass system.

MF=5           Energy Distributions of Secondary Neutrons
  MT=16,22,28,32,33,91
        Based on the GNASH calculation.
```

MF=12-15 Gamma-ray Data
Based on the GNASH calculation.

Table 1 The Optical Potential Parameters

neutron	V = 50.08-0.012E	MeV	r0 = 1.22 fm	a0 = 0.66 fm
	Ws = 8.91+0.618E	MeV	rl = 1.45 fm	al = 0.13 fm
	Vsym= 5.50	MeV	r0 = 1.15 fm	a0 = 0.50 fm
proton	V = 51.30-0.220E	MeV	r0 = 1.21 fm	a0 = 0.61 fm
	Ws = 6.40-0.050E	MeV	rl = 1.03 fm	al = 0.53 fm
	Vsym= 6.00	MeV	r0 = 1.06 fm	a0 = 0.53 fm
deuteron	Perey-Perey's potential/6/			
triton	Becchetti-Greenlees's potential/7/			
alpha	V = 43.9	MeV	r0 = 1.91 fm	a0 = 0.45 fm
	Wv = 3.85	MeV	rl = 1.91 fm	al = 0.45 fm

Table 2 The Level Density Parameters

	a(1/MeV)	T(MeV)	Pair.(MeV)	Ex(MeV)
B-11	1.431	6.149	2.67	25.58
B-12	1.491	6.201	0.0	26.78
C-12	1.700	5.971	5.60	37.91
C-13	1.846	5.382	2.80	30.57
C-14	1.988	4.887	5.00	28.94
C-15	1.988	4.600	0.0	19.28
N-14	1.600	5.000	0.0	10.00
N-15	2.130	3.758	2.20	10.07
N-16	2.130	4.547	0.0	22.11

Table 3 The Level Scheme (Energy(MeV), Spin and Parity) /2,8,9/

	N-14		N-15		N-16		C-15		C-14		C-13	
gs	0.0	1+	0.0	1/2-	0.0	2-	0.0	1/2+	0.0	0+	0.0	1/2-
1	2.313	0+	5.270	5/2+	0.120	0-	0.740	5/2+	6.094	1-	3.089	1/2+
2	3.948	1+	5.299	1/2+					6.589	0+	3.685	3/2-
3	4.915	0-	6.324	3/2-					6.728	3-	3.854	5/2+
4	5.106	2-	7.155	5/2+					6.903	0-		
5	5.691	1-	7.301	3/2+					7.012	2+		
6	5.834	3-	7.567	7/2+					7.341	2-		
7	6.204	1+	8.313	1/2+								
8	6.446	3+	8.571	3/2+								
9	7.029	2+	9.050	1/2+								
10			9.152	3/2-								
11			9.155	5/2+								
12			9.225	1/2-								
13			9.758	5/2-								
14			9.829	7/2-								
15			9.928	3/2-								

	C-12		B-11		B-12	
gs	0.0	0+	0.0	3/2-	0.0	1+
1			2.125	1/2-	0.953	2+
2			4.445	5/2-	1.674	2-
3			5.020	3/2-	2.620	1-
4			6.743	7/2-	2.720	0+
5			6.793	1/2+		

3 of Nitrogen-15

16	10.070 3/2+	6	7.286 5/2+

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MAT number = 3081

```
  8-O - 16 JNDC        Eval-Dec83 Y.Kanda(KYU) T.Murata(NAIG)+
                       Dist-Sep89
History
83-12  New evaluation for JENDL-3
        Sub-working group on evaluation of O-16,
        working group on nuclear data for fusion,
        Japanese Nuclear Data Committee
       In charge
        Sig-t        Y.Nakajima K.Shibata(JAERI)
        Sig-el       T.Murata(NAIG)
        Sig-in       S.Tanaka(JAERI)
        Capture      T.Asami(JAERI)
        (n,2n),(n,p),(n,d),(n,alpha)    Y.Kanda(KYU)
       Compilation
        Evaluated data were compiled by K.Shibata
84-07  Data of MF=4 (MT=16,91) were revised.
       Comment was also modified.
87-01  Data of MF=3 (MT=51-64,67), MF=4 (MT=51-55) and MF=5(MT=16)
       were modified (S.Chiba, JAERI). Comment was also modified

MF=1          General Information
  MT=451   Descriptive data

MF=2          Resonance Parameters
  MT=151   Scattering radius only.

MF=3          Cross Sections
           Calculated 2200m/s cross sections and res. integrals
                  2200m/s (b)        res. integ. (b)
        total      3.780                -
        elastic    3.780                -
        capture    1.9E-4            8.56E-5

  MT=1       Sig-t
          Below 3 MeV, the total cross section was calculated
          with the R-matrix theory.
          Above 3 MeV, based on the experimental data of
          Cierjacks et al./1/.
  MT=2       Sig-el
          Below 3 MeV, calculated with the R-matrix theory.
          Above 3 MeV, the elastic scattering cross section was
          obtained by subtracting the reaction cross sections from
          the total cross section.
  MT=3       Non-elastic
          Sum of MT=4, 16, 102, 103, 104 and 107.
  MT=4       Total inelastic
          Sum of MT=51 to 91.
  MT=16      (n,2n)
          Based on experimental data/2/.
  MT=51-79,91  Sig-in
          Shape of the excitation functions was calculated with
          the statistical model.
          The optical potential parameters are the following:
             V = 48.25-0.053E,  Ws = 3.0 + 0.25E,  Vso = 5.5  (MeV)
             r = 1.255        ,  rs = 1.352      ,  rso = 1.15 (fm)
```

a = 0.536 , b = 0.205 , aso = 0.50 (fm).

level scheme

no	energy(MeV)	spin-parity
g.s.	0.0	0+
1	6.0490	0+
2	6.1300	3-
3	6.9170	2+
4	7.1169	1-
5	8.8720	2-
6	9.6300	1-
7	9.8470	2+
8	10.360	4+
9	10.960	0-
10	11.080	3+
11	11.100	4+
12	11.520	2+
13	11.600	3-
14	12.050	0+
15	12.440	1-
16	12.530	2-
17	12.800	0-
18	12.970	2-
19	13.020	2+
20	13.090	1-
21	13.120	3-
22	13.260	3-
23	13.660	1+
24	13.870	4+
25	13.980	2-
26	14.030	0+
27	14.100	3-
28	14.300	4+
29	14.400	5+

Continuum levels were assumed above 14.4 MeV.
Constant temperature of 3.4 MeV was used.
For the inelastic scattering to the second and third levels, the (n,n')gamma data of Nordborg et al./3/ and Lundberg et al./4/ below 10MeV.
For MT=51 to 55, the 14 MeV cross sections were normalized to the experimental data/5/-/8/.
Cross sections for MT=56-64 and 67 were normalized to reproduce the DDX data at 14 MeV/8/,/9/.

MT=102 Capture
1/v curve normalized to the recommended value in the 4th edition of BNL-325 /10/ at 0.0253 eV.

MT=103 (n,p)
Based on experimental data/11/-/14/.

MT=104 (n,d)
Based on the evaluation of Foster, Jr. and Young /15/.

MT=107 (n,alpha)
Based on experimental data/3/,/16/-/21/.

MT=251 Mu-bar
Calculated from angular distributions in MF=4.

MF=4 Angular Distributions of Secondary Neutrons

MT=2
10e-5 eV to 3 MeV R-matrix calculation

3 MeV to 5 MeV	Based on the experimental data of Lister and Sayres /22/.
5 MeV to 9 MeV	Multi-level formula/23/.
9 MeV to 15 MeV	Based on the experimental data of Glendinning et al./24/
15 MeV to 20 MeV	Calculated with the spherical optical model. The potential parameters are the same as those given in Sig-in.

MT=16

Assumed to be isotropic in the laboratory system.

MT=51-79

Calculated with the statistical model.
For MT=51, 52 and 55, experimental data/8/ at 14.2 MeV.
For MT=53 and 54 ENDF/B-IV was adopted.

MT=91

Isotropic distributions in the center of mass system were transformed into the ones in the laboratory system. The formula is given in ref./25/.

MF=5 Energy Distribution for Secondary Neutrons

MT=16

Evaporation spectrum was assumed. Constant temperature was deduced from the experimental data of Chiba et al. /26/ for Li-7 according to the sqrt(E/a) law.

MT=91

Evaporation spectrum was assumed. Constant temperature of 3.4 MeV was determined from the stair case plotting.

MF=12 Photon Production Multiplicities

MT=52-68,102,103,107

Calculated with GNASH/27/.

MF=13 Photon Production Cross Sections

MT=3

Calculated with GNASH/27/.

MF=14 Photon Angular Distributions

MT=3,52-68,102,103,107

Isotropic

MF=15 Photon Energy Distributions

MT=3,102,103,107

Calculated with GNASH/27/.

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MAT number = 3091

```
  9-F - 19 JAERI        Eval-Jul89 T.Sugi
                        Dist-Sep89
History
83-11 Evaluation for JENDL-2 was performed by Sugi and Nishimura
      (JAERI)/1/.
89-07 Resonance parameters and total cross section were
      re-evaluated for JENDL-3.
89-07 Compiled by T. Narita (JAERI).

MF=1  General Information
  MT=451  Descriptive data and dictionary

MF=2  Resonance Parameters
  MT=151  Resolved resonance parameters : 1.0E-5 eV - 100 keV
      The multi-level Breit-Wigner formula was used.
      Res. energies and Gam-n : The first two levels were based
         on Johnson et al. /2/.  The 3rd and 4th levels were
         adjusted so as to fit to the experimental data of
         Larson et al./3/
      Gam-g : The first three levels were based on Macklin and
         Winters /4/.  The 4th level was adjusted so as to fit
         to the recommended thermal capture cross section of
         Mughabghab et al./5/.
      Scattering radius: 5.525 fm

      Calculated 2200-m/s cross sections and res. integrals.
                        2200 m/s      res. integ.
         elastic        3.643 b          -
         capture        9.6 milli-b   19.5 milli-b
         total          3.652 b          -

MF=3  Neutron Cross Sections
  MT=1     Total cross section
      Below 100 keV: No background.
      Above 100 keV: Based on the experimental data of
      Larson et al./3/
  MT=2     Elastic scattering cross section
      Derived by subtracting the nonelastic cross section from
      the total cross section.
  MT=4     Total inelastic scattering cross section
      Sum of MT=51-56,91.
  MT=16    (n,2n) cross section
      Calculated by fitting the Pearlstein's function /6/
      to the experimental data.
  MT=22    (n,n' alpha) and (n,alpha n') cross sections
      Calculated with a statistical model by using Pearlstein's
      empirical formula.
  MT=28    (n,n' p) and (n,p n') cross sections
      Calculated with a statistical model by using Pearlstein's
      empirical formula.
  MT=51-56  Inelastic scattering cross sections
      Up to 1MeV : Based on the experimental data of Broder
         et al  /7/.
      1MeV - 5.5MeV : Calculated with the Hauser-Feshbach method
         (ELIESE-3 /8/) taking into account (n,alpha) and (n,p)
```

as competing processes. The level scheme of F-19, N-16 O-19 was taken from Ajzenberg-Selove /9/,/10/.
The optical potential parameters are :

V = 51.56 - 1.492•E (MeV),
Ws = 11.82 (MeV),
Vso= 10.0 (MeV),
r0 = rs = rso = 1.31 (fm),
a = aso = 0.66 (fm),
b = 0.47 (fm).

The level density parameter of 3.609 (1/MeV)/11/ and pairing energy of 2.52 MeV /12/ were used.

MT=91 Inelastic to continuum
Calculated with ELIESE-3.

MT=102 Capture cross section
Below 100 keV : No background.
100keV - 1.87MeV : Based on the experimental data of Gabbard et al. /13/.
1.87MeV - 20MeV : Assumed to decrease with 1/v law.

MT=103 (n,p) cross section
Up to 9MeV : Based on the experimental data of Bass et al. /14/.
9MeV - 20MeV : Calculated with the statistical model by using Pearlstein' empirical formula.

MT=104 (n,d) cross section
Calculated with the Pearlstein's empirical formula /15/. The cross section was normalized to 39.5 milli-barns at 14.4 MeV.

MT=105 (n,t) cross section
Calculated with the Pearlstein's empirical formula /15/. The cross section was normalized to 15.0 milli-barns at 14.4 MeV.

MT=107 (n,alpha) cross section
Below 9 MeV, Based on the following experimental data:
Up to 4MeV Davis et al. /16/,
4MeV - 5.5MeV Smith et al. /17/,
5.5MeV - 9MeV Bass et al. /14/.
Above 9 MeV, Calculated with the Pearlstein's formula.

MT=251 Average cosine in the laboratory system
Derived from the angular distributions.

MF=4 Angular Distributions of Secondary Neutrons

MT=2
Calculated with optical model .

MT=16,22,28
Assumed to be isotropic in the laboratory system.

MT=51-56
Assumed to be isotropic in the center-of-mass system.

MT=91
Assumed to be isotropic in the center-of-mass system and transformed into the laboratory system.

MF=5 Energy Distributions of Secondary Neutrons

MT=16,22,28,91
Evaporation spectra were given.

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MAT number = 3111

11-Na- 23 SRI Eval-Mar87 H.Yamakoshi(Ship Research Inst.)
Dist-Sep89

History
87-03 New evaluation was made for JENDL-3.
89-08 The data for MF=15,MT=102 modified.

MF=1 General Information
MT=451 Descriptive data and dictionary

MF=2 Resonance Parameters
MT=151 Resolved resonance parameters
Resolved parameters for MLBW formula were given in the energy region from 1.0E-5 eV to 350 keV.
Parameters were mainly taken from the recommended data of BNL /1/, and the data for some levels were modified so that the calculated total cross sections for Na-23 were fitted to the experimental data.
The scattering radius was assumed to be 5.2 Fermi.
Calculated 2200 m/sec cross sections and resonance integrals are as follows:

	2200 m/s cross section(b)	res. integral(b)
elastic	3.024	
capture	0.531	0.3122
total	3.555	

MF=3 Neutron Cross Sections
Below 350 keV, background cross section was given for the total and elastic scattering cross sections.
The cross-section data are reproduced from the evaluated resolved resonance parameters with MLBW formula.
Above 350 keV, the total and partial cross sections were given pointwise.
MT=1 Total
In the energies between 350 keV and 14 MeV, evaluated based on the experimental data of Cierjacks/2/ in tracing their fine structures. Above 14 MeV, based on the experimental data of Langsford/3/, Stoler/4/ and Larson/5/.
MT=2 Elastic scattering
Obtained by subtracting the sum of the partial cross sections from the total cross section.
MT=4, 51-77, 91 inelastic scattering
Below 5 MeV, the inelastic scattering cross section to the 1st level(MT=51) was evaluated based on the experimental data of Towle and Gilboy/6/, Chrien and Smith/7/, and Lind and Dat/8/.
Below 5 MeV, the inelastic scattering cross section to the 2nd and 3rd level(MT=52, 53) was evaluated based on the experimental data of Freeman and Montague/9/, Lind and Dat/8/, and Towle and Owens/10/. For the inelastic scattering cross sections to the 1st to 3rd levels above 5 MeV and the other inelastic scattering data, optical and statistical model calculations were made with the CASTHY code/11/, taking account of the contribution from the competing processes. The direct component was calculated with with the DWUCK code/12/ for five lowest levels. The deformation parameters were estimated based on a weak coupling model.

The optical potential parameters used are:
V = 46.0 - 0.25•En, Vso = 6.0 (MeV)
Ws = 14.0 - 0.2•En, Wv = 0.125•En (MeV)
r = 1.286, rs = 1.39, rso = 1.07 (fm)
a = 0.62, aso = 0.62, b = 0.7 (fm)

The level data used in the above two calculations were taken from ref./13/ as follows:

MT	Level energy(MeV)	Spin-parity
	0.0	3/2+
51	0.4399	5/2+
52	2.0764	7/2+
53	2.3909	1/2+
54	2.6398	1/2-
55	2.7037	9/2+
56	2.9824	3/2+
57	3.6783	3/2-
58	3.8480	5/2-
59	3.9147	5/2+
60	4.4320	1/2+
61	4.7756	7/2+
62	5.3800	3/2+
63	5.5360	11/2+
64	5.7410	3/2+
65	5.7660	5/2+
66	5.9310	1/2-
67	5.9670	3/2-
68	6.0430	1/2-
69	6.1170	11/2+
70	6.1910	11/2+
71	6.2360	13/2+
72	6.3080	1/2+
73	6.3506	9/2-
74	6.5770	5/2+
75	6.6170	9/2+
76	6.7340	3/2+
77	6.8680	5/2+

Levels above 6.9 MeV were assumed to be overlapping.

MT=16 (n,2n)
Mainly based on the experimental data of Adamski/14/.

MT=22 (n,na)
Calculated with the GNASH code/15/ and normalized to the experimental data of Woelfer/16/ at 16.4 MeV.

MT=28 (n,np)
Calculated with the GNASH code/15/.

MT=102 Capture
Calculated with the CASTHY code/11/ and normalized to 0.3 mb at 500 keV.

MT=103 (n,p)
Below 10 MeV, based on the experimental data/17,18/.
Above 10 MeV, calculated with the GNASH code/15/ and normalized to connect smoothly with the data below 10 MeV.

MT=107 (n,a)
Below 12 MeV, based on the experimental data/17,18/.
Above 12 MeV, calculated with the GNASH code/15/ and normalized to connect smoothly with the data below 10 MeV.

MT=251 Mu-bar

Calculated with the optical model.

MF=4 Angular Distributions of Secondary Neutrons
MT=2
Calculated with the CASTHY code/11/.
MT=51-77
Calculated with the CASTHY code/11/ and the DWUCK code/7/.
MT=91
Calculated with the CASTHY code/11/.
MT=16, 22, 28
Isotropic in the laboratory system.

MF=5 Energy Distributions of Secondary Neutrons
MT=16, 22, 28, 91
Calculated with the GNASH code/15/.

MF=12 Photon Production Multiplicities
MT=102
Calculated with the GNASH code/15/ and modified at thermal based on the experimental data of Maerker/19/.

MF=13 Photon Production Cross Sections
MT=3
Calculated with the GNASH code/15/.

MF=14 Photon Angular Distributions
MT=3, 102
Assumed to be isotropic in the laboratory system.

MF=15 Continuous Photon Energy Spectra
MT=3
Calculated with the GNASH code/15/.
MT=102
Calculated with the GNASH code/15/ and modified at thermal based on the experimental data of Maerker/19/.

References

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2) Cierjacks S. et al. : KfK-1000 (1969).
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6) Towle J.H. and Gilboy W.B. : Nucl. Phys. 32, 610 (1962).
7) Chrien J.P. and Smith A.B. : Nucl. Sci. Eng. 26, 500 (1966).
8) Lind D.A. and Day R.B. : Ann. Phys. 12, 485 (1961).
9) Freeman J.M. and Montague J.H. : Nucl. Phys. 9, 181 (1958).
10) Towle J.H. and Owens R.O. : Nucl. Phys. A100, 257 (1967).
11) Igarasi S. : J. Nucl. Sci. Tech. 12, 67 (1975).
12) Kunz P.D. : Unpublished.
13) ENSDF(Evaluated Nuclear Structure Data File)
14) Adamski L. et al. : Anna. Nucl. Ener. 7, 397 (1980).
15) Young P.G. and Arthur E.D. : LA-6947 (1977).
16) Woelfer G. et al. : Z. Phys. 194, 75 (1966).
17) Williamson C.F. : Phys. Rev. 122, 1877 (1961).
18) Bass R. et al. : 1965 Antwerp Conf. 495 (1966).
19) Maerker R.E. : ORNL-TM-5203 (1976).

MAT number = 3120

12-Mg- 0 DEC,NEDAC Eval-Mar87 M.Hatchya(DEC),T.Asami(NEDAC)
Dist-Sep89

History
87-03 New evaluation was made for JENDL-3.
87-03 Compiled by T.Asami.

MF=1 General Information
MT=451 Descriptive data and dictionary

MF=2 Resonance Parameters
MT=151 Resolved resonance parameters
Resolved parameters for MLBW formula were given in the energy region from 1.0E-5 eV to 520 keV.
The data are constructed from the evaluated resonance parameters for Mg-24, -25 and -26, considering their abundances in the Mg element/1/.

	2200 m/s cross section(b)	res. integral(b)
elastic	3.53	
capture	0.063	0.0366
total	3.59	

MF=3 Neutron Cross Sections
Below 520 keV, zero background cross section was given.
Above 520 keV, the total and partial cross sections were given pointwise.
All the cross-section data were constructed from the evaluated ones for three stable isotopes of Mg considering their abundances in the Mg element.
MT=1 Total
Constructed from the evaluated data for stable isotopes of Mg.
MT=2 Elastic scattering
Obtained by subtracting the sum of the partial cross sections from the total cross section.
MT=4, 51-90, 91 Inelastic scattering
Constructed from the evaluated data for stable isotopes of Mg as follows:

MT	Level energy(MeV)	Mg-24	Mg-25	Mg-26
	0.0			
51	0.5851		51	
52	0.9748		52	
53	1.3686	51		
54	1.6118		53	
55	1.8087			51
56	1.9647		54	
57	2.5638		55	
58	2.7377		56	
59	2.8011		57	
60	2.9384			52
61	3.4052		58	
62	3.4137		59	
63	3.5880			53
64	3.9078		60	
65	3.9405			54
66	3.9707		61	

2 of Natural Magnesium

67	4.0596		62	
68	4.1200	52		
69	4.2384	53		
70	4.2770		63	
71	4.3180			55
72	4.3320			56
73	4.3500			57
74	4.3594		64	
75	4.7114		65	
76	4.7220		66-67	
77	4.8340			58
78	4.9000			59
79	4.9700			60
80	5.2361	54		
81	5.2910			61
82	5.4740			62
83	5.6900			63
84	6.0103	55		
85	6.4322	56		
86	7.3479	57		
87	7.5530	58		
88	7.6162	59		
89	7.7472	60		
90	7.8120	61		

Levels above 7.98 MeV were assumed to be overlapping.

MT=16, 22, 28, 102, 103 and 107 (n,2n), (n,na), (n,np), (n,gamma), (n,p) and (n,a)
Constructed from the evaluated data for three stable isotopes of Mg, taking account of their abundances in the Mg element. The calculated capture cross sections were normalized so as to reproduce the element Mg data of 72 mb at 500 keV/2/.

MT=251 Mu-bar
Constructed from the evaluated data for stable isotopes of Mg, taking account of their abundances in the Mg element.

MF=4 Angular Distributions of Secondary Neutrons

MT=2
Constructed from the evaluated data for stable isotopes of Mg, taking account of their abundances in the Mg element.

MT=51-90, 91
Constructed with the evaluated data for stable isotopes of Mg, taking account of their abundances in the Mg element.

MT=16, 22, 28
Isotropic in the laboratory system.

MF=5 Energy Distributions of Secondary Neutrons

MT=16, 22, 28, 91
Constructed from the evaluated data for stable isotopes of Mg, taking account of their abundances in the Mg element.

MF=12 Photon Production Multiplicities

MT=102
Calculated with the GNASH code/3/.

MF=13 Photon Production Cross Sections

MT=3

Calculated with the GNASH code/3/.

MF=14 Photon Angular Distributions
MT=3, 102
Assumed to be isotropic in the laboratory system

MF=15 Continuous Photon Energy Spectra
MT=3
Calculated with the GNASH code/3/.
MT=102
Calculated with the GNASH code/3/, and modified at thermal energy by using the experimental ones of Spilling/4/.

References

1) Holden N.E., Martin R.L. and Barnes I.L. : Pure & Appl. Chem. 56, 675 (1984).
2) Grenier et al. : CEA-N-2195 (1981).
3) Young P.G. and Arthur E.D. : LA-6947 (1977).
4) Spilling P. et al. : Nucl. Phys. A102, 209 (1967)

MAT number = 3121

12-Mg- 24 DEC,NEDAC Eval-Mar87 M.Hatchya(DEC), T.Asami(NEDAC)
Dist-Sep89

History
87-03 New evaluation was made for JENDL-3.
87-03 Compiled by T.Asami.

MF=1 General Information
MT=451 Descriptive data and dictionary

MF=2 Resonance Parameters
MT=151 Resolved resonance parameters
Resolved parameters for MLBW formula were given in the energy region from 1.0E-5 eV to 520 keV.
Parameters were taken from the recommended data of BNL/1/ and the data for a negative resonance were added so as to reproduce the recommended thermal cross sections for capture and scattering/1/.
The data for some levels were modified so that the calculated total cross sections of the element Mg were fitted to the experimental data of Hibdon/2/ and Singh/3/.
The scattering radius was assumed to be 5.4 Fermi.
Calculated 2200 m/sec cross sections and resonance integrals are as follows:

	2200 m/s cross section(b)	res. integral(b)
elastic	3.75	
capture	0.050	0.0312
total	3.80	

MF=3 Neutron Cross Sections
Below 520 keV, zero background cross section was given and all the cross-section data are reproduced from the evaluated resolved resonance parameters with MLBW formula.
Above 520 keV, the total and partial cross sections were given pointwise.
MT=1 Total
Optical and statistical model calculation was made with CASTHY code/4/. The optical potential parameters used are:

$V = 49.68$, $V_{so} = 7.12$ (MeV)
$W_s = 7.76 - 0.5 \cdot E_n$, $W_v = 0$ (MeV)
$r = 1.17$, $r_s = 1.09$, $r_{so} = 1.17$ (fm)
$a = 0.6$, $a_{so} = 0.6$, $b = 0.69$ (fm)

MT=2 Elastic scattering
Obtained by subtracting the sum of the partial cross sections from the total cross section.
MT=4, 51-61, 91 Inelastic scattering
Calculated with CASTHY /4/, taking account of the contribution from the competing processes. The direct component was calculated with the DWUCK/5/. The calculated data for the first level were normalized at 12 MeV to the experimental data/6/.
The level data used in the above two calculations were taken from ref./7/ as follows:

MT	Level energy(MeV)	Spin-parity
	0.0	0+
51	1.3686	2+

52	4.1200	4+
53	4.2384	2+
54	5.2361	3+
55	6.0103	4+
56	6.4322	0+
57	7.3479	2+
58	7.5530	1-
59	7.6162	3-
60	7.7472	1+
61	7.8120	3+

Levels above 10.0 MeV were assumed to be overlapping.

MT=16, 22, 28, 103, 107 (n,2n), (n,na), (n,np), (n,p), (n,a)
Calculated with the GNASH code/8/ using the above optical model parameters
The (n,2n) cross sections were modified so as to fit to the experimental data.

MT=102 Capture
Calculated with the CASTHY code/4/ and normalized to 1.8 mb at 30 keV.

MT=251 Mu-bar
Calculated with the optical model.

MF=4 Angular Distributions of Secondary Neutrons

MT=2
Calculated with the CASTHY code/4/.

MT=51-61
Calculated with the CASTHY code/4/ and the DWUCK code/5/.

MT=91
Calculated with the CASTHY code/4/.

MT=16, 22, 28
Isotropic in the laboratory system.

MF=5 Energy Distributions of Secondary Neutrons

MT=16, 22, 28, 91
Calculated with the GNASH code/8/.

References

1) Mughabghab S.F. and Garber D.I. :"Neutron Cross Sections", Vol. 1, Part B (1984).
2) Hibdon C.T. : Taken from EXFOR (1969).
3) Singh U.N. et al. : Phys. Rev. C10, 2150 (1974).
4) Igarasi S. : J. Nucl. Sci. Tech. 12, 67 (1975).
5) Kunz P.D. : Unpublished.
6) Foertsch et al. : Nucl. Instr. Meth. 169, 533 (1980).
7) ENSDF(Evaluated Nuclear Structure Data File)
8) Young P.G. and Arthur E.D. : LA-6947 (1977).

MAT number = 3122

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 12-Mg- 25 DEC,NEDAC  Eval-Mar87 M.Hatchya(DEC),T.Asami(NEDAC)
                      Dist-Sep89

History
 87-03  New evaluation was made for JENDL-3.
 87-03  Compiled by T.Asami.

MF=1  General Information
 MT=451  Descriptive data and dictionary

MF=2  Resonance Parameters
 MT=151  Resolved resonance parameters
   Resolved parameters for MLBW formula were given in
   the energy region from 1.0E-5 eV to 220 keV.
   Parameters were taken from the recommended data of BNL/1/ and
   modified for some levels so as to reproduce the experi-
   mental total cross section of the element Mg.
   The data for a negative resonance were added so as to reproduce
   the recommended thermal cross sections for capture and scatter-
   ing/1/.
   The data for some levels were modified so that the calculated
   total cross sections of the element Mg were fitted to the
   experimental data of Hibdon/2/ and Singh/3/.
   The scattering radius was assumed to be 4.9 Fermi.
   Calculated 2200 m/sec cross sections and resonance integrals
   are as follows:
             2200 m/s cross section(b)     res. integral(b)
   elastic      2.60
   capture      0.190                        0.0989
   total        2.79

MF=3  Neutron Cross Sections
  Below 220 keV, zero background cross section was given and  all
  the cross-section data are reproduced from the evaluated resolv-
  ed resonance parameters with MLBW formula.
  Above 220 keV, the total and partial cross sections were given
  pointwise.
 MT=1 Total
  Optical and statistical model calculation was made with
  the CASTHY code/2/. The optical potential parameters used are:
    V = 49.68,                 Vso = 7.12    (MeV)
   Ws = 7.76 - 0.5*En,          Wv = 0        (MeV)
    r = 1.17,   rs = 1.09,  rso = 1.17       (fm)
    a = 0.6,    aso = 0.6,    b = 0.69       (fm)
 MT=2 Elastic scattering
  Obtained by subtracting the sum of the partial cross sections
  from the total cross section.
 MT=4, 51-67, 91 inelastic scattering
  Calculated with CASTHY/2/, taking account of the contribution
  from the competing processes. The direct component was
  calculated with the DWUCK/3/.
  The level data used in the above two calculations were taken
  from ref./4/ as follows:
    MT   Level energy(MeV)   Spin-parity
              0.0               5/2+
```

51	0.5851	1/2+
52	0.9748	3/2+
53	1.6118	7/2+
54	1.9647	5/2+
55	2 5638	1/2+
56	2.7377	7/2+
57	2.8011	3/2+
58	3.4052	9/2+
59	3.4137	3/2-
60	3.9078	5/2+
61	3.9707	7/2-
62	4.0596	9/2+
63	4.2770	1/2-
64	4.3594	3/2+
65	4.7114	9/2+
66	4.7220	1/2-
67	5.0122	7/2+

Levels above 8.0 MeV were assumed to be overlapping.

MT=16, 22, 28, 103, 107 (n,2n), (n,na), (n,np), (n,p), (n,a)
Calculated with the GNASH code/5/ using the above optical model parameters
The (n,p) cross sections were normalized to the experimental data at 14 MeV of Bormann/8/.

MT=102 Capture
Calculated with the CASTHY code/2/ and normalized to 4.7 mb at 30 keV.

MT=251 Mu-bar
Calculated with the optical model.

MF=4 Angular Distributions of Secondary Neutrons

MT=2
Calculated with the CASTHY code/2/.

MT=51-67
Calculated with the CASTHY code/2/ and the DWUCK code/3/.

MT=91
Calculated with the CASTHY code/2/.

MT=16, 22, 28
Isotropic in the laboratory system.

MF=5 Energy Distributions of Secondary Neutrons

MT=16, 22, 28, 91
Calculated with the GNASH code/5/.

References

1) Mughabghab S.F. and Garber D.I. :"Neutron Cross Sections", Vol. 1, Part B (1984).
2) Hibdon C.T. : Taken from EXFOR (1969).
3) Singh U.N. et al. : Phys. Rev. C10, 2150 (1974).
4) Igarasi S. : J. Nucl. Sci. Tech. 12, 67 (1975).
5) Kunz P.D. : Unpublished.
6) ENSDF(Evaluated Nuclear Structure Data File)
7) Young P.G. and Arthur E.D. : LA-6947 (1977).
8) Bormann M. et al. : 1966 Paris Conf. Vol.1, 225 (1967).

MAT number = 3123

12-Mg- 26 DEC,NEDAC Eval-Mar87 M.Hatchya(DEC),T.Asami(NEDAC)
Dist-Sep89

History
87-03 New evaluation was made for JENDL-3.
87-03 Compiled by T.Asami.

MF=1 General Information
MT=451 Descriptive data and dictionary

MF=2 Resonance Parameters
MT=151 Resolved resonance parameters
Resolved parameters for MLBW formula were given in the energy region from 1.0E-5 eV to 450 keV.
Parameters were taken from the recommended data of BNL/1/ and the data for a negative resonance were added so as to reproduce the recommended thermal cross sections for capture and scattering/1/.
The scattering radius was assumed to be 4.3 Fermi.
Calculated 2200 m/sec cross sections and resonance integrals are as follows:

	2200 m/s cross section(b)	res. integral(b)
elastic	2.83	
capture	0.038	0.0190
total	2.87	

MF=3 Neutron Cross Sections
Below 450 keV, zero background cross section was given and all the cross-section data are reproduced from the evaluated resolved resonance parameters with MLBW formula.
Above 450 keV, the total and partial cross sections were given pointwise.
MT=1 Total
Optical and statistical model calculation was made with the CASTHY code/2/. The optical potential parameters used are:

V = 49.68,		Vso = 7.12	(MeV)
Ws = 7.76 - 0.5*En,		Wv = 0	(MeV)
r = 1.17,	rs = 1.09,	rso = 1.17	(fm)
a = 0.6,	aso = 0.6,	b = 0.69	(fm)

MT=2 Elastic scattering
Obtained by subtracting the sum of the partial cross sections from the total cross section.
MT=4, 51-63, 91 Inelastic scattering
Calculated with CASTHY /2/, taking account of the contribution from the competing processes. The direct component was calculated with the DWUCK code/3/.
The level data used in the above two calculations were taken from ref./4/ as follows:

MT	Level energy(MeV)	Spin-parity
	0.0	0+
51	1.8087	2+
52	2.9384	2+
53	3.5880	0+
54	3.9405	3+
55	4.3180	4+

56	4.3320	2+
57	4.3500	3+
58	4.8340	2+
59	4.9000	4+
60	4.9720	0+
61	5.2910	2+
62	5.4740	4+
63	5.6900	1+

Levels above 8.0 MeV were assumed to be overlapping.

MT=16, 22, 28, 103, 107 (n,2n), (n,na), (n,np), (n,p), (n,a)
Calculated with the GNASH code/6/ using the above optical model parameters
The (n,a) cross sections were normalized to the experimental data of Bormann/5/ at 14 MeV.

MT=102 Capture
Calculated with the CASTHY code/2/ and normalized to 1.7 mb at 30 keV.

MT=251 Mu-bar
Calculated with the optical model.

MF=4 Angular Distributions of Secondary Neutrons

MT=2
Calculated with the CASTHY code/2/.

MT=51-63
Calculated with the CASTHY code/2/ and the DWUCK code/3/.

MT=91
Calculated with the CASTHY code/2/.

MT=16, 22, 28
Isotropic in the laboratory system.

MF=5 Energy Distributions of Secondary Neutrons

MT=16, 22, 28, 91
Calculated with the GNASH code/6/.

References

1) Mughabghab S.F. and Garber D.I. :"Neutron Cross Sections", Vol. 1, part B (1984).
2) Igarasi S. : J. Nucl. Sci. Tech. 12, 67 (1975).
3) Kunz P.D : Unpublished.
4) ENSDF(Evaluated Nuclear Structure Data File)
5) Bormann M. et al. : 1966 Paris Conf. Vol.1, 225 (1967).
6) Young P.G. and Arthur E.D. : LA-6947 (1977).

MAT number = 3131

13 Al- 27 TIT,JAERI Eval-Mar88 Y.Harima,H.Kitazawa,T.Fukahori
Dist-Sep89

HISTORY
88-03 New evaluation was performed for JENDL-3 by Harima, Kitazawa (Tokyo Institute of Tech.) and Fukahori (JAERI). Details are given in ref./1/.
88-03 Compiled by Fukahori.

MF=1 General Information
MT=451 Descriptive data and dictionary

MF=2 Resonance parameters:
MT=151
Resolved resonances : 1.0E-5 eV - 0.21 MeV
The resonance parameters were searched, using MLBW formula/2/. An initial guess of the parameters search was taken from ref. /3/.

Calculated 2200-m/s cross sections and resonance integrals

	2200-m/sec	Res. Integ
elastic	1.414 b	-
capture	0.231 b	0.123 b
total	1.645 b	-

MF=3 Neutron Cross Sections
MT=1 Total cross section
Between 0.21 and 20 MeV, the cross sections were obtained by an eye-guide so as to follow the experimental data.
MT=2 Elastic scattering cross sections
Obtained by subtracting partial cross sections from the total cross sections.
MT=4,51-66,91 Inelastic scattering cross sections
Calculated with the statistical-model code CASTHY /4/ and the coupled-channel model code ECIS /5/ or JUPITOR-1 /6/, taking account of competitive processes for neutron, proton, alpha-particle and gamma-ray emission./1/

Level scheme was taken from ref./11/.

No.	Energy(MeV)	Spin-parity
g.s.	0.0	5/2 +
1.	0.8438	1/2 +
2.	1.0145	3/2 +
3.	2.2100	7/2 +
4.	2.7340	5/2 +
5.	2.9814	3/2 +
6.	3.0040	9/2 +
7.	3.6780	1/2 +
8.	3.9560	5/2 +
9.	4.0540	3/2 -
10.	4.4090	5/2 +
11.	4.5103	11/2 +
12.	4.5800	7/2 +
13.	4.8120	5/2 +
14.	5.1550	3/2 -
15.	5.2460	5/2 +

16. 5.4330 9/2 +

Continuum levels were assumed above 5.6 MeV. Level density was calculated, using the Gilbert-Cameron formula. The level-density parameters were obtained from a cumulative plot of observed levels./1/.

MT=16 (n,2n) cross sections
Calculated by the statistical model, using the GNASH code /1,7/

MT=22 (n,na) cross sections
Calculated by the statistical model, using the GNASH code /1,7/
Optical potential for alpha-particles was determined, using the dispersion theory./8/

MT=28 (n,np) cross sections
Calculated by the statistical model, using the GNASH code /1,7/

MT=102 Capture
Calculated with the statistical model code CASTHY /4/ and the direct-semidirect-model code HIKARI /9/. The statistical model calculations were normalized to 0.6 mb at 0.6 MeV.

MT=103 (n,p) cross sections
Calculated by the statistical model, using the GNASH code /1,7/

MT=107 (n,a) cross sections
Obtained by an eye-guide to follow observed values /10/

MT=111 (n,2p) cross sections
Calculated by the statistical model, using the GNASH code /1,7/

MT=251 Mu-bar
Calculated with statistical-model code CASTHY /1,4/

MF=4 Angular Distributions of Secondary Neutrons

MT=2
Calculated with the statistical-model code CASTHY /1,4/.

MT=16,22,28
Isotropic in the laboratory system.

MT=51-66
Incoherent sum of the statistical model and coupled-channel model calculations./1/ Calculated with CASTHY and ECIS or JUPITOR-1.

MT=91
Isotropic in the center-of-mass system converted to the distribution in the laboratory system.

MF=5 Energy Distributions of Secondary Neutrons

MT=16,22,28,91
Calculated by using the GNASH code./1,7/

MF=12 Gamma-ray Multiplicities

MT=51-66,102,103,107
Calculated by using the GNASH code./1,7/

MF=13 Gamma-ray Production Cross Sections

MT=3
Calculated by the statistical model and coupled-channel model, using the GNASH code /7/ and the ECIS /5/ or JUPITOR-1 code /6/. Branching ratios for transitions between discrete levels were taken from ref./12/. Gamma-ray transition strength in the continuum was calculated by the Brink-Axel giant resonance model for E1 transition and by the Weisskopf single-particle model for E2 and M1 transition./1/

MF=14 Gamma-ray Angular Distributions
MT=3,51-66,102,103,107
Isotropic distribution was assumed.

MF=15 Gamma-ray Spectra
MT=3,102,103,107
Calculated with the GNASH code./1,7/

References

1) Kitazawa H. et al.: Proc. Int. Conf. Nuclear Data for Science and Technology, Mito, 1988, p.473, (1988).
2) Nakagawa T.: JAERI-M 84-192 (1984).
3) Mughabghab S.F. et al.: "Neutron Cross Sections, Vol. 1 Part A", Academic Press (1981).
4) Igarasi S.: J. Nucl. Sci. Technol., 12, 67 (1965).
5) Raynal J.: Computer Program ECIS79 for coupled-channel calculations, 1979 (unpublished).
6) Tamura T.: Rev. Mod. Phys., 37, 679 (1965).
7) Young P.G. and Arthur E.D.: La-6947 (1977).
8) Kitazawa H. et al.: unpublished.
9) Kitazawa H.: Computer program HIKARI for direct-semidirect capture calculations, 1980 (unpublished).
10) Vonach H.: Nuclear data standards for nuclear measurements, IAEA technical reports series No. 227 (1983).
11) Endt P.M. and Van Der Leun C.: Nucl. Phys., A310, 1 (1978).

MAT number = 3140

14-Si- 0 TIT,JAERI Eval-Mar88 H.Kitazawa,Y.Harima,T.Fukahori
Dist-Sep89

HISTORY
88-03 New evaluation was performed for JENDL-3 by Kitazawa, Harima (Tokyo Institute of Tech.) and Fukahori (JAERI). Details are given in ref./1/.
88-03 Compiled by Fukahori.

MF=1 General Information
MT=451 Descriptive data and dictionary

MF=2 Resonance parameters:
MT=151
Resolved resonances : 1.0E-5 eV - 1.81 MeV
The resonance parameters were searched, using MLBW formula/2/. *An initial guess of the parameters search was taken from ref. /3/.*

Calculated 2200-m/s cross sections and resonance integrals

	2200-m/sec	Res. Integ.
elastic	2.172 b	-
capture	0.171 b	0.104 b
total	2.343 b	-

MF=3 Neutron Cross Sections
MT=1 Total cross section
Between 1.81 and 12.5 MeV, the cross sections were obtained by an eye-guide so as to follow the experimental data.
Above 12.5 MeV, the cross sections were calculated with the statistical-model code CASTHY./1,4/
MT=2 Elastic scattering cross sections
Obtained by subtracting partial cross sections from the total cross sections.
MT=4,51-90,91 Inelastic scattering cross sections
Calculated with the statistical-model code CASTHY /4/ and the coupled-channel model code ECIS /5/ or JUPITOR-1 /6/, taking account of competitive processes for neutron, proton, alpha-particle and gamma-ray emission./1/
Below 11 MeV, the imaginary potential strength of the neutron spherical optical potential was modified from that in ref./1/ to be W = 1.09 + 0.55*E (MeV).

Level scheme was taken from ref./10/.

Si-28		Si-29		Si-30	
Energy(MeV)	J-Pi	Energy(MeV)	J-Pi	Energy(MeV)	J-Pi
0.0	0 +	0.0	1/2+	0.0	0 +
1.7789	2 +	1.2733	3/2+	2.2355	2 +
4.6178	4 +	2.4256	3/2+	3.7696	1 +
4.9791	0 +	3.6235	7/2-	4.8090	2 +
6.2765	3 +	4.7410	9/2+	5.2300	3 +
6.6914	0 +	4.8950	5/2+	5.3720	0 +
6.8786	3 -	5.2546	9/2-	5.6130	2 +
6.8888	4 +	5.6520	9/2+	6.5030	4 -
7.3807	2 +	5.9490	3/2+	6.6340	2 -

7.4173	2 +	6.1910	7/2-	6.7447	1 -
7.7988	3 +	6.4240	7/2+	6.9140	2 +
7.9334	2 +	6.5220	3/2+		
8.2590	2 +	6.6970	3/2-		
8.3280	1 +	6.7150	3/2+		
8.4133	4 -	6.9070	1/2-		
8.5430	6 +				
8.5890	3 +				

Continuum levels were assumed above 6.999 MeV. Level density was calculated, using the Gilbert-Cameron formula. The level-density parameters were obtained from a cumulative plot of observed levels /1/.

MT=16 (n,2n) cross sections
Calculated by the statistical model, using the GNASH code /1,7/. Below 11 MeV, the imaginary potential strength of the neutron spherical optical potential was modified from that in ref /1/ to be W = 1.09 + 0.55•E (MeV).

MT=22 (n,na) cross sections
Calculated by the statistical model, using the GNASH code /1,7/. Optical potential for alpha-particles was determined, using the dispersion theory./8/

MT=28 (n,np) cross sections
Calculated by the statistical model, using the GNASH code /1,7/

MT=102 Capture
Calculated with the statistical-model code CASTHY /4/ and the direct-semidirect-model code HIKARI /9/.

MT=103 (n,p) cross sections
Calculated by the statistical model, using the GNASH code./1,7/ The imaginary potential strength of the proton spherical optical model was modified from that in ref./1/ to be W = 11.0 MeV between 11 and 20 MeV and W = 8.8 + 0.2•E (MeV) below 11 MeV.

MT=107 (n,a) cross sections
Cnstructed from the isotopic data.

MT=111 (n,2p) cross sections
Calculated by the statistical model, using the GNASH code./1,7/

MT=251 Mu-bar
Calculated with statistical-model code CASTHY /1,4/

MF=4 Angular Distributions of Secondary Neutrons

MT=2
Calculated with the statistical-model code CASTHY /1,4/.

MT=16,22,28
Isotropic in the laboratory system.

MT=51-90
Incoherent sum of the statistical model and coupled-channel model calculations./1/ Calculated with CASTHY and ECIS or JUPITOR-1.

MT=91
Isotropic in the center-of-mass system converted to the distribution in the laboratory system.

MF=5 Energy Distributions of Secondary Neutrons

MT=16,22,28,91
Calculated by using the GNASH code./1,7/

MF=12 Gamma-ray Multiplicities
MT=51-90,102,103,107
Calculated by using the GNASH code /1,7/

MF=13 Gamma-ray Production Cross Sections
MT=3
Calculated by the statistical model and coupled-channel model, using the GNASH code /7/ and the ECIS /5/ or JUPITOR-1 code /6/. Branching ratios for transitions between discrete levels were taken from ref./11/. Gamma-ray transition strength in the continuum was calculated by the Brink-Axel giant resonance model for E1 transition and by the Weisskopf single-particle model for E2 and M1 transition./1/

MF=14 Gamma-ray Angular Distributions
MT=3,51-90,102,103,107
Isotropic distribution was assumed.

MF=15 Gamma-ray Spectra
MT=3,102,103,107
Calculated with the GNASH code./1,7/

References

1) Kitazawa H. et al.: Proc. Int. Conf. Nuclear Data for Science and Technology, Mito, 1988, p.473, (1988).
2) Nakagawa T.: JAERI-M 84-192 (1984).
3) Mughabghab S.F. et al.: "Neutron Cross Sections, Vol. 1 Part A", Academic Press (1981).
4) Igarasi S.: J. Nucl. Sci. Technol., 12, 67 (1965).
5) Raynal J.: Computer Program ECIS79 for coupled-channel calculations, 1979 (unpublished).
6) Tamura T.: Rev. Mod. Phys., 37, 679 (1965).
7) Young P.G. and Arthur E.D.: La-6947 (1977).
8) Kitazawa H. et al.: unpublished.
9) Kitazawa H.: Computer program HIKARI for direct-semidirect capture calculations, 1980 (unpublished).
10) Endt P.M. and Van Der Leun C.: Nucl. Phys., A310, 1 (1978).

MAT number = 3141

14-Si- 28 TIT,JAERI Eval-Mar88 H.Kitazawa,Y.Harima,T.Fukahori
Dist-Sep89

HISTORY
88-03 New evaluation was performed for JENDL-3 by Kitazawa, Harima (Tokyo Institute of Tech.) and Fukahori (JAERI). Details are given in ref./1/.
88-03 Compiled by Fukahori.

MF=1 General Information
MT=451 Descriptive data and dictionary

MF=2 Resonance parameters:
MT=151
Resolved resonances : 1.0E-5 eV - 1.81 MeV
The resonance parameters were searched, using MLBW formula/2/. An initial guess of the parameters search was taken from ref. /3/.

Calculated 2200-m/s cross sections and resonance integrals

	2200-m/sec	Res. Integ.
elastic	2.149 b	-
capture	0.177 b	0.085 b
total	2.325 b	-

MF=3 Neutron Cross Sections
MT=1 Total cross section
Between 1.81 and 12.5 MeV, the cross sections were obtained by an eye-guide so as to follow the experimental data.
Above 12.5 MeV, the cross sections were calculated with the statistical-model code CASTHY./1,4/
MT=2 Elastic scattering cross sections
Obtained by subtracting partial cross sections from the total cross sections.
MT=4,51-66,91 Inelastic scattering cross sections
Calculated with the statistical-model code CASTHY /4/ and the coupled-channel model code ECIS /5/ or JUPITOR-1 /6/, taking account of competitive processes for neutron, proton, alpha-particle and gamma-ray emission./1/
Below 11 MeV, the imaginary potential strength of the neutron spherical optical potential was modified from that in ref./1/ to be W = 1.09 + 0.55*E (MeV).

Level scheme was taken from ref./11/.

No.	Energy(MeV)	Spin-parity
g.s.	0.0	0 +
1.	1.7789	2 +
2.	4.6178	4 +
3.	4.9791	0 +
4.	6.2765	3 +
5.	6.6914	0 +
6.	6.8786	3 -
7.	6.8888	4 +
8.	7.3807	2 +
9.	7.4173	2 +
10.	7.7988	3 +

11.	7.9334	2 +
12.	8.2590	2 +
13.	8.3280	1 +
14.	8.4133	4 −
15.	8.5430	6 +
16.	8.5890	3 +

Continuum levels were assumed above 8.9 MeV. Level density was calculated, using the Gilbert-Cameron formula. The level-density parameters were obtained from a cumulative plot of observed levels./1/.

MT=16 (n,2n) cross sections
Calculated by the statistical model, using the GNASH code./1,7/ Below 11 MeV, the imaginary potential strength of the neutron spherical optical potential was modified from that in ref./1/ to be W = 1.09 + 0.55•E (MeV).

MT=22 (n,na) cross sections
Calculated by the statistical model, using the GNASH code./1,7/ Optical potential for alpha-particles was determined, using the dispersion theory./8/

MT=28 (n,np) cross sections
Calculated by the statistical model, using the GNASH code./1,7/

MT=102 Capture
Calculated with the statistical-model code CASTHY /4/ and the direct-semidirect-model code HIKARI /9/. The statistical-model calculations were normalized to 0.6 mb at 2.0 MeV.

MT=103 (n,p) cross sections
Calculated by the statistical model, using the GNASH code./1,7/ The imaginary potential strength of the proton spherical optical model was modified from that in ref./1/ to be W = 11.0 MeV between 11 and 20 MeV and W = 8.8 + 0.2•E (MeV) below 11 MeV. The strength was determined so as to reproduce observed values /10/.

MT=107 (n,a) cross sections
Calculated by the statistical model, using the GNASH code./1,7/ Optical potential for alpha-particles was determined, using the dispersion theory./8/

MT=111 (n,2p) cross sections
Calculated by the statistical model, using the GNASH code./1,7/

MT=251 Mu-bar
Calculated with statistical-model code CASTHY /1,4/.

MF=4 Angular Distributions of Secondary Neutrons

MT=2
Calculated with the statistical-model code CASTHY /1,4/.

MT=16,22,28
Isotropic in the laboratory system.

MT=51-66
Incoherent sum of the statistical model and coupled-channel model calculations./1/ Calculated with CASTHY and ECIS or JUPITOR-1.

MT=91
Isotropic in the center-of-mass system converted to the distribution in the laboratory system.

MF=5 Energy Distributions of Secondary Neutrons

MT=16,22,28,91

Calculated by using the GNASH code./1,7/

MF=12 Gamma-ray Multiplicities
MT=51-66,102,103,107
Calculated by using the GNASH code./1,7/

MF=13 Gamma-ray Production Cross Sections
MT=3
Calculated by the statistical model and coupled-channel model, using the GNASH code /7/ and the ECIS /5/ or JUPITOR-1 code /6/. Branching ratios for transitions between discrete levels were taken from ref./12/. Gamma-ray transition strength in the continuum was calculated by the Brink-Axel giant resonance model for E1 transition and by the Weisskopf single-particle model for E2 and M1 transition./1/

MF=14 Gamma-ray Angular Distributions
MT=3,51-66,102,103,107
Isotropic distribution was assumed.

MF=15 Gamma-ray Spectra
MT=3,102,103,107
Calculated with the GNASH code./1,7/

References

1) Kitazawa H. et al.: Proc. Int. Conf. Nuclear Data for Science and Technology, Mito, 1988, p.473, (1988).
2) Nakagawa T.: JAERI-M 84-192 (1984).
3) Mughabghab S.F. et al.: "Neutron Cross Sections, Vol. 1 Part A", Academic Press (1981).
4) Igarasi S.: J. Nucl. Sci. Technol., 12, 67 (1965).
5) Raynal J.: Computer Program ECIS79 for coupled-channel calculations, 1979 (unpublished).
6) Tamura T.: Rev. Mod. Phys., 37, 679 (1965).
7) Young P.G. and Arthur E.D.: La-6947 (1977).
8) Kitazawa H. et al.: unpublished.
9) Kitazawa H.: Computer program HIKARI for direct-semidirect capture calculations, 1980 (unpublished).
10) Ikeda Y.: JAERI 1312 (1988).
11) Endt P.M. and Van Der Leun C.: Nucl. Phys., A310, 1 (1978).

MAT number = 3142

14-Si- 29 TIT,JAERI Eval-Mar88 H.Kitazawa,Y.Harima,T Fukahori
Dist-Sep89

HISTORY
88-03 New evaluation was performed for JENDL-3 by Kitazawa, Harima (Tokyo Institute of Tech.) and Fukahori (JAERI) Details are given in ref./1/.
88-03 Compiled by Fukahori.

MF=1 General Information
MT=451 Descriptive data and dictionary

MF=2 Resonance parameters:
MT=151
Resolved resonances : 1.0E-5 eV - 0.1 MeV
The resonance parameters were searched, using MLBW formula/2/
An initial guess of the parameters search was taken from ref /3/.

Calculated 2200-m/s cross sections and resonance integrals

	2200-m/sec	Res. Integ
elastic	2.843 b	-
capture	0.101 b	0.067 b
total	2.944 b	-

MF=3 Neutron Cross Sections
MT=1 Total cross section
Above 0.1 MeV, the cross sections were calculated with the statistical-model code CASTHY./1,4/
MT=2 Elastic scattering cross sections
Obtained by subtracting partial cross sections from the total cross sections.
MT=4,51-79,91 Inelastic scattering cross sections
Calculated with the statistical-model code CASTHY /4/ and the coupled-channel model code ECIS /5/, taking account of competitive processes for neutron, proton, alpha-particle and gamma-ray emission./1/
Below 11 MeV, the imaginary potential strength of the neutron spherical optical potential was modified from that in ref./1/ to be W = 1.09 + 0.55·E (MeV).

Level scheme was taken from ref./11/.

No.	Energy(MeV)	Spin-parity
g.s.	0.0	1/2 +
1.	1.2730	3/2 +
2.	2.0280	5/2 +
3.	2.4250	3/2 +
4.	3.0670	5/2 +
5.	3.6240	7/2 -
6.	4.0800	7/2 +
7.	4.7410	9/2 +
8.	4.8400	1/2 +
9.	4.8950	5/2 +
10.	4.9340	3/2 -
11.	5.2550	9/2 -
12.	5.2860	..2 +

13.	5.6520	9/2 +
14.	5.8130	7/2 +
15.	5.9490	3/2 +
16.	6.1070	5/2 +
17.	6.1920	7/2 −
18.	6.3780	1/2 −
19.	6.4230	7/2 +
20.	6.4960	1/2 +
21.	6.5220	3/2 +
22.	6.6150	9/2 +
23.	6.6970	3/2 −
24.	6.7100	5/2 +
25.	6.7150	3/2 +
26.	6.7820	11/2 −
27.	6.9070	1/2 −
28.	6.9210	7/2 +
29.	7.0140	5/2 −

Continuum levels were assumed above 7.057 MeV. Level density was calculated, using the Gilbert-Cameron formula
The level-density parameters were obtained from a cumulative plot of observed levels./1/.

MT=16 (n,2n) cross sections
Calculated by the statistical model, using the GNASH code./1,6/
Below 11 MeV, the imaginary potential strength of the neutron spherical optical potential was modified from that in ref./1/ to be W = 1.09 + 0.55•E (MeV).

MT=22 (n,na) cross sections
Calculated by the statistical model, using the GNASH code./1,6/
Optical potential for alpha-particles was determined, using the dispersion theory./7/

MT=28 (n,np) cross sections
Calculated by the statistical model, using the GNASH code./1,6/

MT=102 Capture
Calculated with the statistical-model code CASTHY /4/ and the direct-semidirect-model code HIKARI /8/. The statistical-model calculations were normalized to 0.6 mb at 0.1 MeV.

MT=103 (n,p) cross sections
Calculated by the statistical model, using the GNASH code./1,6/
The imaginary potential strength of the proton spherical optical model was modified from that in ref./1/ to be W = 11.0 MeV between 11 and 20 MeV and W = 8.8 + 0.2•E (MeV) below 11 MeV. The strength was determined so as to reproduce observed values /9/.

MT=107 (n,a) cross sections
Calculated by the statistical model, using the GNASH code./1,6/
Optical potential for alpha-particles was determined, using the dispersion theory./7/

MT=111 (n,2p) cross sections
Calculated by the statistical model, using the GNASH code./1,6/

MT=251 Mu-bar
Calculated with statistical-model code CASTHY /1,4/.

MF=4 Angular Distributions of Secondary Neutrons

MT=2
Calculated with the statistical-model code CASTHY /1,4/.

MT=16,22,28

Isotropic in the laboratory system.

MT=51-79

Incoherent sum of the statistical model and coupled-channel model calculations./1/ Calculated with CASTHY and ECIS.

MT=91

Isotropic in the center-of-mass system converted to the distribution in the laboratory system.

MF=5 Energy Distributions of Secondary Neutrons

MT=16,22,28,91

Calculated by using the GNASH code./1,6/

MF=12 Gamma-ray Multiplicities

MT=51-79,102,103,107

Calculated by using the GNASH code./1,6/

MF=13 Gamma-ray Production Cross Sections

MT=3

Calculated by the statistical model and coupled-channel model, using the GNASH code /6/ and the ECIS /5/ code.
Branching ratios for transitions between discrete levels were taken from ref./10/. Gamma-ray transition strength in the continuum was calculated by the Brink-Axel giant resonance model for E1 transition and by the Weisskopf single-particle model for E2 and M1 transition./1/

MF=14 Gamma-ray Angular Distributions

MT=3,51-79,102,103,107

Isotropic distribution was assumed.

MF=15 Gamma-ray Spectra

MT=3,102,103,107

Calculated with the GNASH code./1,6/

References

1) Kitazawa H. et al : Proc. Int. Conf. Nuclear Data for Science and Technology, Mito, 1988, p.473, (1988).
2) Nakagawa T.: JAERI-M 84-192 (1984).
3) Mughabghab S.F. et al.: "Neutron Cross Sections, Vol. 1 Part A", Academic Press (1981).
4) Igarasi S.: J. Nucl. Sci. Technol., 12, 67 (1965).
5) Raynal J.: Computer Program ECIS79 for coupled-channel calculations, 1979 (unpublished).
6) Young P.G. and Arthur E.D.: La-6947 (1977).
7) Kitazawa H. et al.: unpublished.
8) Kitazawa H.: Computer program HIKARI for direct-semidirect capture calculations, 1980 (unpublished).
9) Ikeda Y. et al.: JAERI 1312 (1988).
10) Endt P.M. and Van Der Leun C.: Nucl. Phys., A310, 1 (1978).
11) Betz P. et al.: Z. Phys. A-Atoms and Nuclei, 309, 163 (1982).

MAT number = 3143

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 14-Si- 30 TIT,JAERI  Eval-Mar88 H.Kitazawa,Y.Harima,T.Fukahori
                      Dist-Sep89
HISTORY
88-03  New evaluation was performed for JENDL-3 by Kitazawa,
       Harima (Tokyo Institute of Tech.) and Fukahori (JAERI).
       Details are given in ref./1/.
88-03  Compiled by Fukahori.

MF=1  General Information
 MT=451   Descriptive data and dictionary

MF=2  Resonance parameters:
 MT=151
   Resolved resonances  : 1.0E-5 eV - 0.5 MeV
   The resonance parameters were searched, using MLBW formula/2/.
   An initial guess of the parameters search was taken from ref.
   /3/.

    Calculated 2200-m/s cross sections and resonance integrals
                   2200-m/sec    Res. Integ.
      elastic        2.491 b         -
      capture        0.108 b       0.709 b
      total          2.598 b         -

MF=3  Neutron Cross  Sections
 MT=1        Total cross section
   Above 0.5 MeV, the cross sections were calculated with the
   statistical-model code CASTHY./1,4/
 MT=2        Elastic scattering cross sections
   Obtained by subtracting partial cross sections from the
   total cross sections.
 MT=4,51-69,91  Inelastic scattering cross sections
   Calculated with the statistical-model code CASTHY /4/ and the
   coupled-channel model code ECIS /5/, taking account of
   competitive processes for neutron, proton, alpha-particle
   and gamma-ray emission./1/
   Below 11 MeV, the imaginary potential strength of the neutron
   spherical optical potential was modified from that in ref./1/
   to be W = 1.09 + 0.55*E (MeV).

   Level scheme was taken from ref./9/.
          No. Energy(MeV)  Spin-parity
         g.s.    0.0          0 +
           1.    2.2355       2 +
           2.    3.4982       2 +
           3.    3.7696       1 +
           4.    3.7877       0 +
           5.    4.8090       2 +
           6.    4.8305       3 +
           7.    5.2300       3 +
           8.    5.2790       4 +
           9.    5.3720       0 +
          10.    5.4876       3 -
          11.    5.6130       2 +
          12.    5.9500       4 +
```

13.	6.5030	4 −
14.	6.5370	2 +
15.	6.6340	2 −
16.	6.6400	0 +
17.	6.7447	1 −
18.	6.8650	2 −
19.	6.9140	2 +

Continuum levels were assumed above 6.999 MeV. Level density was calculated, using the Gilbert-Cameron formula.
The level-density parameters were obtained from a cumulative plot of observed levels./1/.

MT=16 (n,2n) cross sections
Calculated by the statistical model, using the GNASH code./1,6/
Below 11 MeV, the imaginary potential strength of the neutron spherical optical potential was modified from that in ref./1/ to be W = 1.09 + 0.55•E (MeV).

MT=22 (n,na) cross sections
Calculated by the statistical model, using the GNASH code./1,6/
Optical potential for alpha-particles was determined, using the dispersion theory./7/

MT=28 (n,np) cross sections
Calculated by the statistical model, using the GNASH code./1,6/

MT=102 Capture
Calculated with the statistical-model code CASTHY /4/ and the direct-semidirect-model code HIKARI /8/. The statistical-model calculations were normalized to 0.6 mb at 0.5 MeV.

MT=103 (n,p) cross sections
Calculated by the statistical model, using the GNASH code./1,6/
The imaginary potential strength of the proton spherical optical model was modified from that in ref./1/ to be W = 11.0 MeV between 11 and 20 MeV and W = 8.8 + 0.2•E (MeV) below 11 MeV.

MT=107 (n,a) cross sections
Calculated by the statistical model, using the GNASH code./1,6/
Optical potential for alpha-particles was determined, using the dispersion theory./7/

MT=111 (n,2p) cross sections
Calculated by the statistical model, using the GNASH code./1,6/

MT=251 Mu-bar
Calculated with statistical-model code CASTHY /1,4/.

MF=4 Angular Distributions of Secondary Neutrons

MT=2
Calculated with the statistical-model code CASTHY /1,4/.

MT=16,22,28
Isotropic in the laboratory system.

MT=51-69
Incoherent sum of the statistical model and coupled-channel model calculations./1/ Calculated with CASTHY and ECIS.

MT=91
Isotropic in the center-of-mass system converted to the distribution in the laboratory system.

MF=5 Energy Distributions of Secondary Neutrons

MT=16,22,28,91
Calculated by using the GNASH code./1,6/

MF=12 Gamma-ray Multiplicities
MT=51-69,102,107
Calculated by using the GNASH code./1,6/

MF=13 Gamma-ray Production Cross Sections
MT=3
Calculated by the statistical model and coupled-channel model, using the GNASH code /6/ and the ECIS /5/ code.
Branching ratios for transitions between discrete levels were taken from ref./9/. Gamma-ray transition strength in the continuum was calculated by the Brink-Axel giant resonance model for E1 transition and by the Weisskopf single-particle model for E2 and M1 transition./1/

MF=14 Gamma-ray Angular Distributions
MT=3,51-69,102,107
Isotropic distribution was assumed.

MF=15 Gamma-ray Spectra
MT=3,102,107
Calculated with the GNASH code./1,6/

References

1) Kitazawa H. et al.: Proc. Int. Conf. Nuclear Data for Science and Technology, Mito, 1988, p.473, (1988).
2) Nakagawa T.: JAERI-M 84-192 (1984).
3) Mughabghab S.F. et al.: "Neutron Cross Sections, Vol. 1 Part A", Academic Press (1981).
4) Igarasi S.: J. Nucl. Sci. Technol., 12, 67 (1965).
5) Raynal J.: Computer Program ECIS79 for coupled-channel calculations, 1979 (unpublished).
6) Young P.G. and Arthur E.D.: La-6947 (1977).
7) Kitazawa H. et al.: unpublished.
8) Kitazawa H.: Computer program HIKARI for direct-semidirect capture calculations, 1980 (unpublished).
9) Endt P.M. and Van Der Leun C.: Nucl. Phys., A310, 1 (1978).

MAT number = 3151

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 15-P - 31 Fuji E.C.  Eval-May87 H.Nakamura
                      Dist-Sep89
HISTORY
87-05  Newly Evaluated by H.Nakamura (Fuji Electric Co., Ltd.)

MF=1  General Information
           MT=451   Descriptive data and dictionary

MF=2       MT=151   Resonance parameters:
  Resolved resonances for MLBW Formula : 1.0E-5 eV - 500 keV
         Parameters are taken from BNL 325 4th edition/1/, and
         R.L.Macklin et al./2/.
         Cross sections calculated with these parameters are to
         be corrected by adding MF=3, MT=1,2and 102 data.
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Calculated 2200-m/s cross sections and resonance integrals

	2200-m/sec	Res. Integ.	Ref.
elastic	3.134 b	-	/1/
capture	0.166 b	0.081 b	/1/
total	3.300 b	-	

```
MF=3  Neutron Cross  Sections
    Below 500 keV
        Background cross section.
        MT=1,2    0.07029 b
        MT=251 Mu-bar=0.0217
    Above 500 keV
       MT=1,2,4,51-56,91,102 Total, Elastic, Inelastic and Capture
       Calculated with CASTHY code/3/, considering the
       competition with the threshold reaction channels.
    Optical potential parameters of C.Y.Fu/4/ are adjusted
    to reproduce the following experimental data:
    MT=1 total NESTOR data (many authors)
    MT=2 elastic  -
    MT=4 inelastic  -
    The spherical optical potential parameters:
      V=43.0                   Vso=5.37 (MeV)
      Ws=9.13                   Wu =0.0  (MeV)
      r =rso=1.26              rs=1.39  (fm)
      a=aso=0.76               b=0.40   (fm)

   MT=102 capture data are normalized to 1.8 mb at 500 keV
    based on (7 mb at 30 keV) by R.L.Macklin et al./5/.
```

The discrete level scheme taken from Ref./6/:

No.	Energy (MeV)	Spin-Parity
(g.s.)	0.0	1/2 -
1	1.266	3/2 +
2	2.234	5/2 +
3	3.134	1/2 +
4	3.295	5/2 +
5	3.415	7/2 +
6	3.506	3/2 +

Continuum levels assumed above 4.0 MeV. The level density parameters of Asano et al. /7/ are used.

MT=16(n,2n), 22(n,n'a), 28(n,n'p), 103(n,p), 107(n,a)
Based on the statistical model calculations with GNASH code /8/, without the precompound reaction correction. Transmission coefficients for proton and alpha particle are calculated by using the OMP of Becchetti-Greenlees /9/ and Huizenga-Igo/10/, respectively. In the cases of MT=103 and 107, the experimental data were also considered together with the calculations.
Level density parameters are based on built-in values.

MT=251 Mu-bar
Calculated with optical model (CASTHY).

MF=4 Angular Distributions of Secondary Neutrons
MT=2 Calculated with optical model(CASTHY).
MT=51-91 Calculated with Hauser-Feshbach formula(CASTHY)
MT=16,22,28 Isotropic in the laboratory system.

MF=5 Energy Distributions of Secondary Neutrons
MT=16,22,28,91,103,107 Evaporation spectra.

References

1) Mughabghab, S.F. et al.: Neutron Cross Section, Vol.1 (1981).
2) Macklin, R.L. et al.: Phys. Rev. C32, 379 (1985).
3) Igarasi, S.: J. Nucl. Sci. Tech. 12, 67 (1975).
4) Fu, C.Y.: Atom. Data and Nucl. Data Tables. 17, 127 (1976).
5) Macklin, R.L. et al.: Phys. Rev. 129, 2695 (1963).
6) Lederer, C.M. et al.: Table of Isotopes. 7th Edit.
7) Asano et al.: private communication.
8) Young, P.G. and Arthur, E.D.: LA-6947 (1977).
9) Becchetti, Jr. and Greenless, G.W.: Polarization Phenomena in Nuclear Reactions, p.682 (1971).
10) Huizenga, Jr. and Igo, G.J.: Nucl. Phys. 29, 462 (1962).

MAT number = 3160

16-S - 0 Fuji E.C. Eval-May87 H.Nakamura
Dist-Sep89

HISTORY
87-05 Newly Evaluated by H.Nakamura (Fuji Electric Co., Ltd.)
87-07 Compiled by T.Fukahori (JAERI).
88-02 Modifications on (n,p) and inelastic scattering cross sections of S-32. Direct inelastic components from DWBA calculations were added to the compound components so as to reproduce DDX data of OKTAVIAN (OSA, 1986).
88-08 Modified due to correcting S-32 data by T.Fukahori (JAERI)

Natural sulphur data constructed from S-isotopes

MF=1 General Information
MT=451 Descriptive data and dictionary

MF=2 Resonance Parameters
MT=151 Resolved Resonances
Resonance region : 1.0E-5 eV - 1.57 MeV
The multilevel Breit-Wigner formula was used Parameters were adopted from the following sources.
S-32 : -10 keV - 1.57 MeV, R = 3.92 fm
S-33 : -7.1 - 260 keV, R = 3.85 fm
S-34 : -10 - 480 keV, R = 3.60 fm

Calculated 2200-m/s Cross Sections and Res. Integrals.

	2200-m/s	Res. Integ.
Elastic	1.024 b	-
Capture	0.514 b	0.2432 b
Total	1.546 b	-

MF=3 Neutron Cross Sections
Below 1.57 MeV, background cross sections consisting of (n,p) and (n,alpha) cross sections were given.

MT=1 TOTAL
For energies 10 - 20 MeV, fine resolution data of Cierjacks+/1/ were adopted. In the range of 1.57 - 10 MeV. the weighted sum of isotopic data were taken. The isotopic calculations were performed by using CASTHY code/2/.
MT=2 ELASTIC SCATTERING
Given as total minus other cross sections.
MT=4 TOTAL INELASTIC SCATTERING
Sum of MT=51-73, 91
MT=16,22,28,103,107
The weighted sum of isotopes was adopted. The cross sections of isotopes were calculated using GNASH code/3/.
MT=51-73,91 INELASTIC SCATTERING
Isotopic data were obtained from the CASTHY/2/ calculation. Isotopic levels were sorted with energies.

Optical potential parameters used in the calculation are as follows:
V = 38.0, R0 = 1.26, A0 = 0.76
Ws = 9.13, Rs = 1.39, As = 0.40

Vso= 5.37, Rso= 1.26, Aso= 0.76
energies in MeV unit, lengths in fm unit.

MT=102 CAPTURE
Above 1.57 MeV, the CASTHY/2/ calculation was adopted.
MT=103(N,P), 107(N,ALPHA)
For S-32 the evaluation was made on the basis of experimental data. For S-33,34,36, the GNASH/3/ calculation was adopted.
MT=251 MU-BAR
Calculated with CASTHY/2/.

MF=4 ANGULAR DISTRIBUTIONS OF SECONDARY NEUTRONS
MT=2,51-73
Optical and statistical-model calculations.
MT=16,22,28,91
Assumed to be isotropic in the laboratory system.

MF=5 ENERGY DISTRIBUTIONS OF SECONDARY NEUTRONS
MT=16,22,28,91
Calculated with GNASH/3/.

REFERENCES
1) Cierjacks, S. et al.: KFK-1000 (1968)
2) Igarasi, S. : J. NUCL. SCI. TECHNOL., 12, 67 (1975).
3) Young, P.G. and Arthur, E.D.: LA-6947 (1977).

MAT number = 3161

16-S - 32 Fuji E.C. Eval-May87 H.Nakamura
Dist-Sep89

HISTORY
87-03 Newly Evaluated by H.Nakamura (Fuji Electric Co.Ltd.)
88-08 The following quantities were modified by H.Nakamura:
(n,p) cross section, inelastic scattering cross sections and angular distributions of the first, third and continuum levels.

MF=1 General Information
MT=451 Descriptive data and dictionary

MF=2 MT=151 Resonance Parameters:
Resolved resonances for MLBW formula: 1.0E-5 eV - 1500 keV
Parameters are taken from BNL 325 4th edition/1/, and some parameters are assumed to fit the measured data.
Cross sections calculated with these parameters are to be corrected by adding MF=3, MT=1, 2 and 102 data.

Calculated 2200-m/s cross sections and resonance integrals

	2200-m/sec	Res. Integ.	Ref.
elastic	0.963 b	-	-
capture	0.528 b	0.250 b	/1/
total	1.499 b	-	-

MF=3 Neutron Cross Sections
Below 1500keV
Background data for
MT=107 0.007 b, based on 2200-m/s data of Ref./1/.
MT=251 Mu-bar=0.0210.
Above 1500keV
MT=1, 2, 4, 51-56, 91, 102 Total, Elastic, Inelastic and Capture calculated with CASTHY code /2/, considering the competition with the threshold reaction channels.
Optical potential parameters of C.Y.Fu/3/ are adjusted to reproduce the following experimental data:
MT=1 total -
MT=2 elastic G.A.Petitt et al./4/, A.Virdis/5/.
MT=4 inelastic -
The spherical optical potential parameters:
V=38.0 Vso=5.37 (MeV)
Ws=9.13 Wv =0.0 (MeV)
r =rso=1.26 rs=1.39 (fm)
a=aso =0.76 b =0.40(fm)
MT=102 Capture data are normalized to the experimental data of A.Lindholm et al. at 3 - 6 MeV/6/.

MT=51, 53 Direct Interaction
Calculated by using DWBA calculation, are added to the compound components, respectively.
MT=2, 4
Modified after the above direct component addition.

The discrete level scheme taken from Ref./7/:

No.	Energy(MeV)	Spin-Parity
(g.s.)	0.0	0+
1	2.230	2+
2	3.779	0+
3	4.282	2+
4	4.459	4+
5	4.695	1+
6	5.006	3-

Continuum levels assumed above 5.4 MeV. The level density parameters of Asano et al./8/are used

MT=16(n,2n), 22(n,n'a), 28(n,n'p), 103(n,p), 107(n,a)
Based on the statistical model calculations with GNASH code/9/, without the precompound reaction correction. Transmission coefficients for proton and alpha particles are calculated by using the OMP of Becchetti-Geenlees /10/ and Huizenga-Igo/11/, respectively.
Level density parameters are based on built-in values.

MT=103 (n,p) cross section
Adjusted to reproduce R. Ricamo data above 14 MeV /12/.
MT=4, 91
Modified so as to compensate for the (n,p) adjustment.

MT=251 Mu-bar
Calculated with optical model (CASTHY).

MF=4 Angular Distributions of Secondary Neutrons
MT=2 Calculated with optical model (CASTHY).
MT=51-91 Calculated with Hauser-Feshbach formula (CASTHY).
MT=16,22,28 Isotropic in the laboratory system.

MT=51, 53 Direct Components
Calculated using DWBA calculation, are added to reproduce DDX data of OKTAVIAN /13/.

MF=5 Energy Distributions of Secondary Neutrons
MT=16,22,28,91,103,107 Evaporation spectra,

References

1) Mughabghab,S.F. et al.: Neutron Cross Section, Vol.1 (1981).
2) Igarasi,S: J. Nucl. Sci. Tech. 12, 67 (1975).
3) Fu,C.Y.: Atom. Data and Nucl. Data Tables. 17, 127 (1976).
4) Petitt,G.A. et al.: Nucl. Phys. 79, 231 (1960).
5) Virdis,A.: CEA-R-5144 (1981).
6) Lindholm,A. et al.: Nucl. Phys. A279, 445 (1977).
7) Leder,C.M. et al.: Table of Isotopes. 7th Edit.
8) Asano et al.: private communication.
9) Young,P.G. and Arthur,E.D.: LA-6947 (1977).
10) Becchetti,Jr. and Greenlees,G.W.: Polarization Phenomena in Nuclear Reactions, p.682 (1971).
11) Huizenga,Jr. and Igo,G.J.: Nucl. Phys. 29, 462 (1962).
12) Ricamo, R. : NC. 8, 383 (1951)
13) INDC(JPN)-10, OSA (1986)

MAT number = 3162

16-S - 33 Fuji E.C. Eval-May87 H.Nakamura
Dist-Sep89

HISTORY
87-05 Newly Evaluated by H.Nakamura (Fuji Electric Co., Ltd.)

MF=1 General Information
MT=451 Descriptive data and dictionary

MF=2 MT=151 Resonance parameters:
Resolved resonances for MLBW formula: 1.0E-5 eV - 260 keV
Parameters are taken from BNL325 4th edition/1/, and
C.Wagemans and H.Weigmann/2/.
Cross sections calculated with these parameters are to
be corrected adding MF=3, MT=1, 2 and 102 data

Calculated 2200-m/s cross sections and resonance integrals

	2200-m/sec	Res. Integ	Ref.
elastic	2.84 b	-	/1/
capture	0.35 b	0.164 b	/1/
total	3.36 b	-	-

MF=3 Neutron Cross Sections
Below 260 keV
Background cross sections are given for MT=1:
MT=1 0.171b : 0.002(n,p) + 0.169(n,a) b
MT=103 (n,p) 0.0016 b, based on 2200-m/s data /1/.
MT=107 (n,a) 0.169 b, same as the above.
MT=251 Mu-bar = 0.0210
Above 260 keV.
MT=1,2,4,51-57,91,102
Total, Elastic, Inelastic and Capture cross sections
calculated with CASTHY code /3/, considering the
competition with the threshold reaction channels.
Optical potential parameters of C.Y.Fu/4/ are adjusted
to reproduce the following experimental data:
MT=1 total -
MT=2 elastic cross sections of S-32.
MT=4 inelastic -
The spherical optical potential parameters :
V = 38.0 Vso= 5.37 (MeV)
Ws= 9.13 Wv = 0.0 (MeV)
r=rso= 1.26 rs = 1.39 (fm)
a=aso= 0.76 b = 0.40 (fm)
MT=102 Capture data are normalized to 0.5 mb at 260 keV
based on S-32 capture cross sections.
The discrete level scheme taken from Ref./5/:

No.	Energy(MeV)	Spin-Parity	
(g.s.)	0.0	3/2	+
1	0.8404	1/2	+
2	1.966	5/2	+
3	2.313	3/2	+
4	2.866	5/2	+
5	2.934	7/2	-
6	2.969	7/2	+

7 3.220 3/2 -

Continuum levels are assumed above 3 6MeV. The level density parameters of Asano et al./6/ are used.

MT=16(n,2n), 22(n,n'a),28(n,n'p),103(n,p),107(n,a)

Based on the statistical model calculations with GNASH code /7/, without the precompound reaction correction. Transmission coefficients for proton and alpha particles are calculated by using the OMP of Becchetti-Greenlees/8/ and Huizenga-Igo/9/, respectively.

Level density parameters are based on built-in values.

MT=251 Mu-bar

Calculated with optical model (CASTHY).

MF=4 Angular Distributions of Secondary Neutrons

MT=2 Calculated with optical model (CASTHY).

MT=51-91 Calculated with Hauser-Feshbach formula (CASTHY)

MT=16,22,28 Isotropic in the laboratory system

MF=5 Energy Distributions of Secondary Neutrons

MT=16,22,28,91,103,107 Evaporation spectra

References

1) Mughabghab, S.F. et al.: Neutron Cross Section, Vol 1 (1981)
2) Wagemans, C. and Weigman, H. Grenoble-Conf., 462 (1981).
3) Igarasi, S.: J. Nucl. Sci. Tech., 12, 67 (1975)
4) Fu, C.Y.: Atom.Data and Nucl. Data Tables, 17, 127 (1976).
5) Ledrer, C.M. et al.: Table of Isotopes. 7th Edit.
6) Asano et al.: private communication.
7) Young, P.G. and Arthur, E.D.: LA-6947 (1977).
8) Becchetti, Jr. and Greenlees, G.W.: Polarization Phenomena in Nuclear Reactions, p.682 (1971).
9) Huizenga, Jr. and Igo, G.J.: Nucl. Phys., 29, 462 (1962).

MAT number = 3163

16-S - 34 Fuji E.C. Eval-May87 H.Nakamura
Dist-Sep89

HISTORY
87-05 Newly Evaluated by H.Nakamura (Fuji Electric Co., Ltd.)

MF=1 General Information
MT=451 Descriptive data and dictionary

MF=2 MT=151 Resonance parameters:
Resolved resonances for MLBW formula: 1.0E-5 eV - 480 keV
Parameters are taken from BNL 325 4th edition/1/, and some parameters are assumed to fit the measured data. Cross sections calculated with these parameters are to be corrected by adding MF=3, MT=1, 2 and 102 data.
Calculated 2200-m/s cross sections and resonance integrals

	2200-m/sec	Res Integ.	Ref
elastic	2.08 b	-	-
capture	0.22 b	0.101 b	/1/
total	2.30 b	-	-

MF=3 Neutron Cross Sections
Below 480keV
No Background cross section.
MT=251 Mu-bar=0.0198
Above 480 keV.
MT=1,2,4,51-55,91,102
Total, Elastic, Inelastic and Capture calculated with CASTHY code/2/, considering the competition with the threshold reaction channels.
Optical potential parameters of C.Y.Fu/3/ are adjusted to reproduce the following experimental data:
MT=1 total -
MT=2 elastic cross sections of S-32
MT=4 inelastic -
The spherical optical potential parameters :

V = 38.0	Vso= 5.37	(MeV)
Ws= 9.13	Wv = 0.0	(MeV)
r =rso= 1.26	rs = 1.39	(fm)
a =aso= 0.76	b = 0.40	(fm)

MT=102 capture data are normalized to 0.3mb at 480 keV based on S-32 capture cross section.
The discrete level scheme taken from Ref./4/:

No.	Energy(MeV)	Spin-Parity
(g.s.)	0.0	0 +
1	2.127	2 +
2	3.304	2 +
3	3.914	0 +
4	4.072	1 +
5	4.115	2 +

Continuum levels assumed above 4.5 MeV. The level density parameters of Asano et al./5/ are used.
MT=16(n,2n), 22(n,n'a), 28(n,n'p), 103(n,p), 107(n,a)
Based on the statistical model calculations with GNASH code /6/, without the precompound reaction correction.

Transmission coefficients for proton and alpha particle are calculated by using the OMP of Becchetti-Greenlees/7/ and Huizenga-Igo/8/, respectively.
Level density parameters are based on built-in values
MT=251 Mu-bar
Calculated with optical model (CASTHY)

MF=4 Angular Distributions of Secondary Neutrons
MT=2 Calculated with optical model (CASTHY)
MT=51-91 Calculated with Hauser-Feshbach formula (CASTHY)
MT=16,22,28 Isotropic in the laboratory system

MF=5 Energy Distributions of Secondary Neutrons
MT=16,22,28,91,103,107 Evaporation spectra

References

1) Mughabghab, S.F. et al.: Neutron Cross Section, Vol 1 (1981)
2) Igarasi, S.: Jr. Nucl. Sci. Tech., 12, 67 (1975)
3) Fu, C.Y.: Atom. Data and Nucl. Data Tables, 17, 127 (1976)
4) Lederer, C.M. et al.: Table of Isotopes, 7th Edit.
5) Asano et al.: private communication
6) Young, P.G. and Arthur, E.D.: La-6947 (1977).
7) Becchetti, Jr. and Greenlees, G.W.: *Polarization Phenomena in Nuclear Reactions*, p.682 (1971).
8) Huizenga, Jr. and Igo, G.J.: Nucl. Phys., 29, 462 (1962).

MAT number = 3164

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 16-S - 36 Fuji E.C.   Eval-May87 H.Nakamura
                       Dist-Sep89
HISTORY
87-05  Newly Evaluated by H.Nakamura (Fuji Electric Co., Ltd.)

 MF=1  General Information
      MT=451  Descriptive data and dictionary

 MF=2 MT=151 Resonance parameters: (Not given)

 MF=3  Neutron Cross Sections
      Below 1000 keV
          Assumed cross sections, guided by those of S-32
             (10**-5)eV (0.025)eV (1.0**4)eV (1.0**6)eV INT
        MT=2     1.0 b      1.0  b     1.0    b  6.0      b   5
        MT=102   3.5 b      0.15 b     0.001  b  0.00015 b    5
        MT=1     4.5 b      1.15 b     1.001  b  6.00015 b    -
        MT=251   Mu-bar=0.0210
      Above 1000 keV
        MT=1,2,4,51-55,91,102
           Total, Elastic, Inelastic and Capture
          calculated with CASTHY code /2/, considering the
          competition with the threshold reaction channels.
           Optical potential parameters of C.Y.Fu/3/ are adjusted
          to reproduce the following experimental data:
             MT=1   total -
             MT=2   elastic cross sections of S-32
             MT=4   inelastic -
          The spherical optical potential parameters:
             V = 38.0        Vso= 5.37  (MeV)
             Ws= 9.13        Wv = 0.0   (MeV)
             r =rso= 1.26    rs = 1.39  (fm)
             a =aso= 0.76    b  = 0.40  (fm)
           MT=102 Capture data are normalized to 0.15 mb at 1 MeV
          based on S-32 capture cross section.
           The discrete level scheme taken from Ref./4/:
             No.      Energy (MeV)      Spin-Parity
           (g.s.)        0.0               0   +
               1         3.291             2   +
               2         3.346             0   +
               3         4.192             3   -
               4         4.523             1   +
               5         4.575             2   +
          Continuum levels assumed above 5.0 MeV. The level
          density parameters of Asano et al./5/ are used.
        MT=16(n,2n), 22(n,n'a), 28(n,n'p), 103(n,p), 107(n,a)
           Based on the statistical model calculations with GNASH
          code /6/, without the precompound reaction correction.
          Transmission coefficients for proton and alpha particle
          are calculated by using the OMP of Becchetti-Greenlees
          /7/ and Huizenga-Igo/8/,respectively.
           Level density parameters are based on built-in values.
        MT=251  Mu-bar
           Calculated with optical model (CASTHY).
```

MF=4 Angular Distributions of Secondary Neutrons
MT=2 Calculated with optical model (CASTHY).
MT=51-91 Calculated with Hauser-Feshbach formula(CASTHY)
MT=16,22,28 Isotropic in the laboratory system.

MF=5 Energy Distributions of Secondary Neutrons
MT=16,22,28,91,103,107 Evaporation spectra.

References

1) Mughabghab, S.F. et al.: Neutron Cross Section, Vol.1 (1981).
2) Igarasi, S.: J. Nucl. Sci. Tech., 12, 67 (1975).
3) Fu, C.Y.: Atom. Data and Nucl. Data Tables., 17, 127 (1976).
4) Lederer, C.M. et al.: Table of Isotopes. 7th Edit.
5) Asano et al.: private communication.
6) Young, P.G. and Arthur, E.D.: LA-6947 (1977).
7) Becchetti, Jr. and Greenlees, G.W.: Polarization Phenomena in Nuclear Reactions, p.682 (1971).
8) Huizenga, Jr. and Igo, G.J.: Nucl. Phys., 29, 462 (1962).

MAT number = 3190

19-K - 0 Fuji E.C. Eval-May87 H.Nakamura
Dist-Sep89

HISTORY
87-05 Newly Evaluated by H.Nakamura (Fuji Electric Co., Ltd.)
87-07 Compiled by T.Fukahori (JAERI).

Natural potassium constructed from its isotopes.

MF=1 General Information
MT=451 Descriptive data and dictionary

MF=2 Resonance Parameters
MT=151 Resolved Resonances
Resonance region : 1.0E-5 eV - 200 keV
The multilevel Breit-Wigner formula was used. Parameters were adopted from the following sources.
K-39 : -4.0 - 200 keV, R = 1.80 fm
K-41 . -6.6 - 125 keV, R = 2.00 fm

Calculated 2200-m/s Cross Sections and Res. Integrals.

	2200-m/s	Res. Integ.
Elastic	2.096 b	-
Capture	2.058 b	1.118 b
Total	4.159 b	-

MF=3 Neutron Cross Sections
Below 200 keV, background cross sections consisting of elastic, capture, (n,p) and (n,alpha) cross sections were given.

MT=1 TOTAL
For energies 0.2 - 20 MeV, the weighted sum of isotopes data was taken. The isotopic calculations were performed by using CASTHY code/1/.
MT=2 ELASTIC SCATTERING
Given as total minus other cross sections.
MT=4 TOTAL INELASTIC SCATTERING
Sum of MT=51-61, 91
MT=16,22,28,103,107
The weighted sum of isotopes was adopted. The cross sections of isotopes were calculated using GNASH code/2/.
MT=51-61,91 INELASTIC SCATTERING
Isotopic data were obtained from the CASTHY/1/ calculation. Isotopic levels were sorted with energies.

Optical potential parameters used in the calculation are as follows:
V = 46.72, R0 = 1.26, A0 = 0.76
Ws = 9.13, Rs = 1.39, As = 0.40
Vso= 5.37, Rso= 1.26, Aso= 0.76
energies in MeV unit, lengths in fm unit.

MT=102 CAPTURE
Above 200 keV, the CASTHY/1/ calculation was adopted.
MT=103(N,P), 107(N,ALPHA)

Above 200 keV, based on calculations using the GNASH/2/ code.

MT=251 MU-BAR

Calculated with CASTHY/1/.

MF=4 Angular Distributions of Secondary Neutrons

MT=2,51-61

Optical and statistical-model calculations.

MT=16,22,28,91

Assumed to be isotropic in the laboratory system.

MF=5 Energy Distributions of Secondary Neutrons

MT=16,22,28,91

Calculated with GNASH/2/.

REFERENCES

1) Igarasi, S. : J. Nucl. Sci. Technol., 12, 67 (1975).
2) Young, P.G. and Arthur, E.D.: LA-6947 (1977).

MAT number = 3191

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 19-K - 39 Fuji E.C.  Eval-May87 H.Nakamura
                      Dist-Sep89
HISTORY
87-05  Newly Evaluated by H.Nakamura (Fuji Electric Co., Ltd.)

MF=1  General Information
     MT=451  Descriptive data and dictionary

MF=2 MT=151  Resonance parameters:
        Resolved resonances for MLBW formula: 1.0E-5 eV - 200 keV
      Parameters are taken from BNL 325 4th edition/1/, and
      some parameters are assumed to fit the measured data.
      Cross sections calculated with these parameters are to
      be corrected by adding MF=3, MT=1, 2 and 102 data.
      Calculated 2200-m/s cross sections and resonance integrals

                    2200-m/sec   Res.Integ.   Ref.
          elastic     2.06 b        -          -
          capture     2.10 b       1.1 b      /1/
          total       4.16 b        -          -

MF=3  Neutron Cross Sections
     Below 200 keV
        Background data for MT=1 : (MT=107)-cross sections.
      MT=107 (n,a)=0.04 b (10**-5 eV), 0.0043 b (2200m/s)/1/,
             INT=5.
      MT=251 Mu-bar=0.0173
     Above 200 keV
      MT=1,2,4,51-54,91,102  total, elastic, inelastic and capture
         Calculated with CASTHY code /2/, considering the
       competition with the threshold reaction channels.
       Optical potential parameters of C.Y.Fu/3/ are used.
       The spherical optical potential parameters:
           V = 46.72            Vso= 5.37     (MeV)
           Ws=  9.13            Wv = 0.0      (MeV)
           r =rso= 1.26         rs = 1.39     (fm)
           a =aso= 0.76         b  = 0.40     (fm)
      MT=102  Capture data are normalized to 4.2 mb at 200 keV.
         The discrete level scheme taken from Ref./4/:
           No.       Energy(MeV)      Spin-Parity
          (g.s)        0.0             3/2   +
            1          2.523           1/2   +
            2          2.814           7/2   -
            3          3.019           3/2   -
            4          3.598           9/2   -
       Continuum levels assumed above 3.8 MeV. The level
       density parameters of Asano et al./5/ are used.
    200 keV - 1.0 MeV
      MT=107 (n,a)-cross section = 2.6*10**-5 b (constant):
         Assumed from the calculated value at 1.0 MeV.
    Above 1.0 MeV
      MT=16,22,28,103,107  (n,2n), (n,na), (n,np), (n,p), (n,a)
         Based on the statistical model calculations with GNASH
       code/6/, without the precompound reaction correction.
       Transmission coefficients for proton and alpha particle
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are calculated by using the OMP of Becchetti-Greenlees /7/ and Huizenga-Igo/8/, respectively.
Level density parameters are based on built-in values.
At the energy range of 4 - 20 MeV, (n,p) cross section was based on the experimental data/9-11/.
MT=251 Mu-bar
Calculated with optical model (CASTHY).

MF=4 Angular Distributions of Secondary Neutrons
MT=2 Calculated with optical model (CASTHY).
MT=51-91 Calculated with Hauser-Feshbach formula (CASTHY)
MT=16,22,28 Isotropic in the laboratory system.

MF=5 Energy Distributions of Secondary Neutrons
MT=16,22,28,91,103,107 Evaporation spectra.

References

1) Mughabghab, S.F. et al.: Neutron Cross Section, Vol.1 (1981).
2) Igarasi, S.: J. Nucl. Sci. Tech., 12, 67 (1975).
3) Fu, C.Y.: Atom. Data and Nucl. Data Tables., 17, 127 (1976).
4) Lederer, C.M et al.: Table of Isotopes 7th Edit
5) Asano et al.: private communication.
6) Young, P.G. and Arthur, E.D.: LA-6947 (1977)
7) Becchetti, Jr. and Greenlees, G.W.: Polarization Phenomena in Nuclear Reactions, p.682 (1971).
8) Huizenga, Jr. and Igo, G.J.: Nucl. Phys., 29, 462 (1962).
9) Bass, R. et al.: Nucl. Phys., 56, 569 (1964).
10) Bormann, M. et al.: Zeitschrift f. Naturforschung, section A, 15, 200 (1960).
11) Aleksandrov,D.V. et al.: Atomnaya Energiya, 39(2), 137 (1975).

MAT number = 3192

19-K - 40 Fuji E.C. Eval-May87 H.Nakamura
Dist-Sep89

HISTORY

87-05 Newly Evaluated by H.Nakamura (Fuji Electric Co., Ltd.)

MF=1 General Information
MT=451 Descriptive data and dictionary

MF=2 MT=151 Resonance parameters: (Not given)

MF=3 Neutron Cross Sections

Below 30 keV

Assumed or interpolated cross sections, guided by those of K-39:

	(10**-5)	(2200m/s)		(5.10**2)	(3.10**4)	INT
MT=2	1.0 b	1.0 b		1.0 b	1.85 b	5
MT=102	1509.0 b	30.0 b	/1/	0.2 b	0.023 b	5
MT=103	370.0 b	4.4 b	/1/	0.012 b	0.012 b	5
MT=107	2.2 b	0.39 b	/1/	0.04 b	0.015 b	5
MT=1	1882.2 b	35.79 b		1.252 b	1.9 b	-

MT=251 Mu-bar=0.0168

30 keV - 1.0 MeV

MT=1,2,4,102 : Calculated with CASTHY code /2/.

MT=103 : 0.012 b, guided by measurements of H.Weigmann/3/.

Above 30 keV.

MT=1,2,4,51-91,102

Total, Elastic, Inelastic and Capture calculation with CASTHY code /2/, considering the competition with the the threshold reaction channels.

Optical potential parameters of C.Y.Fu/3/ are used.

The spherical optical potential parameters :

V = 46.72	Vso= 5.37	(MeV)
Ws= 9.13	Wv = 0.0	(MeV)
r =rso= 1.26	rs = 1.39	(fm)
a =aso= 0.76	b = 0.40	(fm)

MT=102 capture data are normalized to 4.2 mb at 200 keV.

The discrete level scheme taken from Ref. /4/ :

No.	Energy(MeV)	Spin-Parity
(g.s.)	0.0	4 -
1	0.0296	3 -
2	0.800	2 -
3	0.892	5 -
4	1.644	0 +
5	1.959	2 +

Continuum levels assumed above 2.1 MeV. The level density parameters of Asano et al./5/ are used.

MT=16(n,2n), 22(n,n'a), 28(n,n'p), 103(n,p), 107(n,a)

Based on the statistical model calculations with GNASH code /6/, without the precompound reaction correction. Transmission coefficients for proton and alpha particle are calculated by using the OMP of Becchetti-Greenlees /7/ and Huizenga-Igo/8/, respectively.

Level density parameters are based on built -in values.

MT=251 Mu-bar

Calculated with optical model (CASTHY).

MF=4 Angular Distributions of Secondary Neutrons
MT=2 Calculated with optical model (CASTHY).
MT=51-91 Calculated with Hauser-Feshbach formula(CASTHY)
MT=16,22,28 Isotropic in the laboratory system

MF=5 Energy Distributions of Secondary Neutrons
MT=16,22,28,91,103,107 Evaporation spectra.

References

1) Mughabghab, S.F. et al.: Neutron Cross Section, Vol.1 (1981).
2) Igarasi, S.: J. Nucl. Sci. Tech., 12, 67 (1975).
3) Weigmann, H.: NESTOR data.
4) Fu, C.Y.: Atom. Data and Nucl. Data Tables., 17, 127 (1976).
5) Lederer, C.M. et al.: Table of Isotopes. 7th Edit.
6) Asano et al.: private communication.
7) Young, P.G and Arthur, E.D.: LA-6947 (1977).
8) Becchetti, Jr. and Greenlees, G.W.: Polarization Phenomena in Nuclear Reactions, p.682 (1971).
9) Huizenga, Jr. and Igo, G.J.: Nucl. Phys., 29, 462 (1962).

MAT number = 3193

19-K - 41 Fuji E.C. Eval-May87 H.Nakamura
Dist-Sep89

HISTORY
87-05 Newly Evaluated by H.Nakamura (Fuji Electric Co., Ltd.)

MF=1 General Information
MT=451 Descriptive data and dictionary

MF=2 MT=151 Resonance parameters:
Resolved resonances for MLBW formula: 1.0E-5 eV - 125 keV
Parameters are taken from BNL 325 4th edition /1/, and some parameters are assumed to fit the measured data.
Cross sections calculated with these parameters are to be corrected by adding MF=3, MT=1, 2 and 102 data
Calculated 2200-m/s cross sections and resonance integrals

	2200-m/sec	Res. Integ.	Ref.
elastic	2.57 b	-	-
capture	1.46 b	1.58 b	/1/
total	4.03 b	-	-

MF=3 Neutron Cross Sections
Below 125 keV
MT=251 Mu-bar= 0.0164
Above 125 keV.
MT=1,2,4,51-,91,102
Total, Elastic, Inelastic and Capture calculated with CASTHY code /2/, considering the competition with the threshold reaction channels.
Optical ootential parameters of C.Y.Fu/3/ are used.
The spherical optical potential parameters:

V = 46.72	Vso= 5.37	(MeV)
Ws= 9.13	Wv = 0.0	(MeV)
r =rso= 1.26	rs = 1.39	(fm)
a =aso= 0.76	b = 0.40	(fm)

MT=102 Capture data are normalized to the experimental data of 15 mb at 150 keV /4/ .
The discrete level scheme taken from Ref./5/:

No.	Energy(MeV)	Spin-Parity	
(g.s.)	0.0	3/2	+
1	0.9804	1/2	+
2	1.294	7/2	-

Continuum levels assumed above 1.5 MeV. The level density parameters of Asano et al./6/ are used.
MT=16(n,2n), 22(n,n'a), 28(n,n'p), 103(n,p), 107(n,a)
Based on the statistical model calculations with GNASH code /7/, without the precompound reaction correction .
Transmission coefficients for proton and alpha particle are calculated by using the OMP of Becchetti-Greenlees /8/ and Huizenga-Igo/9/, respectively.
Level density parameters are based on built-in values.
(n,2n), (n,p) and (n,a) cross sections were normalized to the experimental data of Adam+/10/ for (n,2n), and of Bass+/11/ for (n,p) and (n,a).
MT=251 Mu-bar

Calculated with optical model (CASTHY).

MF=4 Angular Distributions of Secondary Neutrons
MT=2 Calculated with optical model (CASTHY).
MT=51-91 Calculated with Hauser -Feshbach formula (CASTHY)
MT=16,22,28 Isotropic in the laboratory system.

MF=5 Energy Distributions of Secondary Neutrons
MT=16,22,28,91,103,107 Evaporation spectra.

References

1) Mughabghab, S.F. et al.: *Neutron Cross Section, Vol.1 (1981)*.
2) Igarasi, S.: J. Nucl. Sci. Tech., 12, 67 (1975).
3) Fu, C.Y.: Atom. Data and Nucl. Data Tables., 17, 127 (1976).
4) Stupegia et al.: J. Nucl. Energ., 22, 267 (1968).
5) Lederer, C.M. et al.: Table of Isotopes. 7th Edit.
6) Asano et al.: private communication.
7) Young, P.G. and Arthur, E.D.: LA-6947 (1977).
8) Becchetti, Jr. and Greenlees, G.W.: Polarization Phenomena in Nuclear Reactions, p.682 (1971).
9) Huizenga, Jr. and Igo, G.J.: Nucl. Phys., 29, 462 (1962).
10) Adam, A. et al.: Nucl. Phys., A180, 587 (1972).
11) Bass, R.et al.: EANDC(E)-57U, 1 (1965).

MAT number = 3200

20-Ca- 0 DEC Eval-Mar87 M.Hatchya(Data Eng. Co.)
Dist-Sep89

History
87-03 New evaluation was made to give a full revision for JENDL-2 data.
87-03 Compiled by T.Asami(NEDAC)

MF=1 General Information
MT=451 Descriptive data and dictionary

MF=2 Resonance Parameters
MT=151 Resolved resonance parameters
Resolved parameters for MLBW formula were given in the energy region from 1.0E-5 eV to 500 keV.
The data were constructed from the evaluated resonance parameters for each Ca isotope except for Ca-46, considering their abundances in the Ca element/1/.

	2200 m/s cross section(b)	res. integral(b)
elastic	3.019	
capture	0.4358	0.2262
total	3.455	

MF=3 Neutron Cross Sections
Below 500 keV, background cross section was given.
The total, elastic scattering and capture cross sections of Ca-42 in the energies of 300 to 500 keV and of Ca-43 in the energies of 40 to 500 keV, multiplied by their abundances, were given as the background cross sections for MT=1, 2 and 102, respectively.
Above 500 keV, the total and partial cross sections were given pointwise.
All the cross-section data except for the total ones above 500 keV were constructed from the evaluated ones for five stable isotopes of Ca except for Ca-46, considering their abundances in the Ca element/1/. The data of Ca-46 were ignored because of its very low abundance in the Ca element (0.004 %).
MT=1 Total
The data in the energies above 500 keV were evaluated based on mainly the experimental ones of/2, 3/ by following their fine structures.
MT=2 Elastic scattering
Obtained by subtracting the sum of the partial cross sections from the total cross section.
MT=4, 51-88, 91 Inelastic scattering
The data for each level were constructed from the evaluated ones for the Ca isotopes as follows:

MT	Level energy(MeV)	Ca-40	Ca-42	Ca-43	Ca-44	Ca-48
g.s.	0.0					
51	0.3730			51		
52	0.5930			52		
53	0.9900			53		
54	1.200				51	
55	1.395			54		

56	1.525		51			
57	1.837		52			
58	1.860				52	
59	1.931			55		
60	2.2831				53	
61	2.424		53			
62	2.600				54	
63	2.752		54			
64	3.0443				55	
65	3.189		55			
66	3.200				56	
67	3.3013				57	
68	3.3079				58	
69	3.352	51				
70	3.3572				59	
71	3.445		56			
72	3.737	52				
73	3.832					51
74	3.904	53				
75	4.492	54				
76	4.503					52
77	4.507					53
78	4.612					54
79	5.249	55				
80	5.370					55
81	5.627	56				
82	6.285	57				
83	6.585	58				
84	6.614					56
85	6.685					57
86	6.910	59				
87	6.932	60				
88	7.401					58
91	4.000	91	91	91	91	91

MT=16, 22, 28, 102, 103, 107, 111 (n,2n), (n,na), (n,np), capture, (n,p), (n,a) and (n,2p)
Constructed from the evaluated data for five Ca isotopes except for Ca-46, in considering their abundances in the element Ca.
MT=251 Mu-bar
Calculated with the optical model.

MF=4 Angular Distributions of Secondary Neutrons
MT=2
Calculated with the CASTHY code/4/.
MT=51-88, 91
Calculated with the CASTHY code/4/.
MT=16, 22, 28
Assumed to be isotropic in the laboratory system.

MF=5 Energy Distributions of Secondary Neutrons
MT=16, 22, 28, 91
Calculated with the GNASH code/5/.

MF=12 Photon Production Multiplicities
MT=102, 107

Calculated with the GNASH code/5/.

MF=13 Photon Production Cross Sections
MT=3
Calculated with the GNASH code/5/.

MF=14 Photon Angular Distributions
MT=3, 102, 107
Assumed to be isotropic in the laboratory system

MF=15 Continuous Photon Energy Spectra
MT=3, 102, 107
Calculated with the GNASH code/5/.

References

1) Holden N.E., Martin R.L. and Barnes I.L. : Pure & Appl Chem. 56, 675 (1984).
2) Cierjacks S. *et al.* : KfK-1000 (1968).
3) Foster Jr. D.G. et al. : Phys. Rev. C3, 576 (1971)
4) Igarasi S. : J. Nucl. Sci. Tech. 12, 67 (1975)
5) Young P.G. and Arthur E.D. : LA-6947 (1977).

MAT number = 3201

20-Ca- 40 DEC Eval-Mar87 M.Hatchya(Data Eng. Co.)
Dist-Sep89

History
87-03 New evaluation was made to give a full revision for JENDL-2 data.
87-03 Compiled by T.Asami(NEDAC)

MF=1 General Information
MT=451 Descriptive data and dictionary

MF=2 Resonance Parameters
MT=151 Resolved resonance parameters
Resolved parameters for MLBW formula were given in the energy region from 1.0E-5 eV to 500 keV.
Parameters were taken from the recommended data of BNL/1/ and the data for a negative resonance were added so as to reproduce the recommended thermal cross sections for capture and scattering/1/.
The scattering radius was assumed to be 3.6 Fermi
Calculated 2200 m/sec cross sections and resonance integrals are as follows:

	2200 m/s cross section(b)	res. integral(b)
elastic	3.022	
capture	0.408	0.2125
total	3.430	

MF=3 Neutron Cross Sections
Below 500 keV, zero background cross section was given and all the cross-section data are reproduced from the evaluated resolved resonance parameters with MLBW formula.
Above 500 keV, the total and partial cross sections were given pointwise.
MT=1 Total
Optical and statistical model calculation was made with CASTHY /2/. The optical potential parameters used are:

V = 49.68,		Vso = 7.12	(MeV)
Ws = 7.76 - 0.5•En,		Wv = 0	(MeV)
r = 1.17,	rs = 1.09,	rso = 1.17	(fm)
a = 0.6,	aso = 0.6,	b = 0.69	(fm)

MT=2 Elastic scattering
Obtained by subtracting the sum of the partial cross sections from the total cross section.
MT=4, 51-60, 91 inelastic scattering
Calculated with the CASTHY code/2/, taking account of the contribution from the competing processes. The direct component was calculated with the DWUCK/3/.
The level data used in the above two calculations were taken from ref./4/ as follows:

MT	Level energy(MeV)	Spin-parity	Beta-l
	0.0	0+	
51	3.352	0+	
52	3.737	3-	0.29
53	3.904	2+	0.12
54	4.492	5-	0.19

55	5.249	2+	0.039
56	5.627	2+	0.044
57	6.285	3-	0.14
58	6.585	3-	0.096
59	6.910	2+	0.099
60	6.932	3-	0.18

Levels above 8.0 MeV were assumed to be overlapping.

MT=16 (n,2n)
Taken from the JENDL-2 data, which were evaluated based on the experimental data of Arnold/5/.
MT=22, 28, 103, 107, 111 (n,na), (n,np), (n,p), (n,a), (n,2p)
Calculated with the GNASH code/6/ using the above optical model parameters
The (n,p) cross sections were normalized so as to fit to the experimental data of Urech at 5.95 MeV/7/.
The (n,a) cross sections were normalized to the experimental data of Barnes/8/ at 14.1 MeV.
MT=102 Capture
Calculated with the CASTHY code/4/ and normalized to 1.8 mb at 30 keV.
MT=251 Mu-bar
Calculated with the optical model.

MF=4 Angular Distributions of Secondary Neutrons
MT=2
Calculated with the CASTHY code/2/.
MT=51-60
Calculated with the CASTHY code/2/ and the DWUCK code/3/.
MT=91
Calculated with the CASTHY code/2/.
MT=16, 22, 28
Isotropic in the laboratory system.

MF=5 Energy Distributions of Secondary Neutrons
MT=16, 22, 28, 91
Calculated with the GNASH code/6/.

MF=12 Photon Production Multiplicities
MT=102, 107
Calculated with the GNASH code/6/.

MF=13 Photon Production Cross Sections
MT=3
Calculated with the GNASH code/6/.

MF=14 Photon Angular Distributions
MT=3, 102, 107
Assumed to be isotropic in the laboratory system.

MF=15 Continuous Photon Energy Spectra
MT=3, 102, 107
Calculated with the GNASH code/6/.

References
1) Mughaghab S.F. and Garber D.I. :"Neutron Cross Sections", Vol.

1, Part B (1984).
2) Igarasi S. : J. Nucl. Sci. Tech. 12, 67 (1975).
3) Kunz P.D. : Unpublished.
4) ENSDF(Evaluated Nuclear Structure Data File)
5) Arnold D.W. : Taken from EXFOR (1965).
6) Young P.G. and Arthur E.D. : LA-6947 (1977).
7) Urech S. : Nucl. Phys. A111, 184 (1968).

MAT number = 3202

20-Ca- 42 DEC Eval-Mar87 M.Hatchya(Data Eng Co.)
Dist-Sep89

History
87-03 New evaluation was made to give a full revision for JENDL-2 data.
87-03 Compiled by T.Asami(NEDAC)

MF=1 General Information
MT=451 Descriptive data and dictionary

MF=2 Resonance Parameters
MT=151 Resolved Resonance Parameters
Resolved parameters for MLBW formula were given in the energy region from 1.0E-5 eV to 300 keV.
Parameters were taken from the recommended data of BNL/1/ and the data for a negative resonance were added so as to reproduce the recommended thermal cross sections for capture and scattering/1/.
The scattering radius was assumed to be 3.6 Fermi.
Calculated 2200 m/sec cross sections and resonance integrals are as follows:

	2200 m/s cross section(b)	res. integral(b)
elastic	1.222	
capture	0.683	0.3762
total	1.905	

MF=3 Neutron Cross Sections
Below 300 keV, zero background cross section was given and all the cross-section data are reproduced from the evaluated resolved resonance parameters with MLBW formula.
Above 300 keV, the total and partial cross sections were given pointwise.
MT=1 Total
Optical and statistical model calculation was made with the CASTHY code/2/. The optical potential parameters used are:
V = 49.68, Vso = 7.12 (MeV)
Ws = 7.76 - 0.5*En, Wv = 0 (MeV)
r = 1.17, rs = 1.09, rso = 1.17 (fm)
a = 0.6, aso = 0.6, b = 0.69 (fm)
MT=2 Elastic scattering
Obtained by subtracting the sum of the partial cross sections from the total cross section.
MT=4, 51-56, 91 Inelastic scattering
Calculated with CASTHY /2/, taking account of the contribution from the competing processes.
The level data used in the above calculations were taken from ref./3/ as follows:

MT	Level energy(MeV)	Spin-parity
	0.0	0+
51	1.525	2+
52	1.837	0+
53	2.424	2+
54	2.752	4+
55	3.19	6+

56 3.445 3-

Levels above 7.0 MeV were assumed to be overlapping.

MT=16, 22, 28, 103, 107 (n,2n), (n,na), (n,np), (n,p), (n,a)
Calculated with the GNASH code/4/ using the above optical model parameters.
The (n,np) cross sections were normalized to 180 mb at 14.5 MeV.

MT=102 Capture
Calculated with the CASTHY code/2/ and normalized to 12.6 mb at 45 keV.

MT=251 Mu-bar
Calculated with the optical model.

MF=4 Angular Distributions of Secondary Neutrons

MT=2
Calculated with the CASTHY code/2/.

MT=51-56
Calculated with the CASTHY code/2/.

MT=91
Calculated with the CASTHY code/2/.

mt=16, 22, 28
Isotropic in the laboratory system.

MF=5 Energy Distributions of Secondary Neutrons

MT=16, 22, 28, 91
Calculated with the GNASH code/4/.

References

1) Mughabghab S.F. and Garber D.I. :"Neutron Cross Sections", Vol. 1, Part B (1984).
2) Igarasi S. : J. Nucl. Sci. Tech. 12, 67 (1975).
3) ENSDF(Evaluated Nuclear Structure Data File)
4) Young P.G. and Arthur E.D. : LA-6947 (1977).

MAT number = 3203

20-Ca- 43 DEC Eval-Mar87 M.Hatchya(Data Eng. Co.)
Dist-Sep89

History
87-03 New evaluation was made to give a full revision for JENDL-2 data.
87-03 Compiled by T.Asami(NEDAC)

MF=1 General Information
MT=451 Descriptive data and dictionary

MF=2 Resonance Parameters
MT=151 Resolved resonance parameters
Resolved parameters for MLBW formula were given in the energy region from 1.0E-5 eV to 40 keV.
Parameters were taken from the recommended data of BNL/1/ and the data for a negative resonance were added so as to reproduce the recommended thermal cross sections for capture and scattering/1/.
The scattering radius was assumed to be 3.6 Fermi.
Calculated 2200 m/sec cross sections and resonance integrals are as follows:

	2200 m/s cross section(b)	res. integral(b)
elastic	4.160	
capture	11.66	5.798
total	15.82	

MF=3 Neutron Cross Sections
Below 40 keV, zero background cross section was given and all the cross-section data are reproduced from the evaluated resolved resonance parameters with MLBW formula.
Above 40 keV, the total and partial cross sections were given pointwise.
MT=1 Total
Optical and statistical model calculation was made with the CASTHY code/2/. The optical potential parameters used are:

V = 49.68,		Vso = 7.12	(MeV)
Ws = 7.76 - 0.5•En,		Wv = 0	(MeV)
r = 1.17,	rs = 1.09,	rso = 1.17	(fm)
a = 0.6,	aso = 0.6,	b = 0.69	(fm)

MT=2 Elastic scattering
Obtained by subtracting the sum of the partial cross sections from the total cross section.
MT=4, 51-55, 91 Inelastic scattering
Calculated with CASTHY /2/, taking account of the contribution from the competing processes.
The level data used in the above calculations were taken from ref./3/ as follows:

MT	Level energy(MeV)	Spin-parity
	0.0	7/2-
51	0.373	5/2-
52	0.593	3/2-
53	0.990	3/2+
54	1.395	5/2+
55	1.931	5/2-

Levels above 5.0 MeV were assumed to be overlapping.

MT=16, 22, 28, 103, 107 (n,2n), (n,na), (n,np), (n,p), (n,a)
Calculated with the GNASH code/4/ using the above optical model parameters
MT=102 Capture
Calculated with the CASTHY code/2/ and normalized to 22 mb at 45 keV.
MT=251 Mu-bar
Calculated with the optical model.

MF=4 Angular Distributions of Secondary Neutrons
MT=2
Calculated with the CASTHY code/2/.
MT=51-55
Calculated with the CASTHY code/2/.
MT=91
Calculated with the CASTHY code/2/.
MT=16, 22, 28
Isotropic in the laboratory system.

MF=5 Energy Distributions of Secondary Neutrons
MT=16, 22, 28, 91
Calculated with the GNASH code/4/.

References

1). Mughabghab S.F. and Garber D.I. :"Neutron Cross Sections", Vol. 1, Part B (1984).
2) Igarasi S. : J. Nucl. Sci. Tech. 12, 67 (1975).
3) ENSDF(Evaluated Nuclear Structure Data File)
4) Young P.G. and Arthur E.D. : LA-6947 (1977).

MAT number = 3204

20-Ca- 44 DEC Eval-Mar87 M.Hatchya(Data Eng. Co.)
Dist-Sep89

History
87-03 New evaluation was made to give a full revision for JENDL-2 data.
87-03 Compiled by T.Asami(NEDAC)

MF=1 General Information
MT=451 Descriptive data and dictionary

MF=2 Resonance Parameters
MT=151 Resolved resonance parameters
Resolved parameters for MLBW formula were given in the energy region from 1.0E-5 eV to 500 keV.
Parameters were taken from the recommended data of BNL/1/ and the data for a negative resonance were added so as to reproduce the recommended thermal cross sections for capture and scattering/1/.
The scattering radius was assumed to be 3.6 Fermi.
Calculated 2200 m/sec cross sections and resonance integrals are as follows:

	2200 m/s cross section(b)	res. integral(b)
elastic	3.320	
capture	0.888	0.4254
total	4.208	

MF=3 Neutron Cross Sections
Below 500 keV, zero background cross section was given and all the cross-section data are reproduced from the evaluated resolved resonance parameters with MLBW formula.
Above 500 keV, the total and partial cross sections were given pointwise.
MT=1 total
Optical and statistical model calculation was made with the CASTHY code/2/. The optical potential parameters used are:

V = 49.68,		Vso = 7.12	(MeV)
Ws = 7.76 - 0.5•En,		Wv = 0	(MeV)
r = 1.17,	rs = 1.09,	rso = 1.17	(fm)
a = 0.6,	aso = 0.6,	b = 0.69	(fm)

MT=2 Elastic scattering
Obtained by subtracting the sum of the partial cross sections from the total cross section.
MT=4, 51-59, 91 Inelastic scattering
Calculated with CASTHY /2/, taking account of the contribution from the competing processes. The direct component was calculated with the DWUCK code/3/.
The level data used in the above two calculations were taken from ref./4/ as follows:

MT	Level energy(MeV)	Spin-parity
	0.0	0+
51	1.20	2+
52	1.86	0+
53	2.2831	4+
54	2.60	2+

55	3.0443	4+
56	3.20	6+
57	3.3013	2+
58	3.3079	3-
59	3.3572	4+

Levels above 4.0 MeV were assumed to be overlapping.

MT=16, 22, 28, 103, 107 (n,2n), (n,na), (n,np), (n,p), (n,a)
Calculated with the GNASH code/5/ using the above optical model parameters
The (n,p) and (n,a) cross sections were normalized to 42 mb and 28.6 mb at 14.5 MeV, respectively.

MT=102 Capture
Calculated with the CASTHY code/2/ and normalized to 7.1 mb at 45 keV.

MT=251 Mu-bar
Calculated with the optical model.

MF=4 Angular Distributions of Secondary Neutrons

MT=2
Calculated with the CASTHY code/2/.

MT=51-59
Calculated with the CASTHY code/2/ and the DWUCK code/3/.

MT=91
Calculated with the CASTHY code/2/.

MT=16, 22, 28
Isotropic in the laboratory system.

MF=5 Energy Distributions of Secondary Neutrons

MT=16, 22, 28, 91
Calculated with the GNASH code/5/.

References

1) Mughabghab S.F. and Garber D.I. :"Neutron Cross Sections", Vol. 1, Part B (1984).
2) Igarasi S. : J. Nucl. Sci. Tech. 12, 67 (1975).
3) Kunz P.D. : Unpublished.
4) ENSDF(Evaluated Nuclear Structure Data File)
5) Young P.G. and Arthur E.D. : LA-6947 (1977).

MAT number = 3205

20-Ca- 46 Mitsui E.S.Eval-Apr80 M.Hatchya
Dist-Feb84

History
80-04 New evaluation was made by M.Hatchya (Mitsui).
83-11 Ang. dist. was modified.
84-02 Comment was added.
88-10 Unchanged from JENDL-2.

MF=1 General Information
MT=451 Descriptive data and dictionary

MF=2 Resonance Parameters
MT=151 No resonance parameters

2200-m/sec cross sections and calculated resonance integrals

	2200-m/sec	Res.Integ.
elastic	2.900 b	-
capture	0.7400 b	0.339 b
total	3.640 b	-

MF=3 Neutron Cross Sections
Thermal region was assumed below 1.0 keV. The capture and elastic scattering cross sections were assumed to be 0.74 barns /1/ and 2.9 barns at 0.0253 eV, respectively. The total cross section was calculated as a sum of these two. Above 1.0 keV, data were evaluated as follows.

MT=1 Total cross section
The optical model calculation with CASTHY /2/ was adopted.

Optical potential parameters were taken from Ref. /3/.

V = 46.72 (MeV),
Ws = 9.13 (MeV),
Vso= 5.37 (MeV),
r0 = rso = 1.26 (fm),
rs = 1.39 (fm),
a = aso= 0.76 (fm),
b = 0.40 (fm).

MT=2 Elastic scattering cross section
Derived by subtracting partial cross sections from the total cross section.

MT=4,51-53,91 Inelastic scattering cross sections
Calculated with optical and statistical model code CASTHY /2/.

Level scheme

Level scheme was taken from Table of Isotopes /4/.

No.	Energy(MeV)	Spin-Parity
g.s.	0.0	0 +
1	1.347	2 +
2	3.024	2 +
3	3.613	3 -

Levels above 4.463 MeV were assumed to be overlapping.

Level density parameters (Gilbert and Cameron /5/)

isotope	46	47
a (1/MeV)	7.135	7.075
S-C(1/SQRT(MeV))	3.03	3.08
Delta(MeV)	3.37	1.83
Ex (MeV)	9.131	7.522

MT=16 (n,2n) cross section
Based on available data.
MT=102 Capture cross section
Calculated with CASTHY /2/.
MT=103,107 (n,p) and (n,alpha) cross sections
Statistical and pre-equilibrium model calculations using the optical potential parameters and the level density parameters given above. Fitted to available data.
MT=251 Mu-bar
Calculated with optical model.

MF=4 Angular Distributions of Secondary Neutrons
MT=2,51-53,91
Optical model calculation
MT=16
Isotropic in the laboratory system.

MF=5 Energy Distributions of Secondary Neutrons
MT=16,91
Evaporation spectra.

References

1) Mughabghab S.F. et al.: Neutron Cross Sections, Vol. 1, Part A (1981).
2) Igarasi S.: J. Nucl. Sci. Thecnol., 12, 67 (1975).
3) Fu C.Y.: Atomic Data and Nuclear Data Table 17, 127 (1976).
4) Lederer C.M. and Shirley V.S.: Table of Isotopes, 7th Ed., Wiley-Interscience (1978).
5) Gilbert A. and Cameron A.G.W.: Can. J. Phys. 43, 1446 (1965).

MAT number = 3206

20-Ca- 48 DEC Eval-Mar87 M.Hatchya(Data Eng. Co.)
Dist-Sep89

History
87-03 New evaluation was made to give a full revision for JENDL-2 data.
87-03 Compiled by T.Asami(NEDAC)

MF=1 General Information
MT=451 Descriptive data and dictionary

MF=2 Resonance Parameters
MT=151 Resolved resonance parameters
Resolved parameters for MLBW formula were given in the energy region from 1.0E-5 eV to 500 keV.
Parameters were taken from the recommended data of BNL/1/ and the data for a negative resonance were added so as to reproduce the recommended thermal cross sections for capture and scattering/1/.
The scattering radius was assumed to be 3.6 Fermi.
Calculated 2200 m/sec cross sections and resonance integrals are as follows:

	2200 m/s cross section(b)	res. integral(b)
elastic	3.717	
capture	1.092	0.4859
total	4.809	

MF=3 Neutron Cross Sections
Below 500 keV, zero background cross section was given and all the cross-section data are reproduced from the evaluated resolved resonance parameters with MLBW formula.
Above 500 keV, the total and partial cross sections were given pointwise.
MT=1 Total
Optical ar statistical model calculation was made with the CASTHY code/2/. The optical potential parameters used are:
V = 49.68, Vso = 7.12 (MeV)
Ws = 7.76 - 0.5•En, Wv = 0 (MeV)
r = 1.17, rs = 1.09, rso = 1.17 (fm)
a = 0.6, aso = 0.6, b = 0.69 (fm)
MT=2 Elastic scattering
Obtained by subtracting the sum of the partial cross sections from the total cross section.
MT=4, 51-58, 91 Inelastic scattering
Calculated with CASTHY /2/, taking account of the contribution from the competing processes.
The level data used in the above calculations were taken from ref./3/ as follows:

MT	Level Energy(MeV)	Spin-parity
	0.0	0+
51	3.832	2+
52	4.503	4+
53	4.507	3-
54	4.612	3+
55	5.37	3-

56	6.614	1-
57	6.685	3-
58	7.401	3-

Levels above 8.0 MeV were assumed to be overlapping.

MT=16, 22, 28, 103, 107 (n,2n), (n,na), (n,np), (n,p), (n,a)
Calculated with the GNASH code/4/ using the above optical model parameters.
The (n,p) cross sections were normalized to the experimental data of Tiwari et al./5/ at 14.5 MeV.

MT=102 Capture
Calculated with the CASTHY code/2/ and normalized to 1.05 mb at 30 keV.

MT=251 Mu-bar
Calculated with the optical model.

MF=4 Angular Distributions of Secondary Neutrons

MT=2
Calculated with the CASTHY code/2/.

MT=51-58
Calculated with the CASTHY code/2/.

MT=91
Calculated with the CASTHY code/2/.

MT=16, 22, 28
Isotropic in the laboratory system.

MF=5 Energy Distributions of Secondary Neutrons

MT=16, 22, 28, 91
Calculated with the GNASH code/4/.

References

1) Mughabghab S.F. and Garber D.I. "Neutron Cross Sections", Vol. 1, Part B (1984).
2) Igarasi S. : J. Nucl. Sci. Tech. 12, 67 (1975).
3) ENSDF(Evaluated Nuclear Structure Data File)
4) Young P.G. and Arthur E.D. : LA-6947 (1977).
5) Tiwari P.N. et al. : Phys. Rev. 167, 1091 (1968).

MAT number = 3211

```
 21-Sc- 45 KHI          Eval-Aug88 T.Watanabe
                        Dist-Sep89
History
88-08  JENDL-2 modified by T.Watanabe
                             (Kawasaki Heavy Industries, Ltd.)

MF=1    General Information
  MT=451   Descriptive data and dictionary

MF=2
  MT=151   Resonance Parameters              : 1.0E-5 eV - 100 keV
       Resolved resonances for MLBW formula:
          Parameters were evaluated based on experimental data
          /1/,/2/,/3/ and modified to reproduce experimental
          total cross sections. Negative energy levels were added
          to reproduce the total and capture cross sections/4/
          at thermal and the total cross section /5/ at 2 keV.

       Calculated 2200 m/s cross sections and resonance integrals
                       2200 m/sec          res. integ
          elastic        22.5 b               -
          capture        27.1 b             11.9 b
          total          49.7 b               -

MF=3    Neutron Cross Sections                       : above 100 keV
  MT=1,2,4,51-74,91,102  Total, elastic, inelastic and capture
          Calculated with optical and statistical model.
          Direct inelastic reaction cross sections were evaluated
          with DWBA /6/ and added to compound processes.

       The spherical optical potential parameters were evaluated
          to reproduce total experimental cross sections
          /7/,/8/,/9/.
          V = 56.2 - 0.3244*En  MeV  r0= 1.155 fm  a0= 0.666 fm
          Ws= 8.638-0.003093*En MeV  rs= 1.473 fm  b = 0.262 fm
          Vso=5.254 MeV              rso=1.003 fm  aso=0.485 fm

       Statistical model calculation with CASTHY code /10/ was
          performed. MT=102 capture cross section was normalized
          to the experimental data of Kenney+ /2/, 34.4 mb, at
          0.1 MeV.

       The level scheme taken from ref./11/:
          no.         energy(MeV)   spin-parity     beta
          g.s         0.0            7/2-
           1          0.012396       3/2+
           2          0.37659        3/2-          0.108
           3          0.543          5/2+
           4          0.72017        5/2-          0.0867
           5          0.9392         1/2+          0.0211
           6          0.97461        7/2+
           7          1.0672         3/2-          0.0586
           8          1.23723       11/2-          0.143
           9          1.30342        3/2+
          10          1.40887        7/2-
```

11	1.43367	9/2+	
12	1.5564	3/2-	
13	1.66231	9/2-	0.0843
14	1.8004	5/2+	

Continuum levels assumed above 1.9 MeV
Level density parameters were evaluated using D0, and level data /4/, /11/.

	a	T	Ex	sig**2(0)
21-Sc-45	7.855	1.282	10.08	7.602
21-Sc-46	7.231	1.268	7.328	7.867

MT=16 (n,2n)
The JENDL-2 data were modified by using experimental data /12/.

MT=103 (n,p)
Taken from compilation by Alley and Lessler /13/

MT=107 (n,alpha)
Same as MT=103, but slightly modified to reproduce /12/ experimental data.

MT=251 Mu-bar
Calculated from the data in MF=4.

MF=4 Angular Distributions of Secondary Neutrons
MT=2 Calculated with optical model.
MT=51-91 Calculated with Hauser-Feshbach formula added with direct reaction.
MT=16 Isotropic in the laboratory system

MF=5 Energy Distributions of Secondary Neutrons
Calculated with SINCROS /14/.

References

1) Liou, H.I. et al.: Nucl. Sci. Eng. 67, 326 (1978).
2) Kenny, M.J. et al.: Australian J. Phys. 30, 605 (1977).
3) Allen, B.J. et al.: Nucl. Sci. Eng. 82, 230 (1982).
4) Mughabghab, S.F., et al: 'Neutron Cross Sections Vol.I Part A' Academic Press (1981)
5) Fujita, Y: J. Nucl. Sci. Technol. 20, 191 (1983).
6) Kunz, P.D.: Unpublished (1974).
7) Poenitz, W.P. and Whalen, J.F.: ANL/NDM-80 (1983).
8) Barnard, E. et al.: Z. Phys. 245, 36 (1971).
9) Foster, Jr. D.G. and Glasgow D.W.: Phys. Rev. C3, 576 (1971).
10) Igarasi, S.: J. Nucl. Sci. Technol. 12,67 (1975).
11) Burrows, T.W.: Nuclear Data Sheets 40, 216 (1983).
12) Ikeda, Y., et al.: JAERI 1312 (1988).
13) Alley, W.E. and Lessler, R.M: Nuclear Data Tables A11,648 (1973).
14) Yamamuro, N.: JAERI-M 88-140 (1988).

MAT number = 3220

22-Ti- 0 KUR Eval-Sep88 K.Kobayashi(KUR),H.Hashikura(TOK)
Dist-Sep89

History
88-09 Compiled by T.Asami(NEDAC)

MF=1 General Information
MT=451 Descriptive data and dictionary

MF=2 Resonance Parameters
MT=151 Resolved resonance parameters
Resolved parameters for MLBW formula were given in the energy region from 1.0E-5 eV to 100 keV.
Parameters were constructed with the evaluated data for Ti-46, -47, -48, -49 and -50 of Ti stable isotopes, considering their abundances in the Ti element. The abundance data were taken from ref./1/.

	2200 m/s cross section(b)	res integral(b)
elastic	4.087	
capture	6.092	2.92
total	10.18	

MF=3 Neutron Cross Sections
Below 100 keV, no background cross section was given.
Above 100 keV, the total and partial cross sections were given pointwise.
All the cross-section data were deduced from the evaluated ones for five stable isotopes of Ti considering their abundances in the Ti element, except for the total cross sections in the energies above 100 keV.

MT=1 Total
The data in the energies above 100 keV were evaluated based on several experimental ones/2/-/4/, following fine structures in the cross sections. The data in the other energy range were constructed with the evaluated ones for five isotopes of Ti.

MT=2 Elastic scattering
Obtained by subtracting the sum of the partial cross sections from the total cross section.

MT=4, 51-90, 91 Inelastic scattering
The data were constructed from the evaluated ones for each Ti isotope. The isotopic data were calculated with the CASTHY code /5/, including both the effects of the direct process and the competing reactions. The direct process was calculated based on the DWBA method.
The discrete levels were lumped as given below:

MT	Level energy(MeV)	Ti-46	Ti-47	Ti-48	Ti-49	Ti-50
g.s.	0.0					
51	0.1607		51			
52	0.889	51				
53	0.984			51		
54	1.382				51	
55	1.550		52			
56	1.555					51
57	1.585				52	
58	1.723				53	

2 of Natural Titanium

59	1.762				54	
60	1.794		53			
61	2.010	52				
62	2.165		54			
63	2.295			52		
64	2.421			53		
65	2.506				55	
66	2.526		55			
67	2.611	53				
68	2.675					52
69	2.793		56			
70	2.962	54				
71	2.999			54		
72	3.059	55				
73	3.168	56				
74	3.175				56	
75	3.21					53
76	3.224			55-56		
77	3.236	57				
78	3.260				57	
79	3.299	58				
80	3.332			57-59		
81	3.428				58	
82	3.438	59				
83	3.508			60		
84	3.618			61		
85	3.703			62-63		
86	3.741			64-65		
87	3.853			66		
88	3.87					54
89	4.036			67		

The threshold for the continuum of inelastic scattering was set to be 2.85 MeV.

MT=16 (n,2n)
Evaluated based on experimental data.

MT=22 (n,na)
Calculated with the GNASH code/6/.

MT=28 (n,np)
Calculated with the GNASH code/6/.

MT=102 Capture
Composed from the isotopic data calculated with the CASTHY code/5/.

MT=103 (n,p)
Composed from the isotopic data.

MT=107 (n,a)
Composed from the isotopic data.

MT=251 Mu-bar
Calculated based on optical model.

MF=4 Angular Distributions of Secondary Neutrons

MT=2
Calculated with the CASTHY code/5/.

MT=51-89, 91
Constructed from the isotopic data.
The direct interaction was considered for MT=52,53,56,61,63,64,67,68,70,72,80,84,87,89.

MT=16, 22, 28

Assumed to be isotropic in the laboratory system

MF=5 Energy Distributions of Secondary Neutrons
MT=16, 22, 28, 91
Constructed from the isotopic data.

MF=12 Photon Production Multiplicities
MT=102
Composed from the isotopic data calculated with the GNASH code/6/.

MF=13 Photon Production Cross Sections
MT=3
Calculated with the GNASH code/6/, and above 2.745 MeV replaced with the measurements of Morgan et al./7/

MF=14 Photon Angular Distributions
MT=3, 102
Assumed to be isotropic in the laboratory system

MF=15 Continuous Photon Energy Spectra
MT=3
Calculated with the GNASH code/6/.
MT=102
Calculated with the GNASH code/6/ except for thermal.
At thermal, based on the measurements of Maerker/8/.

References
1) Holden, N.E., Martin, R.L. and Barnes, I.L. : Pure & Appl. Chem. 56, 675 (1984).
2) Foster, Jr., D.G. and Glasgow D.W.: Phys. Rev. C3,576 (1971).
3) Barnard, E. et al. : CEA-R-4524 (1973).
4) Schwarz : NBS-MONO-138 (1974).
5) Igarasi, S. : J. Nucl. Sci. Tech. 12, 67 (1975).
6) Young, P.G. and Arthur, E.D. : LA-6947 (1977).
7) Morgan, G.L. : ORNL/TM-6323 (1978).
8) Maerker, R.E. : ORNL/TM-5203 (1976).

MAT number = 3221

22-Ti- 46 KUR Eval-Sep88 K.Kobayashi(KUR),H.Hashikura(TOK)
Dist-Sep89

History
88-09 Compiled by T.Asami(NEDAC)

MF=1 General Information
MT=451 Descriptive data and dictionary

MF=2 *Resonance Parameters*
MT=151 Resolved resonance parameters
Resolved parameters for MLBW formula were given in the energy region from 1.0E-5 eV to 180 keV.
Parameters were taken from ref./1/, for positive resonances. Parameters for negative resonance were obtained so that the reproduced cross sections for both scattering and capture gave the 2200 m/s values of 2.78+-0.24 and 0.59+-0.18 barns, respectively/1/.
The scattering radius was assumed to be 4.5 Fermi instead of 3.5 Fermi in ref./1/.
Calculated 2200 m/sec cross sections and resonance integrals are as follows:

	2200 m/s cross section(b)	res. integral(b)
elastic	2.75	
capture	0.596	0.35
total	3.34	

MF=3 Neutron Cross Sections
Below 180 keV, no background cross section was given.
Above 180 keV, the total and partial cross sections were given pointwise.

MT=1 Total
Optical and statistical model calculation was made with the CASTHY code/2/. The optical potential parameters used are:

V = 50.75 - 0.120•En, Vso = 4.72 (MeV)
Ws = 10.9 - 0.234•en, Wv = 0.0 (MeV)
r = 1.26, rs = 1.02, rso = 1.16 (fm)
a = 0.52, aso = 0.52, b = 0.40 (fm)

MT=2 Elastic scattering
Obtained by subtracting the sum of the partial cross sections from the total cross section.

MT=4, 51-59, 91 Inelastic scattering
Calculated with the CASTHY code/2/, taking account of the contribution from the competing processes.
The contributions from the direct process for inelastic scattering were calculated with the DWUCK code/3/.
The deformation parameters used in the calculation were assumed in referring the data from the Ti-46(p,p') reaction /4/, as shown in table below.
The level data in the above two calculations were taken from ref./5/ as follows:

MT	Level energy(MeV)	Spin-parity	Beta-l
g.s.	0.0	0+	-
51	0.889	2+	0.29
52	2.010	4+	0.16

53	2.611	0+	0.04
54	2.962	2+	0.053
55	3.059	3-	0.16
56	3.168	1-	-
57	3.236	2+	-
58	3.299	6+	-
59	3.438	3-	-

Levels above 3.5 MeV were assumed to be overlapping.

MT=16 (n,2n)
Evaluated based on the experimental data.
MT=22 (n,na)
Calculated with GNASH code/6/.
MT=28 (n,np)
Calculated with GNASH code/6/.
MT=102 Capture
Calculated with the CASTHY code/2/ and normalized to 26.9 mb at 30 keV.
MT=103 (n,p)
Evaluated based on the experimental data.
MT=107 (n,a)
Calculated with GNASH code/6/.
MT=251 Mu-bar
Calculated with optical model.

MF=4 Angular Distributions of Secondary Neutrons
MT=2
Calculated with the CASTHY code/2/.
MT=51-59, 91
Calculated with the CASTHY code/2/.
The direct interaction was considered for MT=51-55.
MT=16, 22, 28
Assumed to be isotropic in the laboratory system.

MF=5 Energy Distributions of Secondary Neutrons
MT=16, 22, 28, 91
Calculated with the GNASH code/6/.

References

1) Mughabghab S.F et al. : " Neutron Cross Sections ", vol.1, Part A (1981).
2) Igarasi S. : J. Nucl. Sci. Tech. 12, 67 (1975).
3) Kunz, P.D. : Unpublished.
4) Peterson, R.J. and Perlman, D.E.: Nucl. Phys. A117,185(1968).
5) Evaluated Nuclear Structure Data File (ENSDF).
6) Young, P.G. and Arthur, E.D. : LA-6947 (1977).

MAT number = 3222

```
 22-Ti- 47 KUR          Eval-Sep88 K.Kobayashi(KUR),H.Hashikura(TOK)
                        Dist-Sep89
History
88-09  Compiled by T.Asami(NEDAC)

MF=1  General Information
 MT=451  Descriptive data and dictionary

MF=2  Resonance Parameters
 MT=151  Resolved resonance parameters
   Resolved parameters for MLBW formula were given in
   the energy region from 1.0E-5 eV to 100 keV.
   Parameters were taken from ref /1/, for positive resonances.
   Parameters for negative resonance were obtained so that the
   reproduced cross sections for both scattering and capture gave
   the 2200 m/s values of 3.1+-0.2 and 1.7+-0.2 barns, respec-
   tively/1/.
   The scattering radius was assumed to be 4.5 Fermi instead of
   3.6 Fermi in ref./1/.
   Calculated 2200 m/sec cross sections and resonance integrals
   are as follows:
             2200 m/s cross section(b)     res. integral(b)
    elastic        3.10
    capture        1.70                        1.44
    total          4.80

MF=3  Neutron Cross Sections
   Below 100 keV, no background cross section was given.
   Above 100 keV, the total and partial cross sections were given
   pointwise.
 MT=1 Total
   Optical and statistical model calculation was made with
   CASTHY code/2/. The optical potential parameters used are:
     V = 50.75 - 0.120*En,    Vso = 4.72    (MeV)
    Ws = 10.9 - 0.234*En,      Wv = 0.0     (MeV)
     r = 1.26,  rs = 1.02,  rso = 1.16      (fm)
     a = 0.52,  aso = 0.52,  b = 0.40       (fm)
 MT=2 Elastic scattering
   Obtained by subtracting the sum of the partial cross sections
   from the total cross section.
 MT=4, 51-56, 91 Inelastic scattering
   Calculated with the CASTHY code/2/, taking account of the
   contribution from the competing processes.
   The contribution from the direct process for inelastic scatter-
   ing was ignored.
   The level data in the above calculations were taken from
   ref./3/ as follows:
    MT   Level energy(MeV)   Spin-parity
   g.s.        0.0              5-
    51         0.160            7-
    52         1.550            3-
    53         1.794            1-
    54         2.165            3-
    55         2.526            3-
    56         2.793            1-
```

Levels above 2.85 MeV were assumed to be overiapping

MT=16 (n,2n)
Calculated with the GNASH code/4/.

MT=22 (n,na)
Calculated with the GNASH code/4/.

MT=28 (n,np)
Evaluated based on the experimental data.

MT=102 Capture
Calculated with the CASTHY code/2/ and normalized to 65.5 mb at 30 keV.

MT=103 (n,p)
Evaluated based on the experimental data.

MT=107 (n,a)
Calculated with the GNASH code/4/.

MT=251 Mu-bar
Calculated with optical model.

MF=4 Angular Distributions of Secondary Neutrons

MT=2
Calculated with the CASTHY code/2/

MT=51-56, 91
Calculated with the CASTHY code/2/

MT=16, 22, 28
Assumed to be isotropic in the laboratory system

MF=5 Energy Distributions of Secondary Neutrons

MT=16, 22, 28, 91
Calculated with the GNASH code/4/.

References
1) Mughabghab S.F et al. : " Neutron Cross Sections ", Vol.1, Part A (1981)
2) Igarasi S. . J. Nucl. Sci. Tech. 12, 67 (1975).
3) Evaluated Nuclear Structure Data File (ENSDF).
4) Young P.G. and Arthur E.D. : LA-6947 (1977).

MAT number = 3223

22-Ti- 48 KUR Eval-Sep88 K.Kobayashi(KUR),H.Hashikura(TOK)
Dist-Sep89

History
88-09 Compiled by T.Asami(NEDAC)

MF=1 General Information
 MT=451 Descriptive data and dictionary

MF=2 Resonance Parameters
 MT=151 Resolved resonance parameters
 Resolved parameters for MLBW formula were given in the energy region from 1.0E-5 eV to 100 keV.
 Parameters were taken from ref./1/, for positive resonances.
 Parameters for negative resonance were obtained so that the reproduced cross sections for both scattering and capture gave the 2200 m/s values of 4.61+-0.2 and 7.84+-0.25 barns, respectively/1/.
 The scattering radius was assumed to be 4.2 Fermi instead of 3.9 Fermi in ref./1/.
 Calculated 2200 m/sec cross sections and resonance integrals are as follows:

	2200 m/s cross section(b)	res. integral(b)
elastic	4.61	
capture	7.84	3.69
total	12.45	

MF=3 Neutron Cross Sections
 Below 100 keV, no background cross section was given.
 Above 100 keV, the total and partial cross sections were given pointwise.
 MT=1 Total
 Optical and statistical model calculation was made with CASTHY code/2/ The optical potential parameters used are:

 V = 50.75 - 0.120•En, Vso = 4.72 (MeV)
 Ws = 10.9 - 0.234•En, Wv = 0.0 (MeV)
 r = 1.26, rs = 1.02, rso = 1.16 (fm)
 a = 0.52, aso = 0.52, b = 0.40 (fm)

 MT=2 Elastic scattering
 Obtained by subtracting the sum of the partial cross sections from the total cross section.
 MT=4, 51-67, 91 Inelastic scattering
 Calculated with the CASTHY code/2/, taking account of the contribution from the competing processes.
 The contributions from the direct process for inelastic scattering were calculated with DWUCK code/3/.
 The deformation parameters used in the calculation were assumed in referring the data from the Ti-48(a,a') reaction /4/, as shown in table below.
 The level data in the above two calculations were taken from ref./5/ as follows:

MT	Level energy(MeV)	Spin-parity	Beta-l
g.s.	0.0	0+	-
51	0.984	2+	0.21
52	2.295	4+	0.05
53	2.421	2+	0.058

54	2.999	0+	-
55	3.224	3+	-
56	3.239	4+	0.082
57	3.332	6+	-
58	3.359	3-	0.079
59	3.373	2+	-
60	3.508	6+	-
61	3.618	2+	-
62	3.703	1+	-
63	3.711	1+	-
64	3.741	1+	-
65	3.783	3-	-
66	3.853	3-	-
67	4.036	2+	-

Levels above 4.1 MeV were assumed to be overlapping

MT=16 (n,2n)
Calculated with the GNASH code/6/.

MT=22 (n,na)
Calculated with the GNASH code/6/

MT=28 (n,np)
Calculated with the GNASH code/6/.

MT=102 capture
Calculated with the CASTHY code/2/ and normalized to 4.3 mb at 20 keV.

MT=103 (n,p)
Evaluated based on the experimental data.

MT=107 (n,a)
Evaluated based on the experimental data.

MT=251 Mu-bar
Calculated with optical model.

MF=4 Angular Distributions of Secondary Neutrons

MT=2
Calculated with the CASTHY code/2/.

MT=51-67, 91
Calculated with the CASTHY code/2/.

MT=16, 22, 28
Assumed to be isotropic in the laboratory system.

MF=5 Energy Distributions of Secondary Neutrons

MT=16, 22, 28, 91
Calculated with the GNASH code/6/.

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1) Mughabghab S.F. et al. : " Neutron Cross Sections ", Vol.1, Part A (1981).
2) Igarasi S. : J. Nucl. Sci. Tech. 12, 67 (1975).
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6) Young P.G. and Arthur E.D. : LA-6947 (1977).

MAT number = 3224

22-Ti- 49 KUR Eval-Sep88 K.Kobayashi(KUR),H.Hashikura(TOK)
Dist-Sep89

History
88-09 Compiled by T.Asami(NEDAC)

MF=1 General Information
MT=451 Descriptive data and dictionary

MF=2 Resonance Parameters
MT=151 Resolved resonance parameters
Resolved parameters for MLBW formula were given in the energy region from 1.0E-5 eV to 100 keV.
Parameters were taken from ref./1/, for positive resonances.
Parameters for negative resonance were obtained so that the reproduced cross sections for both scattering and capture gave the 2200 m/s values of 0.7+-0.3 and 2.2+-0.3 barns, respectively/1/.
The scattering radius was assumed to be 4.5 Fermi instead of 4.0 Fermi in ref./1/.
Calculated 2200 m/sec cross sections and resonance integrals are as follows:

	2200 m/s cross section(b)	res. integral(b)
elastic	0.69	
capture	2.21	1.06
total	2.90	

MF=3 Neutron Cross Sections
Below 100 keV, no background cross section was given.
Above 100 keV, the total and partial cross sections were given pointwise.
MT=1 Total
Optical and statistical model calculation was made with CASTHY code/2/. The optical potential parameters used are:
V = 50.75 - 0.120•En, Vso = 4.72 (MeV)
Ws = 10.9 - 0.234•En, Wv = 0.0 (MeV)
r = 1.26, rs = 1.02, rso = 1.16 (fm)
a = 0.52, aso = 0.52, b = 0.40 (fm)
MT=2 Elastic scattering
Obtained by subtracting the sum of the partial cross sections from the total cross section.
MT=4, 51-56, 91 Inelastic scattering
Calculated with the CASTHY code/2/, taking account of the contribution from the competing processes.
The contribution from the direct process for inelastic scattering was ignored.
The level data in the above calculations were taken from ref./3/ as follows:

MT	Level energy(MeV)	Spin-parity
g.s.	0.0	5-
51	0.160	7-
52	1.550	3-
53	1.794	1-
54	2.165	3-
55	2.526	3-
56	2.793	1-

Levels above 2.85 MeV were assumed to be overlapping

MT=16 (n,2n)
Calculated with the GNASH code/4/.

MT=22 (n,na)
Calculated with the GNASH code/4/.

MT=28 (n,np)
Evaluated based on the experimental data.

MT=102 Capture
Calculated with the CASTHY code/2/ and normalized to 22.5 mb at 30 keV.

MT=103 (n,p)
Evaluated based on the experimental data.

MT=107 (n,a)
Calculated with the GNASH code/4/.

MT=251 Mu-bar
Calculated with optical model.

MF=4 Angular Distributions of Secondary Neutrons

MT=2
Calculated with the CASTHY code/2/.

MT=51-56, 91
Calculated with the CASTHY code/2/.

MT=16, 22, 28
Assumed to be isotropic in the laboratory system

MF=5 Energy Distributions of Secondary Neutrons

MT=16, 22, 28, 91
Calculated with the GNASH code/4/.

References

1) Mughabghab S.F. et al. : " Neutron Cross Sections ", Vol.1, Part A (1981).
2) Igarasi S. : J. Nucl. Sci. Tech. 12, 67 (1975).
3) Evaluated Nuclear Structure Data File (ENSDF).
4) Young P.G. and Arthur E.D. : LA-6947 (1977).

MAT number = 3225

22-Ti- 50 KUR Eval-Sep88 K.Kobayashi(KUR),Hashikura(TOK)
Dist-Sep89

History
88-09 Compiled by T.Asami(NEDAC)

MF=1 General Information
MT=451 Descriptive data and dictionary

MF=2 Resonance Parameters
MT=151 Resolved resonance parameters
Resolved parameters for MLBW formula were given in the energy region from 1.0E-5 eV to 200 keV.
Parameters were taken from ref./1/, for positive resonances
Parameters for negative resonance were obtained so that the reproduced cross sections for both scattering and capture gave the 2200 m/s value of 3.7+-0.3 and 0.179+-0.003 barns, respectively/1/.
The scattering radius was assumed to be 4.5 Fermi
Calculated 2200 m/sec cross sections and resonance integrals are as follows:

	2200 m/s cross section(b)	res integral(b)
elastic	3.71	
capture	0.18	0.086
total	3.88	

MF=3 Neutron Cross Sections
Below 180 keV, no background cross section was given.
Above 180 keV, the total and partial cross sections were given pointwise.
MT=1 Total
Optical and statistical model calculation was made with CASTHY code/2/. The optical potential parameters used are:
V = 50.75 - 0.120•En, Vso = 4.72 (MeV)
Ws = 10.9 - 0.234•En, Wv = 0.0 (MeV)
r = 1.26, rs = 1.02, rso = 1.16 (fm)
a = 0.52, aso = 0.52, b = 0.40 (fm)
MT=2 Elastic scattering
Obtained by subtracting the sum of the partial cross sections from the total cross section.
MT=4, 51-59, 91 Inelastic scattering
Calculated with the CASTHY code/2/, taking account of the contribution from the competing processes.
The contributions from the direct process for inelastic scattering were calculated with DWUCK code/3/.
The deformation parameters used in the calculation were were assumed in referring the data on the Ti-50(p,p') reaction /4/, as shown in table below.
The level data in the above two calculations were taken from ref./5/ as follows:

MT	Level energy(MeV)	Spin-parity	Beta-l
g.s.	0.0	0+	-
51	0.889	2+	0.29
52	2.010	4+	0.16
53	2.611	0+	0.04
54	2.962	2+	0.053

55	3.059	3-	0.16
56	3.168	1-	-
57	3.236	2+	-
58	3.299	6+	-
59	3.438	3-	-

Levels above 3.5 MeV were assumed to be overlapping.

MT=16 (n,2n)
Evaluated based on the experimental data.

MT=22 (n,na)
Calculated with the GNASH code/6/.

MT=28 (n,np)
Calculated with the GNASH code/6/.

MT=102 Capture
Calculated with the CASTHY code/2/ and normalized to 2.3 mb at 25 keV.

MT=103 (n,p)
Evaluated based on the experimental data.

MT=107 (n,a)
Calculated with the GNASH code/6/.

MT=251 Mu-bar
Calculated based on optical model

MF=4 Angular Distributions of Secondary Neutrons

MT=2
Calculated with the CASTHY code/2/.

MT=51-59, 91
Calculated with the CASTHY code/2/.

MT=16, 22, 28
Assumed to be isotropic in the laboratory system.

MF=5 Energy Distributions of Secondary Neutrons

MT=16, 22, 28, 91
Calculated with the GNASH code/6/.

References

1) Mughabghab S.F. et al. : " Neutron Cross Sections ", Vol.1, Part A (1981).
2) Igarasi S. : J. Nucl. Sci. Tech. 12, 67 (1975).
3) Kunz P.D. : Unpublished.
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6) Young P.G. and Arthur E.D. : LA-6947 (1977).

MAT number = 3231

23-V - 51 KHI Eval-Aug88 T.Watanabe
Dist-Sep89

History
88-08 JENDL-2 modified by T.Watanabe
(Kawasaki Heavy Industries, Ltd.)

MF=1 General Information
MT=451 Descriptive data and dictionary

MF=2
MT=151 Resonance Parameters : 1.0E-5 eV - 100 keV
Resolved resonances for MLBW formula:
Parameters were evaluated based on experimental data /1/,/2/,/3/,/4/ and modified to reproduce experimental total cross sections. Negative energy levels were added to reproduce 2200 m/s total and capture cross sections.

Calculated 2200 m/s cross sections and resonance integrals

	2200 m/sec	res. integ
elastic	4.8 b	-
capture	4.9 b	2.6 b
total	9.7 b	-

MF=3 Neutron Cross Sections : above 100 keV
MT=1,2,4,51-74,91,102
Total, elastic, inelastic and capture cross sections were calculated with optical and statistical model. Direct inelastic reaction cross sections were evaluated with DWBA method /5/ and added to compound processes.

The spherical optical potential parameters were evaluated to reproduce experimental total cross sections /6/,/7/,/8/.

V = 50.71-0.4793•En MeV r0= 1.227 fm a0= 0.663 fm
Ws= 5.307-0.1911•En MeV rs= 1.370 fm b = 0.394 fm
Vso= 6.560 MeV rso=0.046 fm aso=0.535 fm

Statistical model calculation with CASTHY code /9/ was performed. MT=102 capture cross section was normalized to the experimental data of Dudey+ /10/ at 0.5 MeV 2.63 mb.

The level scheme taken from ref./11/:

no.	energy(MeV)	spin-parity	beta
g.s	0.0	7/2-	
1	0.320853	5/2-	0.0809
2	0.92866	3/2-	0.0494
3	1.60894	11/2-	0.0875
4	1.81308	9/2-	0.0674
5	2.41078	3/2-	0.0427
6	2.5474	1/2+	
7	2.67743	3/2+	
8	2.69963	15/2-	0.0472
9	2.79	9/2-	
10	3.08362	5/2-	

11	3.15	3/2-	
12	3.1951	3/2-	
13	3.2148	3/2-	
14	3.26404	5/2-	0.0494

Continuum levels assumed above 3.28 MeV
Level density parameters were evaluated using D0, and level data /3/, /11/.

	a	T	Ex	sig**2(0)
23-V-51	6.333	1.267	7.04	8.549
23-V-52	7.693	1.053	4.861	7.065

MT=1 Total
100 keV -2 MeV based on the experimental data /7/,/8/
above 2 MeV calculated

MT=1 Elastic scattering
Obtained by subtracting the sum of absorption and inelastic scattering from total cross section.

MT=16 (n,2n)
Guided by experimental data /12/,/13/.

MT=22,28,104,105
Adopted JENDL-2 evaluated data /14/.

MT=103 (n,p)
Guided by experimental data /15/,/16/.

MT=107 (n,alpha)
Guided by experimental data /14/,/17/,/18/,/19/.

MT=251 Mu-bar
Calculated from the data in MF=4.

MF=4 Angular Distributions of Secondary Neutrons
MT=2 Calculated with optical model.
MT=51-91 Calculated with Hauser-Feshbach formula and DWBA
MT=16,22,28
Isotropic in the laboratory system

MF=5 Energy Distributions of Secondary Neutrons
MT=16,22,28,91
Calculated with SINCROS /20/.

References

1) Winters, R.R. et al.: Phys. Rev. C18, 2092 (1978).
2) Garg, J.B. et al.: Nucl. Sci. Eng. 65, 76 (1978).
3) Mughabghab S.F et al.: "Neutron Cross Sections Vol.1 Part A" Academic Press (1981).
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MAT number = 3240

24-Cr- 0 NEDAC Eval-Mar87 T.Asami(NEDAC)
Dist-Sep89

History
87-03 New evaluation was made to give a full revision for JENDL-2 data.
88-12 MF/MT=3/107 modified.
89-08 MF/MT=15/102 modified.

MF=1 General Information
MT=451 Descriptive data and dictionary

MF=2 Resonance Parameters
MT=151 Resolved resonance parameters
Resolved parameters for MLBW formula were given in the energy region from 1.0E-5 eV to 300 keV.
The data were constructed from the evaluated resonance parameters for each Cr isotope, considering their abundances in the Cr element/1/.

	2200 m/s cross section(b)	res. integral(b)
elastic	3.38	
capture	3.07	1.53
total	6.45	

MF=3 Neutron Cross Sections
Below 300 keV, background cross section was given.
As the evaluated data on the resonance parameters of Cr-53 were given below 120 keV, the cross sections of Cr-53 for total, elastic scattering and capture in this energy range, multiplied by its abundance, are provided as the background cross sections for MT=1, 2 and 102, respectively.
Above 300 keV, the total and partial cross sections were given pointwise.
All the cross-section data were deduced from the evaluated ones for four stable isotopes of Cr considering their abundances in the Cr element/1/, except for the total cross sections in the energies above 300 keV.

MT=1 Total
The data in the energies above 300 keV were evaluated based on the experimental ones of/2/-/4/. The data in ref./2/ were used to follow the fine structures and those in refs./3/ and /4/ were used for the normalization of the above data and for the evaluation in high energy region.
The data in the other energy range were constructed from the evaluated ones for four isotopes of Cr.

MT=2 Elastic scattering
Obtained by subtracting the sum of the partial cross sections from the total cross section.

MT=4, 51-90, 91 Inelastic scattering
The data for each level were constructed from the evaluations for each Cr isotope as follows:

MT Level energy(MeV) Cr-50 Cr-52 Cr-53 Cr-54

g.s.	0.0				
51	0.5640			51	
52	0.7833	51			
53	0.8349				51
54	1.0063			52	
55	1.2895			53	
56	1.4341		51		
57	1.5366			54	
58	1.8237				52
59	1.8814	52			
60	1.9736			55	
61	2.1724			56	
62	2.2330			57	
63	2.3208			58	
64	2.3696		52		
65	2.4531			59	
66	2.6195				53
67	2.6470		53		
68	2.6570			60	
69	2.7677		54		
70	2.7720			61	
71	2.8266			62	
72	2.8294				54
73	2.9245	53			
74	2.9646		55		
75	2.9930			63	
76	3.0739				55
77	3.1138		56		
78	3.1600				56
79	3.1611	54			
80	3.1617		57		
81	3.3247	55			
82	3.4152		58		
83	3.4722		59		
84	3.6158		60		
85	3.7000		61		
86	3.7717		62		
87	3.9460		63		
88	4.0154		64		
89	4.5630		65		
90	4.6270		66		
91	3.0500	91	91	91	91

MT=16 (n,2n)
Constructed from the evaluated data for four Cr isotopes so as to reproduce the experimental data of Frehaut/5/.
MT=22 (n,na)
Constructed from the evaluated data for four Cr isotopes.
MT=28 (n,np)
Constructed from the evaluated data for four Cr isotopes.
MT=102 Capture
Calculated with the CASTHY code/6/ and normalized to 10 mb at 50 keV.
MT=103 (n,p)
Constructed from the evaluated data for four Cr isotopes.
MT=107 (n,a)
Constructed from the evaluated data for four Cr isotopes

so as to reproduce the experimental data of Paulsen/7/.
MT=251 Mu-bar
Calculated with optical model.

MF=4 Angular Distributions of Secondary Neutrons
MT=2
Calculated with the CASTHY code/6/.
MT=51-90, 91
Calculated with the CASTHY code.
MT=16, 22, 28
Assumed to be isotropic in the laboratory system.

MF=5 Energy Distributions of Secondary Neutrons
MT=16, 22, 28, 91
Calculated with the GNASH code/6/.

MF=12 Photon Production Multiplicities
MT=102
Calculated with the GNASH code/8/.

MF=13 Photon Production Cross Sections
MT=3
Evaluated based on the experimental data of Morgan/9/.
Below 4.75 MeV, the fine structures in inelastic scattering were considered.

MF=14 Photon Angular Distributions
MT=3, 102
Assumed to be isotropic in the laboratory system.

MF=15 Continuous Photon Energy Spectra
MT=3
Calculated with the GNASH code/8/.
MT=102
Calculated with the GNASH code/8/ and modified by using the gamma-ray intensity data in ENSDF/10/ below thermal energy.

References
1) Holden N.E., Martin R.L. and Barnes I.L. : Pure & Appl. Chem. 56, 675 (1984).
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6) Igarasi S. : J. Nucl. Sci. Technol. 12, 67 (1975).
7) Paulsen A. : Nucl. Sci. Eng. 78, 377 (1981).
8) Young P.G. and Arthur E.D. : LA-6947 (1977).
9) Morgan G.L. et al. : ORNL/TM-5098 (1976).
10) Evaluated Nuclear Structural Data File.

MAT number = 3241

24-Cr- 50 NEDAC Eval-Mar87 T.Asami(NEDAC)
Dist-Sep89

History
87-03 New evaluation was made to give a full revision for JENDL-2 data.
88-12 MF/MT=3/107 modified.

MF=1 General Information
MT=451 Descriptive data and dictionary

MF=2 Resonance Parameters
MT=151 Resolved resonance parameters
Resolved parameters for MLBW formula were given in the energy region from 1.0E-5 eV to 300 keV.
Evaluated based on the experimental data of Stieglitz+71/1/, Beer+74/2/, Allen+77/3/, Kenny+77/4/ and Brusegan+86/5/.
Effective scattering radius = 5.0 fm/6/.

Calculated 2200 m/s cross sections and resonance integral.

	2200 m/s cross section(b)	res. integral(b)
elastic	2.31	
capture	15.9	7.41
total	18.2	

MF=3 Neutron Cross Sections
Below 300 keV, zero background cross section was given.
Above 300 keV, the total and partial cross sections were given pointwise.

MT=1 Total
Optical and statistical model calculation was made with the CASTHY code/7/. The optical potential parameters used are:

V = 46.78 - 0.262•En, Vso = 7.0 (MeV)
Ws = 4.87 + 0.352•En, Wv = 0 (MeV)
r = 1.30, rs = 1.40, rso = 1.30 (fm)
a = 0.55, aso = 0.48, b = 0.40 (fm)

MT=2 Elastic scattering
Obtained by subtracting the sum of the partial cross sections from the total cross section.

MT=4, 51-55, 91 Inelastic scattering
Calculated with the CASTHY code/7/, taking account of the contribution from the competing processes and using the discrete level data/8/ shown below.
The contributions from the direct process for inelastic scattering were calculated with the DWUCK code/9/. The deformation parameters used in the calculation were assumed based on Peterson's data/10/.

	Level energy(MeV)	Spin-parity
g.s.	0.0	0+
1	0.7833	2+
2	1.8814	4+
3	2.9245	2+
4	3.1611	2+
5	3.1641	6+

6	3.3247	4+
7	3.5946	4+
8	3.6101	4+
9	3.6295	1+
10	3.6940	0+
11	3.6978	2-
12	3.7924	5+
13	3.8261	6+
14	3.8443	3+
15	3.8500	0+
16	3.8752	6+
17	3.8953	2+
18	3.8983	4+
19	3.9377	3+
20	4.0517	0+

Levels above 4.066 MeV were assumed to be overlapping.
The calculated data for the inelastic scattering were finally lumped for the convenience on the construction of the elemental data, as follows:

MT no.	Level energy(MeV)	Lumping of level
51	0.7833	1
52	1.8814	2
53	2.9245	3
54	3.1611	4-5
55	3.3247	6
91	3.5946	over 7

MT=16 (n,2n)
Evaluated mainly based on the experimental data of Bormann /11/.

MT=22 (n,na)
Calculated with the GNASH code/12/.

MT=28 (n,np)
Calculated with the GNASH code/12/.

MT=102 Capture
Calculated with the CASTHY code/7/ and normalized at 50 keV to so as to reproduce the element data of 10 mb.

MT=103 (n,p)
Calculated with the GNASH code/12/.

MT=107 (n,a)
Calculated with the GNASH code/12/ and normalized at 14.8 MeV in referring to Grimes's data/13/. The data near the threshold were modified in referring to the experimental data for the element Cr(n,alpha)/14/.

MT=251 Mu-bar
Calculated with optical model.

MF=4 Angular Distributions of Secondary Neutrons

MT=2 Elastic scattering
Calculated with the CASTHY code/7/.

MT=51-55 Inelastic scattering
Calculated with the CASTHY code/7/ and the DWUCK code/9/.

MT=91 Inelastic scattering
Calculated with the CASTHY code/7/.

MT=16, 22, 28 (n,2n), (n,na), (n,np)
Assumed to be isotropic in the laboratory system.

MF=5 Energy Distributions of Secondary Neutrons
MT=16, 22, 28, 91
Calculated with the GNASH code/12/.

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MAT number = 3242

24-Cr- 52 NEDAC Eval-Mar87 T.Asami(NEDAC)
Dist-Sep89

History
87-03 New evaluation was made to give a full revision for JENDL-2 data.
88-12 MF/MT=3/107 modified.

MF=1 General Information
MT=451 Descriptive data and dictionary

MF=2 Resonance Parameters
MT=151 Resolved resonance parameters
Resolved parameters for MLBW formula were given in the energy region from 1.0E-5 eV to 300 keV.
Evaluated mainly based on the experimental data of Stieglitz+71/1/, Beer+74/2/, Allen+77/3/, Kenny+77/4/, Agrawal+84/5/ and Brusegan+86/6/
Effective scattering radius = 5.2 fm /7/

calculated 2200 m/s cross sections and resonance integral

	2200 m/s cross section(b)	res. integral(b)
elastic	2.96	
capture	0.76	0.46
total	3.72	

MF=3 Neutron Cross Sections
Below 300 keV, zero background cross section was given.
Above 300 keV, the total and partial cross sections were given pointwise.

MT=1 Total
Optical and statistical model calculation was made with the CASTHY code/8/. The optical potential parameters used are:

$V = 46.78 - 0.262 \cdot En$, $Vso = 7.0$ (MeV)
$Ws = 4.87 + 0.352 \cdot En$, $Wv = 0$ (MeV)
$r = 1.30$, $rs = 1.40$, $rso = 1.30$ (fm)
$a = 0.55$, $aso = 0.48$, $b = 0.40$ (fm)

MT=2 Elastic scattering
Obtained by subtracting the sum of the partial cross sections from the total cross section.

mt=4, 51-66, 91 inelastic scattering
Calculated with the CASTHY code/8/, taking account of the contribution from the competing processes and using the discrete level data/9/ shown below.
The contributions from the direct process for inelastic scattering were calculated with the DWUCK code/10/. The deformation parameters used in the calculation were assumed based on a weak coupling model.

	Level energy(MeV)	Spin-parity
g.s.	0.0	0+
1	1.4341	2+
2	2.3696	4+
3	2.6470	0+

4	2.7677	4+
5	2.9648	2+
6	3.1138	6+
7	3.1617	2+
8	3.4152	4+
9	3.4722	3+
10	3.6158	5+
11	3.7000	2+
12	3.7717	2+
13	3.9460	4+
14	3.9512	1+
15	4.0154	5+
16	4.0380	4+
17	4.5630	3-
18	4.6270	5+
19	4.7060	2+
20	4.7410	2+
21	4.7507	8+
22	4.7940	0+
23	4.8045	6+

Levels above 4.816 MeV were assumed to be overlapping.
The calculated data for the inelastic scattering were finally lumped for the convieneince on the construction of the element data, as follows:

MT no.	Level energy(MeV)	Lumping
51	1.4341	1
52	2.3696	2
53	2.6470	3
54	2.7677	4
55	2.9648	5
56	3.1138	6
57	3.1617	7
58	3.4152	8
59	3.4722	9
60	3.6158	10
61	3.7000	11
62	3.7717	12
63	3.9460	13-14
64	4.0154	15-16
65	4.5630	17
66	4.6270	18
91	4.7060	over 19

MT=16 (n,2n)
Adopted were the evaluated data in JENDL-2 which have been evaluated based on the experimental data of Wenusch+62/11/, Bormann+68/12/, Maslov+72/13/, Qaim72/14/, Sailer+77/15/ and Ghorai+87/16/.

MT=22 (n,na)
Calculated with the GNASH code/17/ and normalized.

MT=28 (n,np)
Calculated with the GNASH code/17/ and normalized.

MT=102 Capture
Calculated with the CASTHY code/8/ and normalized to 28.5 mb at 50 keV so as to reproduce the element data of 10 mb

MT=103 (n,p)
Calculated with the GNASH code/17/ and normalized at 14.8 MeV to the recommended value of Forrest/18/.

MT=107 (n,a)
Calculated with the GNASH code/17/ and normalized at 14.8 MeV to the average values of the experimental data/19/,/20/. The data were modified near the threshold in referring to the the experimental data of Paulsen /21/ for the element Cr(n,alpha).

MT=251 Mu-bar
Calculated with optical model.

MF=4 Angular Distributions of Secondary Neutrons

MT=2 Elastic scattering
Calculated with the CASTHY code/8/.

MT=51-66 Inelastic scattering
Calculated with the CASTHY code/8/ and the DWUCK code/10/.

MT=91 Inelastic scattering
Calculated with the CASTHY code/8/.

MT=16, 22, 28 (n,2n), (n,na), (n,np)
Assumed to be isotropic in the laboratory system

MF=5 Energy Distributions of Secondary Neutrons

MT=16, 22, 28, 91
Calculated with the GNASH code/17/.

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MAT number = 3243

24-Cr- 53 NEDAC Eval-Mar87 T.Asami(NEDAC)
Dist-Sep89

History
87-03 New evaluation was made to give a full revision for JENDL-2 data.
88-12 MF/MT=3/107 modified.

MF=1 General Information
MT=451 Descriptive data and dictionary

MF=2 Resonance Parameters
MT=151 Resolved resonance parameters
Resolved parameters for MLBW formula were given in the energy region from 1.0E-5 eV to 120 keV.
Evaluated based on the experimental data of Stieglitz+71/1/, Beer+74/2/, Allen+77/3/, Kenny+77/4/, Brusegan+86/5/ and Mueller+71/6/.
Effective scattering radius = 5.4 fm/7/.

Calculated 2200 m/s cross sections and resonance integral.

	2200 m/s cross section(b)	res. integral(b)
elastic	7.78	
capture	18.2	8.61
total	25.9	

MF=3 Neutron Cross Sections
Below 120 keV, no background cross section was given.
Above 120 keV, the total and partial cross sections were given pointwise.
MT=1 Total
Optical and statistical model calculation was made with the CASTHY code/8/. The optical potential parameters used are:
V = 46.78 - 0.262*En, Vso = 7.0 (MeV)
Ws = 4.87 + 0.352*En, Wv = 0 (MeV)
r = 1.30, rs = 1.40, rso = 1.30 (fm)
a = 0.55, aso = 0.48, b = 0.40 (fm)
MT=2 Elastic scattering
Obtained by subtracting the sum of the partial cross sections from the total cross section.

MT=4, 51-63, 91 Inelastic scattering
Calculated with the CASTHY code/8/, taking account of the contribution from the competing processes and using the discrete level data/9/ shown below.
The contributions from the direct process for inelastic scattering were calculated with the DWUCK code/10/. The deformation parameters used in the calculation were assumed based on a weak coupling model.

	Level energy(MeV)	Spin-parity
g.s.	0.0	3/2-
1	0.5640	1/2-
2	1.0063	5/2-
3	1.2895	7/2-
4	1.5366	7/2-

5	1.9736	5/2-
6	2.1724	11/2-
7	2.2330	9/2-
8	2.3208	3/2-
9	2.4531	3/2-
10	2.6570	5/2-
11	2.6695	1/2-
12	2.7065	13/2-
13	2.7080	3/2-
14	2.7720	5/2-
15	2.8266	11/2-
16	2.9930	7/2-
17	3.0841	15/2-
18	3.0930	5/2-
19	3.1380	5/2-
20	3.1703	3/2-
21	3.2439	11/2-
22	3.2610	5/2-

Levels above 3.435 MeV were assumed to be overlapping.
The calculated data for the inelastic scattering were finally lumped for the convenieince on the construction of the element data, as follows:

MT no.	Level energy(MeV)	Lumping
51	0.5640	1
52	1.0063	2
53	1.2895	3
54	1.5366	4
55	1.9736	5
56	2.1724	6
57	2.2330	7
58	2.3208	8
59	2.4531	9
60	2.6570	10-13
61	2.7720	14
62	2.8266	15
63	2.9930	16
91	2.9930	over 17

MT=16 (n,2n)
Calculated with the GNASH code/11/.
MT=22 (n,na)
Calculated with the GNASH code/11/ and normalized.
MT=28 (n,np)
Calculated with the GNASH code/11/ and normalized.
MT=102 Capture
Calculated with the CASTHY code/7/ and normalized at 50 keV to reproduce the element data of 10 mb.
MT=103 (n,p)
Below 9 MeV, evaluated based on the experimental data of Smith/12/.
Above 9 MeV, calculated with the GNASH code/12/ and normalized so as to be connected with the Smith's experimental data/12/.
MT=107 (n,a)
Calculated with the GNASH code/12/ and normalized at 14.7 MeV to Dolja's experimental data/13/. The data near threshold were modified in referring to the experimental data for the element

Cr(n,alpha)/14/.
MT=251 Mu-bar
Calculated with optical model.

MF=4 Angular Distributions of Secondary Neutrons
MT=2 Elastic scattering
Calculated with the CASTHY code/8/.
MT=51-63 Inelastic scattering
Calculated with the CASTHY code/8/ and the DWUCK code/10/.
MT=91 inelastic scattering
Calculated with the CASTHY code/8/.
MT=16, 22, 28 (n,2n), (n,na), (n,np)
Assumed to be isotropic in the laboratory system.

MF=5 Energy Distributions of Secondary Neutrons
MT=16, 22, 28, 91
Calculated with the GNASH code/11/.

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MAT number = 3244

24-Cr- 54 NEDAC Eval-Mar87 T.Asami(NEDAC)
Dist-Sep89

History
87-03 New evaluation was made to give a full revision for
JENDL-2 data.

MF=1 General Information
MT=451 Descriptive data and dictionary

MF=2 Resonance Parameters
MT=151 Resolved resonance parameters
Resolved parameters for MLBW formula were given in
the energy region from 1.0E-5 eV to 300 keV.
Evaluated based on the experimental data of Stieglitz+71/1/,
Beer+74/2/, Allen+77/3/, Kenny+77/4/ and Brusegan+86/5/.
Effective scattering radius = 5.3 fm/6/.

Calculated 2200 m/s cross sections and resonance integral

	2200 m/s cross section(b)	res. integral(b)
elastic	2.54	
capture	0.36	0.18
total	2.90	

MF=3 Neutron Cross Sections
Below 300 keV, no background cross section was given.
Above 300 keV, the total and partial cross sections were given
pointwise.

MT=1 Total
Optical and statistical model calculation was made with
the CASTHY code/7/. The optical potential parameters used are:

V = 46.78 - 0.262•En, Vso = 7.0 (MeV)
Ws = 4.87 + 0.352•En, Wv = 0 (MeV)
r = 1.30, rs = 1.40, rso = 1.30 (fm)
a = 0.55, aso = 0.48, b = 0.40 (fm)

MT=2 Elastic scattering
Obtained by subtracting the sum of the partial cross sections
from the total cross section.

MT=4, 51-60, 91 Inelastic scattering
Calculated with the CASTHY code/7/, taking account of the contribution from the competing processes and using the discrete
level data/8/ shown below.
The contributions from the direct process for inelastic scattering were calculated with the DWUCK code/9/. The deformation
parameters used in the calculation were assumed based on a
weak coupling model.

	Level energy(MeV)	Spin-parity
g.s.	0.0	0+
1	0.8349	2+
2	1.8237	4+
3	2.6195	2+
4	2.8294	0+
5	3.0739	2+
6	3.1600	2+
7	3.2225	6+

8	3.3920	1+
9	3.4366	2+
10	3.4680	1+
11	3.5140	2+
12	3.6552	4+
13	3.7198	2+
14	3.7858	4+
15	3.7989	4+
16	3.8640	2+
17	3.9340	1+
18	3.9900	3+
19	4.0160	0+
20	4.0450	6+
21	4.0832	4+

Levels above 4.088 MeV were assumed to be overlapping.
The calculated data for the inelastic scattering were finally lumped for the convenience on the construction of the element data, as follows:

MT no.	Level energy(MeV)	Lumping
51	0.8349	1
52	1.8237	2
53	2.6195	3
54	2.8294	4
55	3.0739	5
56	3.1600	6
57	3.2225	7
58	3.3920	8
59	3.4366	9
60	3.4680	10
91	3.5140	over 11

MT=16 (n,2n)
Calculated with the GNASH code/10/.
MT=22 (n,na)
Calculated with the GNASH code/10/ and normalized.
MT=28 (n,np)
Calculated with the GNASH code/10/ and normalized.
MT=102 Capture
Calculated with the CASTHY code/7/ and normalized at 50 keV so as to reproduce the element data of 10 mb.
MT=103 (n,p)
Calculated with the GNASH code/10/ and normalized at 14.7 MeV to an average value of the experimental data/11/-/13/.
MT=107 (n,a)
Calculated with the GNASH code/10/ and normalized at 14.8 MeV to an average value of the experimental data/12/-/14/.
MT=251 Mu-bar
Calculated with optical model.

MF=4 Angular Distributions of Secondary Neutrons
MT=2 Elastic scattering
Calculated with the CASTHY code/7/.
MT=51-60 Inelastic scattering
Calculated with the CASTHY code/7/ and the DWUCK code/9/.
MT=91 Inelastic scattering
Calculated with the CASTHY code/7/.

MT=16, 22, 28 (n,2n), (n,na), (n,np)
Assumed to be isotropic in the laboratory system.

MF=5 Energy Distributions of Secondary Neutrons
MT=16, 22, 28, 91
Calculated with the GNASH code/10/.

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MAT number = 3251

25-Mn- 55 JAERI,MAPI Eval-Mar87 K.Shibata,T.Hojuyama
Dist-Sep89

History
87-03 Resonance parameters were evaluated by T.Hojuyama (MAPI).
Multistep Hauser-Feshbach calculations were performed by K.Shibata (JAERI).
88-01 Compiled by K.Shibata (JAERI).
88-03 Covariance data added

MF=1 General Information
MT=451 Descriptive data and dictionary

MF=2 Resonance Parameters
MT=151 Resolved resonance parameters for MLBW formula
The parameters of the lowest four resonances were taken from the work of Macklin /1/. Others were taken from the compilation of Mughabghab et al./2/ except that the parameters of two negative resonances were adjusted so as to fit to experimental thermal cross sections.
Resonance region : 1.0E-5 eV to 100 keV.
Scattering radius: 5.15 fm
Calculated 2200-m/s cross sections and res. integrals

	2200-m/s	res. integ.
elastic	2.167 b	-
capture	13.413 b	11.79 b
total	15.579 b	-

MF=3 Neutron Cross Sections
MT=1 Total
Below 100 keV : No background
Above 100 keV : Based on the experimental data /3,4,5/.
MT=2 Elastic scattering
(Total) (Nonelastic cross section)
MT=3 Non elastic
Sum of MT=4, 16, 22, 28, 102, 103, 104, 105, 106 and 107
MT=4,51-79,91 Inelastic scattering
Statistical-model calculations were performed using the TNG code /6/. The precompound process was considered above 5 MeV. The calculated cross section of MT=51 was multiplied by a factor of 1.2.
For the levels of MT=51,52,57,61,64,65,67,70, the direct process components were taken into account by the DWBA calculations.
The optical potential parameters used are as follows/7/ (in the units of MeV and fm):

V = 49.747 - 0.4295•E - 0.0003•E••2 r0 = 1.287 a0 = 0.56
Ws = 11.2 - 0.09•E rs = 1.345 as = 0.47
Vso= 6.2 rso= 1.120 aso = 0.47

The level scheme was taken from Ref./8/.

No.	Energy(MeV)	Spin-Parity
g.s.	0.0	5/2 -
1.	0.126	7/2 -
2.	0.984	9/2 -
3.	1.290	1/2 -
4.	1.292	11/2 -

5.	1.293	1/2 -
6.	1.528	3/2 -
7.	1.884	7/2 -
8.	2.015	7/2 -
9.	2.198	7/2 -
10.	2.215	5/2 -
11.	2.252	3/2 -
12.	2.267	5/2 -
13.	2.312	13/2 -
14.	2.366	5/2 -
15.	2.398	9/2 +
16.	2.427	1/2 +
17.	2.563	3/2 -
18.	2.727	7/2 -
19.	2.753	5/2 -
20.	2.822	9/2 -
21.	2.824	5/2 -
22.	2.873	1/2 -
23.	2.954	3/2 -
24.	2.976	3/2 -
25.	2.992	7/2 -
26.	3.006	3/2 -
27.	3.036	11/2 -
28.	3.038	1/2 -
29.	3.040	3/2 +

Levels above 3.046 MeV were assumed to be overlapping.

MT=16,22,28,103,107 (n,2n),(n,n'a),(n,n'p),(n,p) and (n,a) cross sections
Calculated with TNG.
Global optical-potential parameters were employed for protons and alpha-particles /9,10/.

MT=102 Radiative capture cross section
Below 100 keV : Resonance parameters given (no background)
Above 100 keV : Based on the experimental data /11/-/15/.

MT=104 (n,d) cross section
The excitation function of the (n,p) cross section calculated with TNG was used for the (n,d) reaction by shifting the threshold energy. The cross sections were normalized to the experimental datum at 14.1 MeV /16/.

MT=105 (n,t) cross section
The excitation function of the (n,p) cross section calculated with TNG was used for the (n,t) reaction by shifting the threshold energy. The cross sections were normalized to the experimental datum at 14.7 MeV /17/.

MT=106 (n,He-3) cross section
Based on the experimental data /18,19/.

MT=251 Mu-bar
Calculated from File-4.

MF=4 Angular Distributions of Secondary Neutrons

MT=2,51-79
Optical and statistical-model calculations
The components of the direct process were added to the levels of MT=51,52,57,61,64,65,67,70 by the DWBA calculations.
MT=16, 22, 28, 91
Assumed to be isotropic in the laboratory system

MF=5 Energy Distributions of Secondary Neutrons
MT=16, 22, 28, 91
Calculated with TNG.

MF=12 Photon Production Multiplicities
MT=4,16,22,28,102,103,107
Calculated with TNG.
For MT=102, modified by using gamma-ray intensity data in ENSDF below thermal energy.

MF=14 Photon Angular Distributions
MT=4,16,22,28,102,103,107
Assumed to be isotropic.

MF=15 Photon Energy Distributions
MT=4,16,22,28,102,103,107
Calculated with TNG.
For MT=102, modified by using gamma-ray intensity data in ENSDF below thermal energy.

MF=33 Covariance Data
MT=1,2,3,4,16,22,28,51-79,91,102,103,104,105,106,107
Estimated from experimental data.

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MAT number = 3260

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 26-Fe-  0 JNDC         Eval-Mar87 S.Iijima,H.Yamakoshi
                        Dist-Sep89
History
87-03  Evaluation was performed for JENDL-3.
87-05  Compiled by K.Shibata (JAERI).

Natural iron data constructed from Fe-isotopes.

MF=1  General Information
  MT=451  Descriptive data and dictionary

MF=2  Resonance Parameters
  MT=151 Resolved resonances
      Resonance region = 1.0E-5 eV to 250.0 keV
      The multilevel Breit-Wigner formula was used.  Parameters
      were adopted from the following sources.
         Fe-54 : Pandey+/1/ for 0 - 680 keV. R=5.6 fm
         Fe-56 : Perey+/2/ for -2.0 - 400 keV. R=5.4 fm from fit-
                 ting to total cross section below 60 keV.
                 Parameters of the 1.15 keV resonance were
                 taken from the result of the NEANDC task
                 force /3/.
         Fe-57 : Allen+/4/ for s-wave resonances, and Beer+/5/
                 for p-wave resonances in 0 - 185 keV.
         Fe-58 : Mughabghab+/6/.
      For Fe-56, a negative level was added at -3.75 keV with
      neutron width of 100 eV and gamma width of 1.0 eV.  Neutron
      width of 27.67-keV resonance was taken as 1420 eV.

      Calculated 2200-m/s cross sections and res. integrals.
                     2200-m/s      res. integ.
         elastic     11.36  b          -
         capture      2.56  b        1.340 b
         total       13.92  b          -

MF=3  Neutron Cross Sections
      Below 250 keV, background cross sections were given.

  MT=1    Total
      For energies 250 keV - 20 MeV, fine resolution data were
      taken by eye-guide using interactive display of NDES (
      Neutron Data Evaluation System) developed by T.Nakagawa at
      the Nuclear Data Center, JAERI.  Below 4 MeV, data of
      Carlson+/7/ were adopted.  Above 4 MeV, data of Cierjacks+
      /8/ were adopted.
  MT=2    Elastic scattering
      Given as total minus nonelastic cross sections
  MT=3    Nonelastic
      Sum of MT=4,16,22,28,102,103,107
  MT=16,22,28,103
      Calculated using GNASH /9/.
  MT=4,51-75,91  Inelastic scattering
      Isotopic data were obtained from the CASTHY/10/ and GNASH
      calculations.  Isotopic levels were grouped into 25
      levels of natural element.  The contributions from the
```

direct process were included in the levels of MT=55,58, 61,63,64,65,70,73,74.
Optical potential parameters used in the calculation are as follows:

```
V   = 46.0-0.25*E          , r0=1.286, a0=0.620
Ws  = 14.0-0.2*E           , rs=1.390, as=0.700
      14.8-0.2*E for Fe-57
Vso= 6.0                   , rso=1.07 ,aso=0.620
  Energies in MeV unit, lengths in fm unit.
```

MT=102 Capture
Background cross section was given below 250 keV.
Above 250 keV, the CASTHY calculation was adopted.

MT=107 (n,alpha)
For Fe-56, the evaluation was made on the basis of experimental data. For Fe-54,57,58, the GNASH calculation was adopted.

MT=251 Mu-bar
Calculated with CASTHY /10/.

MF=4 Angular Distributions of Secondary Neutrons

MT=2,51-75
Optical and statistical-model calculations.
The C.C. calculations were added to the levels of MT=55, 58,61,63,64,65,70,73,74.

MT=16,22,28,91
Assumed to be isotropic in the laboratory system.

MF=5 Energy Distributions of Secondary Neutrons

MT=16,22,28,91
Calculated with GNASH.

MF=12 Photon Multiplicities

MT=3,51,52,102
Multiplicities were calculated using GNASH.
For MT=102, modified by using gamma-ray intensity data in ENSDF below thermal energy.

MF=14 Photon Angular Distributions

MT=3,51,52,102
Assumed to be isotropic.

MF=15 Photon Energy Distributions

MT=3,102
Below 600 keV, based on the data of Igashira et al./11/.
Above 600 keV, calculated with GNASH.
For MT=102, modified by using gamma-ray intensity data in ENSDF below thermal energy.

References
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2) Perey F.G. et al.: Proc. Specialist Meeting on Neutron Data of Structural Materials for Fast Reactors, Geel, (1977), p.530.
3) Nakajima Y.: JAERI-M 85-035, p.196 (1985).
4) Allen B.J. et al.: Proc. Specialist Meeting on Neutron Data

of Structural Materials for Fast Reactors, Geel, (1977), p.476.
5) Beer H. and Spencer R.R.: KfK-2063 (1974).
6) Mughabghab S.F. et al.: "Neutron Cross Sections, Vol. 1, Part A", Academic Press (1981).
7) Carlson A.D. and Cerbone R.J.: Nucl. Sci. Eng., 42, 28 (1970).
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9) Young P.G. and Arthur E.D.: LA-6947 (1977).
10) Igarasi S. : J. Nucl. Sci. Technol., 12, 67 (1975).
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MAT number = 3261

```
 26-Fe- 54 JNDC         Eval-Mar87 S.Iijima,H.Yamakoshi
                        Dist-Sep89
History
87-03  Evaluation was performed for JENDL-3.
87-05  Compiled by K.Shibata (JAERI).

MF=1  General Information
  MT=451  Descriptive data and dictionary

MF=2  Resonance Parameters
  MT=151 Resolved resonances
      Resonance region = 1.0E-5 eV to 250.0 keV
      The multilevel Breit-Wigner formula was used.  Parameters
      were adopted mainly from Pandey+/1/ by assuming the average
      radiative width to be 2.5 eV /2/.  R=5.6 fm was taken from
      Ref. /3/.

      Calculated 2200-m/s cross sections and res. integrals.
                         2200-m/s      Res. Integ.
         elastic          0.4929 b        -
         capture          2.156 b       1.33 b
         total            2.649 b         -

MF=3  Neutron Cross Sections
      Below 250 keV, background cross sections were given for the
      total and elastic scattering cross sections on the upper
      side of the first resonance.  Above 250 keV, the cross
      sections were evaluated as follows.
  MT=1    Total
      Spherical optical model calculation was made by using code
      CASTHY /4/.  Optical potential parameters are as follows:
           V   = 46.0-0.250*E           , r0=1.286, a0=0.620
           Ws  = 14.00-0.200*E          , rs=1.390, as=0.700
           Vso= 6.00                    , rso=1.070,aso=0.620
                 (energies in MeV, lengths in fm)
  MT=2    Elastic scattering
      Given as total minus other cross sections
  MT=3    Nonelastic
      Sum of MT=4,16,22,28,102,103,107.
  MT=16,22,28 (n,2n),(n,n'a),(n,n'p)
      Calculated using the GNASH code /5/.
  MT=4,51-69,91  Inelastic scattering
      Below 7 MeV, the cross sections were calculated using
      CASTHY with width fluctuation corrections.
      Above 7 Mev, the GNASH calculation was performed.
      For MT=51,52,53,54,59,68, the direct process
      component was considered by the C.C. theory.

      Level scheme is given as follows:

         No.      Energy(MeV)  Spin-Parity
         g.s.        0.0          0 +
          1.         1.4082       2 +
          2.         2.5382       4 +
          3.         2.5613       0 +
```

4.	2.9499	6 +
5.	2.9590	2 +
6.	3.1661	2 +
7.	3.2952	4 +
8.	3.3450	3 −
9.	3.8338	4 +
10.	4.0330	4 +
11.	4.0472	4 +
12.	4.0720	3 +
13.	4.2632	4 +
14.	4.2961	0 +
15.	4.5980	2 +
16.	4.6550	2 +
17.	4.7000	3 +
18.	4.7800	3 −
19.	4.9490	4 +

Continuum levels were assumed above 5.145 MeV.

MT=102 Capture
CASTHY calculation was adopted.
MT=103 (n,p)
Below 2.5 MeV, based on the data of Paulsen and Widera/6/.
Between 2.5 and 10 MeV, based on the data of Smith and Meadows/7/.
Above 10 MeV, calculated with GNASH.
MT=107 (n,alpha)
GNASH calculation multiplied by 0.94.
MT=251 Mu-bar
Calculated with CASTHY /4/.

MF=4 Angular Distributions of Secondary Neutrons
MT=2,51-69
Optical and statistical-model calculation.
For MT=51,52,53,54,59,68, the direct-process component was taken into account by the C.C. theory.
MT=16,22,28,91
Assumed to be isotropic in the laboratory system.

MF=5 Energy Distributions of Secondary Neutrons
MT=16,22,28,91
Calculated with GNASH.

MF=12 Photon Multiplicities and Transition Probability Arrays
MT=16,22,28,91,102,103,107
Multiplicities were calculated with GNASH.
MT=51-69
Transition probability arrays

MF=14 Photon Angular Distributions
MT=16,22,28,51-69,91,102,103,107
Assumed to be isotropic.

MF=15 Photon Energy Distributions
MT=16,22,28,91,102,103,107
Calculated with GNASH.

References

1) Pandey M.S. et al.: Proc. Conf. Nuclear Cross Sections and Technology, Washington D.C., (1975), p.748.
2) Spencer R.R. and Beer H.: KfK 2046, 79 (1975).
3) Mughabghab S.F. and Garber D.I.: BNL 325, 3rd Ed. Vol. 1 (1973).
4) Igarasi S. : J. Nucl. Sci. Technol., 12, 67 (1975).
5) Young P.G. and Arthur E.D.: LA-6974 (1977).
6) Paulsen A. and Widera R.: Proc. Conf. Chemical Nuclear Data, Measurements and Application, Canterbury, 1971.
7) Smith D.L. and Meadows J.W.: Nucl. Sci. Eng., 58, 314 (1975).

MAT number = 3262

26-Fe- 56 JNDC Eval-Mar87 S.Iijima,H.Yamakoshi
Dist-Sep89

History
87-03 Evaluation was performed for JENDL-3.
87-05 Compiled by K.Shibata (JAERI).

MF=1 General Information
MT=451 Descriptive data and dictionary

MF=2 Resonance Parameters
MT=151 Resolved resonances
Resonance region = 1.0E-5 eV to 250.0 keV
The multilevel Breit-Wigner formula was used. Parameters were adopted from the experimental data by Perey+ /1/. R=6.5 fm was selected to reproduce the 24-keV window cross section. Neutron width of 27.67-keV resonance was taken as 1420 eV. The parameters of the 1.15-keV resonance were taken from the result of the NEANDC task force /2/.

Calculated 2200-m/s cross sections and res. integrals.

	2200-m/s	Res. Integ.
elastic	12.46 b	-
capture	2.813 b	1.448 b
total	15.27 b	-

MF=3 Neutron Cross Sections
Below 250 keV, background cross sections were given for the total and elastic scattering cross sections.
Above 250 keV, cross sections were evaluated as follows.

MT=1 Total
Spherical optical model calculation was made by using CASTHY code /3/. Parameters are as follows,

V = 46.0-0.25*E , r0=1.286, a0=0.620
Ws = 14.0-0.20*E , rs=1.390, as=0.700
Vso= 6.0 , rso=1.07,aso=0.620
(energies in MeV, lengths in fm).

MT=2 Elastic scattering
Given as total minus nonelastic cross sections.

MT=3 Nonelastic
Sum of MT=4,16,22,28,102,103,107.

MT=16,22,28 (n,2n),(n,n'a),(n,n'p)
Calculated with GNASH /4/.

MT=4,51-77,91 Inelastic scattering
The CASTHY and GNASH calculations were adopted for neutron energies below and above 7 MeV, respectively. The direct-process component was considered for MT=51,52,53,54,77 by the C.C. theory.

The level scheme is given as follows:

No.	Energy(MeV)	Spin-Parity
g.s.	0.0	0 +
1.	0.8468	2 +
2.	2.0851	4 +
3.	2.6576	2 +
4.	2.9417	0 +

5.	2.9600	2 +
6.	3.1200	1 +
7.	3.1229	4 +
8.	3.3702	2 +
9.	3.3884	6 +
10.	3.4454	3 +
11.	3.4493	1 +
12.	3.6009	2 +
13.	3.6019	2 +
14.	3.6070	0 +
15.	3.7480	2 +
16.	3.7558	6 +
17.	3.8320	2 +
18.	3.8565	3 +
19.	4.0940	3 +
20.	4.1003	3 +
21.	4.1200	4 +
22.	4.2982	4 +
23.	4.3020	0 +
24.	4.3950	3 +
25.	4.4010	2 +
26.	4.4584	3 +
27.	4.5100	3 −

Continuum levels were assumed above 4.701 MeV.

MT=102 Capture
Below 250 keV, no background.
The CASTHY calculation was adopted

MT=103 (n,p)
Below 7 MeV, based on the data of Smith and Meadows/5/.
7 − 13 MeV, taken from JENDL-2.
13 − 16 MeV, based on the data of Ikeda et al./6/
16 − 20 MeV, taken from JENDL-2.

MT=107 (n,alpha)
Based on experimental data.

MT=251 Mu-bar
Calculated with CASTHY /3/.

MF=4 Angular Distributions of Secondary Neutrons

MT=2,51-77
Optical and statistical-model calculations were adopted.
The C.C. calculations were added to the levels of MT=51,52,53,54,77.

MT=16,22,28,91
Assumed to be isotropic the laboratory system.

MF=5 Energy Distributions of Secondary Neutrons

MT=16,22,28,91
Calculated with GNASH.

MF=12 Photon Multiplicities and Transition Probability Arrays

MT=16,22,28,91,102,103,107
Multiplicities were calculated with GNASH.

MF=14 Photon Angular Distributions

MT=16,22,28,51-77,91,102,103,107
Assumed to be isotropic.

MF=15 Photon Energy Distributions
MT=16,22,28,91,102,103,107
Calculated with GNASH.

References

1) Perey F.G. et al.: Proc. Specialist Meeting on Neutron Data of Structural Materials for Fast Reactors, Geel, (1977), p.530.
2) Nakajima Y.: JAERI-M 85-035, p. 196 (1985).
3) Igarasi S. : J. Nucl. Sci. Technol., 12, 67 (1975).
4) Young P.G. and Arthur E.D.: LA-6974 (1977).
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MAT number = 3263

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 26-Fe- 57 JNDC         Eval-Mar87 S.Iijima,H.Yamakoshi
                        Dist-Sep89
History
87-03  Evaluation was performed for JENDL-3.
87-05  Compiled by K.Shibata (JAERI)>

MF=1  General Information
  MT=451  Descriptive data and dictionary

MF=2  Resonance Parameters
  MT=151 Resolved resonances
      Resonance region = 1.0E-5 eV to 200.0 keV
      The multilevel Breit-Wigner formula was used. Parameters
      were adopted from Allen+/1/ for s-wave resonances, and
      Beer+/2/ for p-wave resonances in 0 - 185 keV.

      Calculated 2200-m/s cross sections and res. integrals
                        2200-m/s      Res. Integ.
         elastic         0.2021 b         -
         capture         2.462 b        1.43 b
         total           2.664 b          -

MF=3  Neutron Cross Sections
      Below 200 keV, background cross section was given for
      the total and capture cross sections.
      Above 200 keV, the data were evaluated as follows.

  MT=1     Total
      Spherical optical model calculation was made with CASTHY
      code /3/.  Parameters are as follows,
           V   = 46.0-0.25*E                 , r0=1.286, a0=0.620
           Ws  = 14.08-0.20*E                , rs=1.390, as=0.700
           Vso= 6.00                         , rso=1.07,aso=0.620
                 (energies in MeV unit, lengths in fm unit)
  MT=2     Elastic scattering
      Given as total minus nonelastic cross sections
  MT=3     Nonelastic
      Sum of MT=4,16,22,28,102,103,107.
  MT=16,22,28,103,107  (n,2n),(n,n'a),(n,n'p),(n,p),(n,a)
      Calculated with GNASH /4/.
  MT=4,51-71,91  Inelastic scattering
      The CASTHY and GNASH calculations were adopted for
      neutron energies below and above 7 MeV, respectively.
      The level scheme used is given as follows:
         No.       Energy(MeV)   Spin-Parity
         g.s         0.0         1/2 -
          1.         0.0144      3/2 -
          2.         0.1365      5/2 -
          3.         0.3668      3/2 -
          4.         0.7064      5/2 -
          5.         1.0072      7/2 -
          6.         1.1978      9/2 -
          7.         1.2654      1/2 -
          8.         1.3562      7/2 -
          9.         1.6273      3/2 -
```

10.	1.7254	3/2 -
11.	1.9893	9/2 -
12.	1.9910	1/2 -
13.	2.1180	5/2 -
14.	2.2189	5/2 +
15.	2.3300	1/2 -
16.	2.3560	11/2 -
17.	2.4560	9/2 +
18.	2.5053	5/2 +
19.	2.5643	3/2 -
20.	2.6000	5/2 +
21.	2.6974	1/2 -

Continuum levels were assumed above 2.76 MeV.

MT=102 Capture
Calculated with CASTHY.
MT=251 Mu-bar
Calculated with CASTHY.

MF=4 Angular Distributions of Secondary Neutrons
MT=2,51-71
CASTHY calculation
MT=16,22,28,91
Assumed to be isotropic in the laboratory system.

MF=5 Energy Distributions of Secondary Neutrons
MT=16,22,28,91
Calculated with GNASH.

MF=12 Photon Multiplicities and Transition Probability Arrays
MT=16,22,28,91,102,103,107
Multiplicities were calculated with GNASH.

MF=14 Photon Angular Distributions
MT=16,22,28,51-71,91,102,103,107
Assumed to be isotopic.

MF=15 Photon Energy Distributions
MT=16,22,28,91,102,103,107
Calculated with GNASH.

References
1) Allen B.J. et al.: Proc. Specialist Meeting on Neutron Data of Structural Materials for Fast Reactors, Geel, p. 476 (1977).
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MAT number = 3264

26-Fe- 58 JNDC Eval-Mar87 S.Iijima,H.Yamakoshi
Dist-Sep89

History
87-03 Evaluation was performed for JENDL-3.
87-05 Compiled by K.Shibata (JAERI).

MF=1 General Information
MT=451 Descriptive data and dictionary

MF=2 Resonance Parameters
MT=151 Resolved resonances
Resonance region = 1.0E-5 eV to 350.0 keV
The multilevel Breit-Wigner formula was used. Parameters were adopted from the recommended values by Mughabghab et al. /1/.

Calculated 2200-m/s cross sections and res. integrals.

	2200-m/s	res. integ.
elastic	4.433 b	-
capture	1.272 b	1.57 b
total	5.705 b	-

MF=3 Neutron Cross Sections
Below 350 keV, no background cross sections were given.
Above 350 keV, the data were evaluated as follows.

MT=1,4,51-62,91,102 Total, Inelastic and Capture
Calculated with optical and statistical model code CASTHY /2/. Optical potential parameters are as follows:
V = 46.0-0.25*En (MeV),
Ws = 14.0-0.2*En (MeV), Vso= 6.0 (MeV)
R = 1.286 (fm), a0 = 0.62 (fm)
Rs = 1.390 (fm), as = 0.7 (fm)
Rso= 1.07 (fm), aso= 0.62 (fm)

The level scheme used is given as follows:

No.	Energy(MeV)	Spin-Parity
g.s.	0.0	0 +
1.	0.8108	2 +
2.	1.6747	2 +
3.	2.0765	4 +
4.	2.1339	3 +
5.	2.2581	0 +
6.	2.6004	4 +
7.	2.7819	1 +
8.	2.8764	2 +
9.	3.0840	2 +
10.	3.1330	4 +
11.	3.2330	2 +
12.	3.2440	0 +

Levels above 3.389 MeV were assumed to be overlapping.
The capture cross section was normalized to 3 mb at 700 keV.

MT=2 Elastic
Total cross section - reaction cross section

MT=3 Nonelastic
Sum of MT=4,16,22,28,102,103,107.
MT=16,22,28,103,107 (n,2n),(n,n'a),(n,n'p),(n,p),(n,a)
Calculated with GNASH /3/.
MT=251 Mu-bar
Calculated with CASTHY /2/.

MF=4 Angular Distributions of Secondary Neutrons
MT=2,51-62
CASTHY calculation
MT=16,22,28,91
Assumed to be isotropic in the laboratory system.

MF=5 Energy Distributions of Secondary Neutrons
MT=16,22,28,91
Calculated with GNASH.

MF=12 Photon Multiplicities and Transition Probability Arrays
MT=16,22,28,91,102,103,107
Multiplicities were calculated with GNASH.

MF=14 Photon Angular Distributions
Assumed to be isotropic.

MF=15 Photon Energy Distributions
MT=16,22,28,91,102,103,107
Calculated with GNASH.

References
1) Mughabghab S.F. et al.: "Neutron Cross Sections, Vol. 1, Part A", Academic Press (1981).
2) Igarasi S. : J. Nucl. Sci. Technol., 12, 67 (1975).
3) Young P.G. and Arthur E.D.: LA-6974 (1977).

MAT number = 3271

```
 27-Co- 59 KHI          Eval-Aug88 T.Watanabe
                        Dist-Sep89
History
88-08  Newly evaluated by T.Watanabe
                                (Kawasaki Heavy Industries, Ltd.)

MF=1    General Information
  MT=451   Descriptive data and dictionary

MF=2
  MT=151   Resonance Parameters              : 1.0E-5 eV - 100 keV
       Resolved resonances for MLBW formula:
          Parameters were evaluated based on experimental data
          /1/,/2/,/3/ and modified to reproduce experimental
          total cross sections. Negative energy levels were added
          to reproduce 2200 m/s total and capture cross sections.

       Calculated 2200 m/s cross sections and resonance integrals
                        2200 m/sec        res. integ.
           elastic        6.0  b              -
           capture       37.18 b            75.6 b
           total         43.19 b              -

MF=3    Neutron Cross Sections                        : above 100 keV
  MT=1,2,4,51-74,91,102
          Total, elastic, inelastic and capture cross sections
          were calculated with optical and statistical model.
          Yamamuro's evaluation was adopted for direct inelastic
          cross section /4/.

       The spherical optical potential parameters were evaluated
          to reproduce experimental total cross sections /5/,/6/.
          V = 49.65 - 0.114*En MeV  r0= 1.241 fm  a0= 0.533 fm
          Ws= 8.625-0.05306*En MeV  rs= 1.421 fm  b = 0.292 fm
          Vso= 7.724 MeV            rso=1.151 fm  aso=0.7   fm

       Statistical model calculation with CASTHY code /7/ was
          performed. MT=102 capture cross section was guided by
          using experimental data /2/,/16/ above 100 keV.
          The direct inelastic cross sections were adjusted so
          as to fit to the experimental data /17/,/18/.

       The level scheme taken from ref./8/:
          no.        energy(MeV)   spin-parity
          g.s        0.0            7/2-
           1         1.099262       3/2-
           2         1.1905         9/2-          direct
           3         1.291611       3/2-
           4         1.434263       1/2-          direct
           5         1.4595        11/2-
           6         1.48161        5/2-
           7         1.7447         7/2-          direct
           8         2.0628         7/2-
           9         2.0883         5/2-
          10         2.1528         7/2-
```

11	2.183	7/2-	
12	2.205	5/2-	
13	2.3971	9/2-	direct
14	2.479	5/2-	

Continuum levels assumed above 2.54 MeV
Level density parameters were evaluated using D0, and level data /3/, /8/.

	a	T	Ex	sig**2(0)
27-Co-59	8.89	1.005	6.84	6.205
27-Co-60	8.673	1.037	5.804	7.899

MT=1 Total
100 keV - 4 MeV Based on experimental data /5/,/19/.
above 4 MeV Calculated

MT=2 Elastic scattering
Obtained by subtracting the sum of absorption and inelastic scattering from total cross section.

MT=16 (n,2n)
Guided by experimental data /9/,/10/,/11/,/12/ and Yamamuro's theoretical calculations /4/.

MT=103 (n,p)
Guided by experimental data /13/,/14/,/9/,/20/.

MT=107 (n,alpha)
JENDL-2 data were adopted with slight modification based on Evain's evaluation /15/ and experimental data /9/,/21/.

MT=22,28,51-64,91,104 (n,n alpha),(n,np),(n,d)
Yamamuro's evaluation was adopted /4/.

MT=251 Mu-bar
Calculated from the data in MF=4.

MF=4 Angular Distributions of Secondary Neutrons
MT=2 Optical model calculation.
MT=51-64 Yamamuro's evaluation was adopted.
MT=16,22,28,91 Isotropic in lab. system.

MF=5 Energy Distributions of Secondary Neutrons
MT=16,22,28,91 Yamamuro's evaluation was adopted.

References

1) Garg J.B. et al.: Nucl. Sci. Eng. 65,76 (1978).
2) Spencer R.R. and Macklin, R.L.: Nucl.Sci.Eng. 61,346 (1976).
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17) Corcalciuc V. et al.: Nucl. Phys. A307, 445 (1978).
18) Zhou Hongyu et al.: Proc. Int. Conf. Nuclear Data for Science and Technology, Mito, 1988, p.311, (1988).
19) Harvey J.A.: Taken from EXFOR (1986).
20) Hasan S.J. et al.: J. Phys. G12, 397 (1986).
21) Meadows J.W. et al.: Ann. Nucl. Energy 14, 603 (1987).

MAT number = 3280

28-Ni- 0 NAIG Eval-Mar87 S.Iijima
Dist-Sep89

History
87-03 Evaluation was performed for JENDL-3.
87-05 Compiled by K.Shibata (JAERI).

MF=1,MT=451 Comments and dictionary

MF=2,MT=151 Resolved resonance parameters : 1.0E-5 eV - 557 keV

Calculated 2200 m/s values and resonance integrals (barn):

	2200 m/s value	res.int.
total	22.241	-
elastic	17.859	-
capture	4.383	2.143

MF=3 Neutron Cross Sections
Background cross sections (BGCS) applied to resonance region.
MT=1,2,102

Cross sections above resonance region evaluated as follows :

MT=1 : Total cross section
Based on the high-resolution data of Larson+/1/.

MT=2 : Elastic scattering
(Total) - (Nonelastic cross sections).

MT=3 : Nonelastic cross section
Sum of MT=4,16,17,22,28,102,103,104,105,106,107,111.

MT=16,17,22,28,103,104,105,106,107,111: (n,2n),(n,3n),
(n,n'a),(n,n'p),(n,p),(n,d),(n,t),(n,He-3),(n,a),(n,2p)
Constructed from isotopic data.

MT=4,51-70,91 : Inelastic scattering
Isotopic levels were grouped into 20 levels of
natural element.
The contributions from the direct process were
taken into account for the levels of MT=56,59,60,
61,62,63,69,70.

MT=102 : Capture
Calculated with the statistical model code CASTHY /2/.

MT=251 : Mu-bar
Calculated with CASTHY /2/.

MF=4 Angular Distributions of Secondary Neutrons
MT=2 : Calculated with optical model.
MT=16,17,22,28,91 : Isotropic in laboratory system.
MT=51-70 : Calculated with CASTHY. The direct process
was considered for MT=56,59,60,61,62,63,69,
70.

MF=5 Energy Distributions of Secondary Neutrons
MT=16,17,22,28,91 : Constructed from isotopic data.

MF=12 Photon Multiplicities and Transition Probability Arrays
MT=102 : Multiplicities calculated with GNASH/3/ for Ni-58,60. Modified by using the measurements/5/ below thermal energy.

MF=13 Photon Production Cross Sections
MT=3 : Calculated with GNASH for Ni-58,60.

MF=14 Photon Angular Distributions
MT=3,102 : Isotropic

MF=15 Photon Energy Distributions
MT=3,102 : Calculated with GNASH
Experimental data of Igashira et al. /4/ included.
For MT=102, modified by using the measurements/5/ below thermal energy.

References

1) Larson D.C. et al.: ORNL-TM-8203 (1983).
2) Igarasi S.: J.Nucl.Sci.Technol.,12,67 (1975).
3) Young P.G. and Arthur E.D.: LA-6947 (1977).
4) Igashira M. et al.: Int. Conf. Nuclear Data for Science and Technology, Mito, May 30 - June 3, 1988.
5) Maerker R.E.: ORNL/TM-5203 (1976).

MAT number = 3281

```
 28-Ni- 58 NAIG       Eval-Mar87 S.Iijima
                      Dist-Sep89
History
87-03  Evaluation was performed for JENDL-3.
87-05  Compiled by K.Shibata (JAERI).

MF=1,MT=451   Comments and dictionary

MF=2,MT=151   Resolved resonance parameters : 1 0E-5 eV - 420 keV
       Evaluation based on the following data.
          s-wave resonance parameters from Syme+/1/
          p-wave resonance parameters from JENDL-2 and Syme+/1/
       Two negative resonances due to Perey+/2/ with
       modification:
          E = -50  keV   gamma-n = 28.0 keV   gamma-g = 0.0
          E = -6.5 keV   gamma-n = 1400  eV   gamma-g = 2.31 eV
       Scattering radius : 6.0 fm

      Calculated 2200 m/s values and resonance integrals (barn):
                          2200 m/s value       res. int.
          total             30.754                -
          elastic           26.251                -
          capture            4.503              2.161

MF=3  Neutron Cross Sections
  Background cross sections (BGCS) applied to resonance region.
     MT=1,102

  Cross sections above 420 keV evaluated as follows :

     MT=1 : Total cross section
        Between 420 keV to 677 keV, high-resolution
        experimental data were adopted.
        Calculated with optical model from 677 keV to 20 MeV.
        Potential parameters obtained by fitting nat-Ni data /3/:
          V =51.33 - 0.331*En ,Ws=8.068 + 0.112*En ,Vso=7.0 (MeV)
          r0=rso=1.24         ,rs=1.40                   (fm)
          a0=aso=0.541        ,as=0.4                    (fm)

     MT=2 : Elastic scattering
        (Total) - (Nonelastic cross sections).

     MT=2 : Nonelastic cross section
        Sum of MT=4,16,22,28,102,103,104,105,106,107,111.

     MT=16,28,103   (n,2n),(n,n'p),(n,p)
        Based on experimental data.

     MT=22,104,105,106,107,111  (n,n'a),(n,d),(n,t),(n,He-3),
      (n,a),(n,2p)
        The cross sections were calculated using the PEGASUS
        code /4/ and normalized to experimental data.

     MT=4,51-65,91     Inelastic scattering
        The CASTHY /5/ and GNASH /6/ calculations were adopted
```

for neutron energies below and above 7 MeV, respectively. The direct process was taken into account for MT=51,52, 53,55,65. For the level of MT=65, only the direct process was considered.
The level scheme used is given as follows:

No	Energy(MeV)	Spin-Parity
g.s	0.0	0 +
1.	1.4545	2 +
2.	2.4591	4 +
3.	2.7755	2 +
4.	2.9018	1 +
5.	2.9424	0 +
6.	3.0376	2 +
7.	3.2634	2 +
8.	3.4203	3 +
9.	3.5240	4 +
10.	3.5309	0 +
11.	3.5934	1 +
12.	3.6200	4 +
13.	3.7744	3 +
14.	3.8983	2 +
15.	4.4753	3 -

Continuum levels assumed above 3.932 MeV.

MT=102 Capture
Calculated with CASTHY.

MT=251 : Mu-bar
Calculated with optical model.

MF=4 Angular Distributions of Secondary Neutrons
MT=2 : Calculated with optical model.
MT=16,22,28 : Isotropic in the laboratory system.
MT=51-64 : Calculated with CASTHY. Direct process included in MT=51,52,53,55
MT=65 : C.C. calculation
MT=91 : Isotropic in the laboratory system

MF=5 Energy Distributions of Secondary Neutrons
MT=16,22,28 : Calculated with PEGASUS
MT=91 : Calculated with GNASH.

MF=12 Photon Multiplicities and Transition Probability Arrays
MT=16,22,28,91,: Multiplicities calculated with GNASH.
102,103,107
MT=51-65 : Transition probability arrays

MF=14 Photon Angular Distributions
MT=16,22,28,51-65,91,102,103,107 : Isotropic

MF=15 Photon Energy Distributions
MT=16,22,28,91,102,103,107 : Calculated with GNASH

References
1) Syme D.B. et al.: Neutron Data of Structural Materials for FBR,1977 Geel Meet.,p.703,Pergamon Press(1979).
2) Perey C.M. et al.: Proc. Int. Conf. Nuclear Data for Basic

and Applied Science, Santa Fe, 1985, p.1639 (1986).
3) Kawai M. : unpublished.
4) Iijima S. et al.: JAERI-M 87-025, p.337 (1987).
5) Igarasi S.: J.Nucl.Sci.Technol.,12,67 (1975).
6) Young P.G. and Arthur E.D.: LA-6947 (1977).

MAT number = 3282

```
 28-Ni- 60 NAIG        Eval-Mar87 S.Iijima
                       Dist-Sep89
History
87-03  Evaluation was performed for JENDL-3.
87-05  Compiled by K.Shibata (JAERI).

MF=1,MT=451   Comments and dictionary

MF=2,MT=151   Resolved resonance parameters : 1.0E-5 eV - 456 keV
      Evaluation based on the following data.
         Resonance parameters from Perey+/1/
         Two negative resonances due to Perey+/2/ with
         modification:
           E = -50 keV  gamma-n = 12.8 keV   gamma-g = 0.0 eV
           E = -656 eV  gamma-n = 0.60  eV   gamma-g = 6.0 eV

     Calculated 2200 m/s values and resonance integrals (barn):
                          2200 m/s value        res. int.
         total              4.316                  -
         elastic            1.416                  -
         capture            2.900                1.467

MF=3  Neutron Cross Sections
  No background cross sections for MT=1,2,102.

  Cross sections above 456 keV evaluated as follows :

    MT=1 : Total cross section
       Calculated with optical model.
       Potential parameters obtained by fitting nat-Ni data /3/:
         V =51.33 - 0.331*En ,Ws=8.068 + 0.112*En ,Vso=7.0 (MeV)
         r0=rso=1.24         ,rs=1.40                   (fm)
         a0=aso=0.541        ,as=0.4                    (fm)

    MT=2 : Elastic scattering
       (Total) - (Nonelastic cross sections).

    MT=3 : Nonelastic cross section
       Sum of MT=4,16,22,28,102,103,104,105,106,107,111.

    MT=16    : (n,2n)
       Calculated with GNASH /4/.

    MT=103   : (n,p)
       Most of data were taken from JENDL-2.

    MT=22,28,104,105,106,107,111: (n,n'a),(n,n'p),(n,d),
    (n,t),(n,He-3),(n,a),(n,2p)
       The cross sections were calculated with PEGASUS /5/
       and normalized to experimental data.

    MT=4,52-61,91 : Inelastic scattering
       The CASTHY /6/ and GNASH /4/ calculations were adopted
       for neutron energies below and above 7 MeV, respectively.
       The contribution from the direct process was included for
```

MT=51,52,53,54,61. For the level of MT=61, only the direct process was considered.
The level scheme used is as follows:

No	Energy(MeV)	Spin-Parity
g.s	0.0	0 +
1.	1.3325	2 +
2.	2.1588	2 +
3.	2.2849	0 +
4.	2.5058	4 +
5.	2.6260	3 +
6.	3.1198	4 +
7.	3.1240	2 +
8.	3.1861	3 +
9.	3.1941	1 +
10.	3.2696	2 +
11.	4.0397	3 -

Continuum levels assumed above 3.318 MeV.

MT=102 : Capture
Calculated with CASTHY.

MT=251 : Mu-bar
Calculated with optical model.

MF=4 Angular Distributions of Secondary Neutrons
MT=2 : Calculated with optical model.
MT=16,22,28,91: Isotropic in the laboratory system.
MT=51-60 : Calculated with CASTHY. Direct process included in MT=51,52,53,54
MT=61 : C.C. calculation.

MF=5 Energy Distributions of Secondary Neutrons
MT=16,22,28 : Calculated with PEGASUS.
MT=91 : Calculated with GNASH.

MF=12 Photon Multiplicities and Transition Probability Arrays
MT=16,22,28,91,
102,103,107 : Multiplicities calculated with GNASH.
MT=51-65 : Transition probability arrays

MF=14 Photon Angular Distributions
MT=16,22,28,51-65,91,102,103,107 : Isotropic

MF=15 Photon Energy Distributions
MT=16,22,28,91,102,103,107 : Calculated with GNASH

References
1) Perey F.G. et al.: ORNL-5893 (1982).
2) Perey C.M. et al.: Proc. Int. Conf. Nuclear Data for Basic and Applied Science, Santa Fe, 1985, p.1639 (1986).
3) Kawai M. : unpublished.
4) Young P.G. and Arthur E.D.: LA-6947 (1977).
5) Iijima S. et al.: JAERI-M 87-025, p.337 (1987).
6) Igarasi S.: J.Nucl.Sci.Technol.,12,67 (1975).

MAT number = 3283

28-Ni- 61 NAIG Eval-Mar87 S.Iijima
Dist-Sep89

History
87-03 Evaluation was performed for JENDL-3.
87-05 Compiled by K.Shibata (JAERI).

MF=1,MT=451 Comments and dictionary

MF=2,MT=151 Resolved resonance parameters : 1.0E-5 eV - 57.0keV
Parameters were taken from JENDL-2 except that the neutron width of 64.07 keV s-wave resonance was changed from 54.0 eV to 535 eV /1/.
Scattering radius: 6.4 fm

Calculated 2200 m/s values and resonance integrals (barn):

	2200 m/s value	res.int
total	11.239	-
elastic	8.731	-
capture	2.509	2.439

MF=3 Neutron Cross Sections
Background cross sections (BGCS) applied to resonance region.
MT=1,2,102

Cross sections above 57.0 keV evaluated as follows :

MT=1 : Total cross section
High-resolution experimental data were adopted between 57 keV and 74.6 keV. Above 74.6 keV up to 20 MeV, the optical-model calculation was performed.
Potential parameters obtained by fitting nat-Ni data /2/:

```
V =51.33 - 0.331•En ,Ws=8.068 + 0.112•En ,Vso=7.0 (MeV)
r0=rso=1.24         ,rs=1.40                  (fm)
a0=aso=0.541        ,as=0.4                   (fm)
```

MT=2 : Elastic scattering
(Total) - (Nonelastic cross sections).

MT=3 : Nonelastic cross section
Sum of MT=4,16,22,28,102,103,104,105,106,107,111.

MT=16,22,28,103,104,105,106,107,111 (n,2n),(n,n'a),(n,n'p),
(n,p),(n,d),(n,t),(n,He-3),(n,a),(n,2p)
Calculated with PEGASUS /3/.

MT=4,51-70,91,102 : Inelastic scattering and capture
Calculated with the statistical model code CASTHY /4/.
The level scheme used is given as follows:

No	Energy(MeV)	Spin-Parity
g.s	0.0	3/2 -
1.	0.0674	5/2 -
2.	0.2830	1/2 -
3.	0.6560	3/2 -
4.	0.9088	5/2 -
5.	1.0150	7/2 -

6.	1.1000	3/2 -
7.	1.1323	5/2 -
8.	1.1857	3/2 -
9.	1.4580	7/2 -
10.	1.6100	5/2 -
11.	1.7298	3/2 -
12.	1.8080	7/2 -
13.	1.9780	9/2 +
14.	1.9970	3/2 -
15.	2.0030	7/2 -
16.	2.0190	7/2 -
17.	2.1140	9/2 +
18.	2.1230	1/2 -
19.	2.4100	5/2 -
20.	2.4660	7/2 -

Continuum levels assumed above 2..528 MeV.

MT=251 : Mu-bar
Calculated with optical model.

MF=4 Angular Distributions of Secondary Neutrons
MT=2 : Calculated with optical model.
MT=16,22,28,91: Isotropic in the laboratory system.
MT=51-70 : 90 degree symmetric in the center-of-mass system, calculated with CASTHY.

MF=5 Energy Distributions of Secondary Neutrons
MT=16,22,28,91 : Calculated with PEGASUS.

References

1) Moxon M.C.: *KfK-2046, p.156 (1975).*
2) Kawai M. : unpublished.
3) Iijima S. et al.: JAERI-M 87-025, p.337 (1987).
4) Igarasi S.: J.Nucl.Sci.Technol.,12,67 (1975).

MAT number = 3284

```
 28-Ni- 62 NAIG         Eval-Mar87 S.Iijima
                        Dist-Sep89
History
87-03  Evaluation was performed for JENDL-3.
87-05  Compiled by K.Shibata (JAERI).

MF=1,MT=451   Comments and dictionary

MF=2,MT=151   Resolved resonance parameters : 1.0E-5 eV - 557 keV
       Parameters were taken from JENDL-2.
       Scattering radius: 6.2 fm

      Calculated 2200 m/s values and resonance integrals (barn):
                         2200 m/s value       res.int
          total            23.704              -
          elastic           9.505              -
          capture          14.199             6.908

MF=3  Neutron Cross Sections
  Background cross sections (BGCS) applied to resonance region.
    MT=1,2,102

  Cross sections above 557 keV evaluated as follows :

    MT=1 : Total cross section
       High-resolution experimental data were adopted between
       557 keV and 670 keV.  Above 670 keV up to 20 MeV, the
       optical-model calculation was performed.
       Potential parameters obtained by fitting nat-Ni data /1/:
         V =51.33 - 0.331*En ,Ws=8.068 + 0.112*En ,Vso=7.0 (MeV)
         r0=rso=1.24         ,rs=1.40                    (fm)
         a0=aso=0.541        ,as=0.4                     (fm)

    MT=2 : Elastic scattering
       (Total) - (Nonelastic cross section).

    MT=3 : Nonelastic cross section
       Sum of MT=4,16,22,28,102,103,104,105,106,107,111.

    MT=16,22,28,103,104,105,106,111  (n,2n),(n,n'a),(n,n'p),
     (n,p),(n,d),(n,t),(n,He-3),(n,2p)
       Calculated with PEGASUS /2/.

    MT=4,51-71,91,102 : Inelastic scattering and capture
       Calculated with the statistical-model code CASTHY /3/.
       The level scheme used is given as follows:
        No  Energy(MeV) Spin-Parity
        g.s     0.0         0 +
         1.     1.1729      2 +
         2.     2.0486      0 +
         3.     2.3018      2 +
         4.     2.3364      4 +
         5.     2.8912      0 +
         6.     3.0582      2 +
         7.     3.1580      2 +
```

8.	3.1765	4 +
9.	3.2577	2 +
10.	3.2620	4 +
11.	3.2699	2 +
12	3.2774	4 +
13.	3.3703	1 +
14.	3.4620	4 +
15.	3.4860	0 +
16.	3.5185	2 +
17.	3.5229	3 +
18.	3.7570	3 −
19.	3.8493	1 +
20.	3.8530	2 +
21.	3.8600	2 +

Continuum levels assumed above 3.957 MeV.

MT=107 : (n,a)
Based on experimental data.

MT=251 : Mu-bar
Calculated with optical model.

MF=4 Angular Distributions of Secondary Neutrons
MT=2 : Calculated with optical model.
MT=16,22,28,91: Isotropic in the laboratory system.
MT=51-71 : 90 degree symmetric in the center-of-mass system, calculated with CASTHY.

MF=5 Energy Distributions of Secondary Neutrons
MT=16,22,28,91 : Calculated with PEGASUS.

References
1) Kawai M. : unpublished.
2) Iijima S. et al.: JAERI-M 87-025, p.337 (1987).
3) Igarasi S.: J.Nucl.Sci.Technol.,12,67 (1975).

MAT number = 3285

28-Ni- 64 NAIG Eval-Mar87 S.Iijima
Dist-Sep89

History
87-03 Evaluation was performed for JENDL-3.
87-05 Compiled by K.Shibata (JAERI).

MF=1,MT=451 Comments and dictionary

MF=2,MT=151 Resolved resonance parameters : 1.0E-5 eV - 553 keV
Parameters were taken from JENDL-2.
Scattering radius: 6.4 fm

Calculated 2200 m/s values and resonance integrals (barn):

	2200 m/s value	res.int
total	1.515	-
elastic	0.035	-
capture	1.480	0.820

MF=3 Neutron Cross Sections
Background cross sections (BGCS) applied to resonance region.
MT=1,2,102

Cross sections above 553 keV evaluated as follows :

MT=1 : Total cross section
High-resolution experimental data were adopted between 553 keV and 698 keV. Above 698 keV up to 20 MeV, the optical-model calculation was performed.
Potential parameters obtained by fitting nat-Ni data /1/:

```
V =51.33 - 0.331*En ,Ws=8.068 + 0.112*En ,Vso=7.0 (MeV)
r0=rso=1.24          ,rs=1.40                  (fm)
a0=aso=0.541         ,as=0.4                   (fm)
```

MT=2 : Elastic scattering
(Total) - (Nonelastic cross section).

MT=3 : Nonelastic cross section
Sum of MT=4,16,17,22,28,102,103,104,105,106,107,111.

MT=16,17,22,28,103,104,105,106,111: (n,2n),(n,3n),(n,n'a), (n,n'p),(n,p),(n,d),(n,t),(n,He-3),(n,2p)
Calculated with PEGASUS /2/.

MT=4,51-70,91,102 : Inelastic scattering and capture
Calculated with the statistical model code CASTHY /3/.
The level scheme used is given as follows:

No	Energy(MeV)	Spin-Parity
g.s	0.0	0 +
1.	1.3459	2 +
2.	2.2750	0 +
3.	2.6080	4 +
4.	2.7500	2 +
5.	2.8650	0 +
6.	2.8850	2 +
7.	2.9710	2 +

8.	3.0280	0 +
9.	3.1650	4 +
10.	3.2730	2 +
11.	3.3930	3 +
12.	3.4590	1 +
13.	3.4830	4 +
14.	3.5600	3 -
15.	3.6470	2 +
16.	3.7480	4 +
17.	3.7950	1 +
18.	3.8080	3 +
19.	3.8480	5 -
20.	3.9650	4 +

Continuum levels assumed above 4.084 MeV.

MT=107 : (n,a)
Based on experimental data.

MT=251 : Mu-bar
Calculated with optical model.

MF=4 Angular Distributions of Secondary Neutrons
MT=2 : Calculated with optical model.
MT=16,17,22,28,91: Isotropic in the laboratory system.
MT=51-70 : 90 degree symmetric in the center-of-mass system, calculated with CASTHY.

MF=5 Energy Distributions of Secondary Neutrons
MT=16,17,22,28,91 : Calculated with PEGASUS.

References

1) Kawai M. : unpublished.
2) Iijima S. et al.: JAERI-M 87-025, p.337 (1987).
3) Igarasi S.: J.Nucl.Sci.Technol.,12,67 (1975).

MAT number = 3290

```
 29-Cu-  0 NAIG,MAPI  Eval-Mar87 N.Yamamuro,T.Kawakita
                      Dist-Sep89
History
87-03  Evaluation was performed for JENDL-3.
87-05  Compiled by K.Shibata (JAERI).

MF=1          General Information
  MT=451    Descriptive data and dictionary

MF=2          Resonance Parameters
  MT=151    Resolved resonance parameters for MLBW formula
     Parameters of each isotope were mainly taken from the
     work of Mughabghab et al. /1/
     Resonance region : 1.0E-5 eV to 153 keV.
     Scattering radius: 6.70 fm for Cu-63 and Cu-65
     Calculated 2200-m/s cross sections and res. integrals
                  2200-m/s          res. integ.
      elastic     7.868 b              -
      capture     3.785 b           4.121 b
      total      11.653 b              -

MF=3          Neutron Cross Sections
  MT=1       Total
       Below 153 keV    : No background
       153 keV to 3 MeV: Based on the experimental data of
                          natural element /2,3/
       3 MeV to 20 MeV : Optical-model calculation using
                          CASTHY /4/
            The optical potential parameters used are as
            follows /5/ (in the units of MeV and fm):
         V  = 51.725 - 0.447*E   r0 = 1.221    a0  = 0.683
         Ws = 8.44 + 0.055*E     rs = 1.223    as  = 0.507
         Vso= 8.0                rso= 1.221    aso = 0.683
  MT=2      Elastic scattering
       (Total) - (Reaction cross section)
  MT=3      Non elastic
       Sum of MT=4, 16, 22, 28, 32, 102, 103, 104 and 107
  MT=4,51-87,91 Inelastic scattering
       Statistical model calculations were made with CASTHY /4/
       below 3 MeV by taking account of competing processes,
       and with GNASH/6/ above 3 MeV including preequilibrium
       effcets.  The direct process components were considered
       for 10 discrete levels.
 MT=16,22,28,32,103,104 (n,2n),(n,n'a),(n,n'p),(n,n'd),(n,p)
    (n,d) cross sections
       Calculated with GNASH /6/.
       Optical potential parameters for proton, alpha-particle
       and deuteron were as follows /7,8,9/.
    Proton
       V  = 59.11 - 0.55*E     r0 = 1.25    a0 = 0.65
       Ws = 10.4                rs = 1.25    as = 0.47
       Vso= 7.5                rso= 1.25    aso= 0.47

    Alpha-particle
       V  = 164.7              r0 = 1.442   a0 = 0.52
```

```
        Wv = 22.4                rv = 1.442   av = 0.52
                                 rc = 1.30

     Deuteron
        V  = 106.69              r0 = 1.05    a0 = 0.86
        Ws = 13.92               rs = 1.43    as = 0.704
        Vso= 7.0                 rso= 0.75    aso= 0.5
                                 rc = 1.3
```

MT=107 (n,a) cross section
Calculated cross sections of Cu-63 were normalized to the experimental data /10/ at 10 MeV. Above 12 MeV, the excitation function follows the data of Paulsen /11/. For Cu-65, the GNASH calculation was employed.

MT=102 Radiative capture cross section
Calculated with CASTHY.

MT=251 Mu-bar
Calculated with CASTHY.

MF=4 Angular Distributions of Secondary Neutrons
MT=2,51-87
Calculated with CASTHY for equilibrium process
The components of the direct process were added to 10 levels by using the DWUCK code /12/.
MT=16, 22, 28, 32, 91
Assumed to be isotropic in the laboratory system.

MF=5 Energy Distributions of Secondary Neutrons
MT=16, 22, 28, 32, 91
Calculated with GNASH.

MF=12 Photon Production Multiplicities
MT=102
Calculated with GNASH.
At thermal energy, modified by using the measurements/13/ and gamma-ray intensity data in ENSDF.

MF=13 Photon Production Cross Sections
MT=3
Calculated with GNASH.

MF=14 Photon Angular Distributions
MT=3,102
Assumed to be isotropic.

MF=15 Photon Energy Distributions
MT=3,102
Calculated with GNASH.
At thermal energy, modified by using the measurements/13/ and gamma-ray intensity data in ENSDF.

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1) Mughabghab S.F., Divadeenam M. and Holden N.E.: "Neutron Cross Sections, Vol. 1, Part A", Academic Press (1981).
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MAT number = 3291

```
 29-Cu- 63 NAIG,MAPI  Eval-Mar87 N.Yamamuro,T.Kawakita
                      Dist-Sep89
History
87-03  Evaluation was performed for JENDL-3.
87-05  Compiled by K.Shibata.

MF=1          General Information
  MT=451    Descriptive data and dictionary

MF=2          Resonance Parameters
  MT=151    Resolved resonance parameters for MLBW formula
    Parameters were mainly taken from the work of Mughabghab
    et al. /1/
    Resonance region : 1.0E-5 eV to 153 keV.
    Scattering radius: 6.70 fm
    Calculated 2200-m/s cross sections and res. integrals
                  2200-m/s         res. integ.
     elastic      5.102 b            -
     capture      4.506 b          4.972 b
     total        9.608 b            -

MF=3          Neutron Cross Sections
  MT=1        Total
       Below 153 keV    : No background
       153 keV to 3 MeV: Based on the experimental data of
                          natural element /2,3/
       3 MeV to 20 MeV : Optical-model calculation using
                          CASTHY /4/
            The optical potential parameters used are as
            follows /5/ (in the units of MeV and fm):
         V   = 51.725 - 0.447*E    r0 = 1.221    a0  = 0.683
         Ws  = 8.44 + 0.055*E      rs = 1.223    as  = 0.507
         Vso= 8.0                  rso= 1.221    aso = 0.683
  MT=2        Elastic scattering
       (Total) - (Reaction cross section)
  MT=3        Non elastic
       Sum of MT=4, 16, 22, 28, 32, 102, 103, 104 and 107
  MT=4,51-67,91 Inelastic scattering
       Statistical model calculations were made with CASTHY /4/
       below 3 MeV by taking account of competing processes,
       and with GNASH /6/ above 3 MeV including preequilibrium
       effects.  The direct-process components were considered
       for the levels of MT=51-54,65,91 by the DWBA
       calculations.
       The level scheme was taken from Ref. /7/.
         No.     Energy(MeV) Spin-Parity
         g.s.       0.0        3/2 -
          1.        0.6697     1/2 -
          2.        0.9621     5/2 -
          3.        1.3270     7/2 -
          4.        1.4120     5/2 -
          5.        1.5470     3/2 -
          6.        1.8610     7/2 -
          7.        2.0110     3/2 -
          8.        2.0620     1/2 -
```

9.	2.0810	5/2 -
10.	2.0930	7/2 -
11.	2.2080	9/2 -
12.	2.3370	5/2 -
13.	2.4050	7/2 -
14.	2.4970	3/2 -
15.	2.5050	9/2 +
16.	2.5120	1/2 -
17.	2.5360	5/2 -

Levels above 2.54 MeV were assumed to be overlapping.

MT=16,22,28,32,103,104 (n,2n),(n,n'a),(n,n'p),(n,n'd),(n,p)
(n,d) cross sections
Calculated with GNASH/6/.
Optical potential parameters for proton, alpha-particle and deuteron were as follows /8,9,10/.

Proton

V = 59.11 - 0.55*E	r0 = 1.25	a0 = 0.65
Ws = 10.4	rs = 1.25	as = 0.47
Vso= 7.5	rso= 1.25	aso= 0.47

Alpha-particle

V = 164.7	r0 = 1.442	a0 = 0.52
Wv = 22.4	rv = 1.442	av = 0.52
	rc = 1.30	

Deuteron

V = 106.69	r0 = 1.05	a0 = 0.86
Ws = 13.92	rs = 1.43	as = 0.704
Vso= 7.0	rso= 0.75	aso= 0.5
	rc = 1.3	

MT=107 (n,a) cross section
Calculated cross sections were normalized to the experimental data /11/ at 10 MeV. Above 12 MeV, the excitation function follows the data of Paulsen /12/.

MT=102 Radiative capture cross section
Calculated with CASTHY. A value of 0.002 was employed for the gamma-ray strength function for s-wave neutrons.

MT=251 Mu-bar
Calculated with CASTHY

MF=4 Angular Distributions of Secondary Neutrons
MT=2,51-67
Calculated with CASTHY for equilibrium process
The components of the direct process were added to the levels of MT=51-54,65 by using the DWUCK code /13/.
MT=16, 22, 28, 32, 91
Assumed to be isotropic in the laboratory system

MF=5 Energy Distributions of Secondary Neutrons
MT=16, 22, 28, 32, 91
Calculated with GNASH.

MF=12 Photon Production Multiplicities
MT=16,22,28,32,51-67,91,102,103,104,107
Calculated with GNASH.

MF=14 Photon Angular Distributions
MT=16,22,28,32,51-67,91,102,103,104,107
Assumed to be isotropic.

MF=15 Photon Energy Distributions
MT=16,22,28,32,91,102,103,104,107
Calculated with GNASH.

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1) Mughabghab S.F., Divadeenam M. and Holden N.E.: "Neutron Cross Sections, Vol. 1, Part A", Academic Press (1981).
2) Foster, Jr., D.G. and Glasgow, D.W.: Phys. Rev., C3, 576 (1971).
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5) Hetrick, D.M., Fu, C.Y. and Larson, D.C.: "Calculated Neutron-Induced Cross Sections for Cu-63,65 from 1 to 20 MeV and Comparisons with Experiments", ORNL/TM-9083 (1984).
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10) Lohr, J.M. and Haeberli, W.: Nucl. Phys. A232, 381 (1974).
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MAT number = 3292

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 29-Cu- 65 NAIG,MAPI  Eval-Mar87 N.Yamamuro,T.Kawakita
                      Dist-Sep89
History
87-03  Evaluation was performed for JENDL-3.
87-05  Compiled by K.Shibata (JAERI).

MF=1          General Information
  MT=451    Descriptive data and dictionary

MF=2          Resonance Parameters
  MT=151    Resolved resonance parameters for MLBW formula
     Parameters were mainly taken from the work of Mughabghab
     et al. /1/
     Resonance region : 1.0E-5 eV to 153 keV.
     Scattering radius: 6.70 fm
     Calculated 2200-m/s cross sections and res. integrals
                 2200-m/s         res. integ.
      elastic    14.074 b             -
      capture     2.168 b          2.210 b
      total      16.242 b             -

MF=3          Neutron Cross Sections
  MT=1      Total
        Below 153 keV    : No background
        153 keV to 3 MeV: Based on the experimental data of
                          natural element /2,3/.
        3 MeV to 20 MeV : Optical-model calculation using
                          CASTHY /4/.
              The optical potential parameters used are as
              follows /5/ (in the units of MeV and fm):
          V  = 51.725 - 0.447*E   r0 = 1.221    a0  = 0.683
          Ws = 8.44 + 0.055*E     rs = 1.223    as  = 0.507
          Vso= 8.0                rso= 1.221    aso = 0.683
  MT=2      Elastic scattering
        (Total) - (Reaction cross section)
  MT=3      Non elastic
        Sum of MT=4, 16, 22, 28, 32, 102, 103, 104 and 107
  MT=4,51-70,91 Inelastic scattering
        Statistical model calculations were made with CASTHY /4/
        below 3 MeV by taking account of competing processes,
        and with GNASH /6/ above 3 MeV including preequilibrium
        effects.  The direct-process component was considered for
        the levels of MT=51-54,64,91 by the DWBA calculations.
        The level scheme was taken from Ref. /7/.
          No.    Energy(MeV) Spin-Parity
          g.s.   0.0         3/2 -
           1.    0.7706      1/2 -
           2.    1.1160      5/2 -
           3.    1.4820      7/2 -
           4.    1.6230      5/2 -
           5.    1.7250      3/2 -
           6.    2.0940      7/2 -
           7.    2.1070      5/2 -
           8.    2.2130      1/2 -
           9.    2.2780      7/2 -
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10.	2.3290	3/2 -
11.	2.4070	9/2 -
12.	2.5260	9/2 +
13.	2.5330	5/2 -
14.	2.5340	7/2 +
15.	2.5930	1/2 -
16.	2.6440	9/2 -
17.	2.6500	5/2 -
18.	2.6550	5/2 -
19.	2.6690	5/2 -
20.	2.7530	9/2 +

Levels above 2.80 MeV were assumed to be overlapping.

MT=16,22,28,32,103,104,107 (n,2n),(n,n'a),(n,n'p),(n,n'd),(n,p) (n,d) and (n,a) cross sections
Calculated with GNASH/5/.
Optical potential parameters for proton, alpha-particles and deuteron were as follows /8,9,10/.

Proton

V = 59.11 - 0.55*E	r0 = 1.25	a0 = 0.65
Ws = 10.4	rs = 1.25	as = 0.47
Vso= 7.5	rso= 1.25	aso= 0.47

Alpha-particle

V = 164.7	r0 = 1.442	a0 = 0.52
Wv = 22.4	rv = 1.442	av = 0.52
	rc = 1.30	

Deuteron

V = 106.69	r0 = 1.05	a0 = 0.86
Ws = 13.92	rs = 1.43	as = 0.704
Vso= 7.0	rso= 0.75	aso= 0.5
	rc = 1.3	

MT=102 Radiative capture cross section
Calculated with CASTHY. A value of 0.001 was employed for the gamma-ray strength function for s-wave neutrons.

MT=251 Mu-bar
Calculated with CASTHY.

MF=4 Angular Distributions of Secondary Neutrons

MT=2,51-70
Calculated with CASTHY for equilibrium process. The components of the direct process were added to the levels of MT=51-54,64 by using the DWUCK code /11/.

MT=16, 22, 28, 32, 91
Assumed to be isotropic in the laboratory system.

MF=5 Energy Distributions of Secondary Neutrons

MT=16, 22, 28, 32, 91
Calculated with GNASH.

MF=12 Photon Production Multiplicities

MT=16,22,28,32,51-70,91,102,103,104,107
Calculated with GNASH.

MF=14 Photon Angular Distributions
MT=16,22,28,32,51-70,91,102,103,104,107
Assumed to be isotropic.

MF=15 Photon Energy Distributions
MT=16,22,28,32,91,102,103,104,107
Calculated with GNASH.

References

1) Mughabghab S.F., Divadeenam M. and Holden N.E.: "Neutron Cross Sections, Vol. 1, Part A", Academic Press (1981).
2) Foster, Jr., D.G. and Glasgow, D.W.: Phys. Rev., C3, 576 (1971).
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MAT number = 3400

40-Zr- 0 MAPI Eval-Nov88 M.Sasaki (MAPI)
Dist-Sep89

History
88-11 Compiled by T.Asami (JAERI)

MF=1 General Information
MT=451 Descriptive data and dictionary

MF=2 Resonance Parameters
MT=151 Resolved resonance parameters
Resolved parameters for MLBW formula were given in the energy region from 1.0E-5 eV to 100 keV.
The abundance data were taken from ref./1/ to be 0.5145, 0.1122, 0.1715, 0.1738 and 0.0280 for Zr-90, -91, -92, -94 and -96, respectively.

	2200 m/s cross section(b)	res. integral(b)
elastic	6.43	
capture	0.186	1.19
total	6.616	

MF=3 Neutron Cross Sections
Below 100 keV, no background cross section was given.
Above 100 keV, the total and partial cross sections were given pointwise.
MT=1 Total
Based on experimental data.

MT=2 Elastic scattering
Obtained by subtracting the sum of the partial cross sections from the total cross section.

MT=4, 51-89, 91 Inelastic scattering
The data were constructed from the statistical-model/2/ calculations for each isotope.
The data for some levels were lumped as follows:

MT	Level energy(MeV)	Zr-90	Zr-91	Zr-92	Zr-94	Zr-96
g.s.	0.0					
51	0.918				51	
52	0.935			51		
53	1.205		51			
54	1.300				52	
55	1.382			52		
56	1.467		52			
57	1.469				53	
58	1.496			53		
59	1.590					51
60	1.671				54	
61	1.760					52
62	1.761	51				
63	1.847			54		
64	1.882		53			
65	1.900					53
66	2.042		54			
67	2.057				55	

68	2.066			55		
69	2.131		55-56			
70	2.150				56	
71	2.186	52				
72	2.189		57-58			
73	2.210					54
74	2.259		59-60			
75	2.319	53				
76	2.339			56-57		
77	2.480			58		
78	2.739	54				
79	2.740			59		
80	2.748	55				
81	2.820			60-62		
82	2.900			63		
83	2.958			64		
84	3.077	56				
85	3.309	57				
86	3.448	58				
87	3.589	59				
88	3.843	60				
89	3.970	61				

The threshold for the inelastic scattering to the continuum was set to be 2.329 MeV for convenience of the file making.

MT=16, 22, 28, 102, 103 and 107 (n,2n), (n,na), (n,np), (n,gamma), (n,p) and (n,a)
Constructed from the statistical-model calculations for each isotope.
MT=251 Mu-bar
Calculated with optical model.

MF=4 Angular Distributions of Secondary Neutrons
MT=2 Elastic scattering
Constructed from the statistical-model/2/ calculations for each isotope.
MT=51-89, 91 Inelastic scattering
Constructed from the statistical-model/2/ calculations for each isotope.
MT=16, 22, 28 (n,2n), (n,na), (n,np)
Assumed to be isotropic in the laboratory system.

MF=5 Energy Distributions of Secondary Neutrons
MT=16, 22, 28, 91
Constructed from the statistical-model/2/ calculations for each isotope.

MF=12 Photon Production Multiplicities
MT=102
Constructed from the statistical-model/2/ calculations for each isotope.

MF=13 Photon Production Cross Sections
MT=3
Constructed from the statistical-model/2/ calculations for each isotope.

MF=14 Photon Angular Distributions
MT=3, 102
Assumed to be isotropic in the laboratory system.

MF=15 Continuous Photon Energy Spectra
MF=3
Constructed from the statistical-model/2/ calculations for each isotope.
MT=102
Constructed from the statistical-model/2/ calculations for each isotope.
Below thermal energy, modified by using the measurements of Sushkov/3/.

References

1) Holden, N.E., Martin, R.L. and Barnes, I.L. : Pure & Appl. Chem. 56, 675 (1984).
2) Fu, C.Y. : ORNL/TM 7042 (1980).
3) Sushkov, P.A. et al : LIJAF-644 (1981) ; Taken from EXFOR.

MAT number = 3401

40-Zr- 90 JNDC Eval-Aug89 JNDC FP Nuclear Data W.G.
Dist-Oct89

History
84-10 Evaluation for JENDL-2 was made by JNDC FPND W.G./1/
89-08 Modification for JENDL-3 was made/2/.

MF = 1 General information
MT=451 Comments and dictionary

MF = 2 Resonance parameters
MT=151 Resolved resonance parameters
Resolved resonance region (MLBW formula) : below 171 keV
Resonance energies and neutron widths were taken from Musgrove et al./3/. Radiative capture widths were derived from capture areas measured by Boldeman et al./4/. The parameters of the first resonance were slightly adjusted so as to reproduce the capture cross section of 0.011 +- 0.005 barns and elastic scattering of 5.3 +- 0.3 barns at 0.0253 eV /5/.

Average capture width = 0.190 +- 0.110 eV for s-wave res,
0.270 +- 0.120 eV for p-wave res,
0.280 +- 0.120 eV for d-wave res.

The effective scattering radius was adopted from Ref./5/.
No unresolved resonance region

Calculated 2200-m/s cross sections and res. integrals (barns)

	2200 m/s	res. integ.
total	5.511	-
elastic	5.465	-
capture	0.04584	0.196

MF = 3 Neutron cross sections
Below 171 keV, resonance parameters were given.
Above 171 keV, the spherical optical and statistical model calculation was performed with CASTHY/6/, by taking account of competing reactions, of which cross sections were calculated with PEGASUS/7/ standing on a preequilibrium and multi-step evaporation model. The OMP's for neutron given in Table 1 were determined by Iijima and Kawai/8/ to reproduce a systematic trend of the total cross section. The OMP's for charged particles are as follows:

Proton = Perey/9/
Alpha = Huizenga and Igo/10/
Deuteron = Lohr and Haeberli/11/
Helium-3 and triton = Becchetti and Greenlees/12/

Parameters for the composite level density formula of Girbert and Cameron/13/ were evaluated by Iijima et al./14/. More extensive determination and modification were made in the present work. Table 2 shows the level density parameters used in the present calculation. Energy dependence of spin cut-off parameter in the energy range below E-joint is due to Gruppelaar /15/.

MT = 1 Total
Spherical optical model calculation was adopted.

MT = 2 Elastic scattering
Calculated as (total - sum of partial cross sections).

MT = 4, 51 - 91 Inelastic scattering
Spherical optical and statistical model calculation was adopted. The level scheme was taken from Ref./16/.

No.	Energy(MeV)	Spin-parity
GR.	0.0	0 +
1	1.7607	0 +
2	2.1865	2 +
3	2.3191	5 -
4	2.7388	4 -
5	2.7479	3 -
6	3.0772	4 +
7	3.3087	2 +
8	3.4483	6 +
9	3.5894	8 +
10	3.8430	2 +
11	3.9760	5 -
12	4.1250	0 +
13	4.2324	5 -
14	4.2380	2 +

Levels above 4.28 MeV were assumed to be overlapping.

MT = 102 Capture
Spherical optical and statistical model calculation with CASTHY/6/ was adopted. Direct and semi-direct capture cross sections were estimated according to the procedure of Benzi and Reffo/17/ and normalized to 1 milli-barn at 14 MeV.

The gamma-ray strength function (1.407E-05) was adjusted to reproduce the capture cross section of 7.5 milli-barns at 100 keV measured by Musgrove et al./18/

MT = 16 (n,2n) Cross Section
MT = 22 (n,n'a) Cross Section
MT = 28 (n,n'p) Cross Section
MT =103 (n,p) Cross Section
MT =104 (n,d) Cross Section
MT =105 (n,t) Cross Section
MT =106 (n,He3) Cross Section
MT =107 (n,alpha) Cross Section
MT =111 (n,2p) Cross Section
These reaction cross sections were calculated with the preequilibrium and multi-step evaporation model code PEGASUS/7/.

The Kalbach's constant K (=301.6) was estimated by the formula derived from Kikuchi-Kawai's formalism/19/ and level density parameters.

Finally, (n,p) and (n,alpha) cross sections were normalized to the following values at 14.5 MeV:

(n,p)	40.00	mb (recommended by Forrest/20/)
(n,alpha)	10.00	mb (recommended by Forrest/20/)

The (n,2n) cross section was determined by eye-guiding of the data measured by Pavlik et al./21/, Zhao et al./22/, and others.

MT = 251 Mu-bar
Calculated with CASTHY/6/.

MF = 4 Angular Distributions of Secondary Neutrons
Legendre polynomial coefficients for angular distributions are given in the center-of-mass system for MT=2 and discrete inelastic levels, and in the laboratory system for MT=91. They were calculated with CASTHY/6/. For other reactions, isotropic distributions in the laboratory system were assumed.

MF = 5 Energy Distributions of Secondary Neutrons
Energy distributions of secondary neutrons were calculated with PEGASUS/7/ for inelastic scattering from overlapping levels and for other neutron emitting reactions.

Table 1 Neutron Optical Potential Parameters

Depth (MeV)	Radius(fm)	Diffuseness(fm)
V = 46.0-0.25E	R0 = 5.893	a0 = 0.62
Ws = 7.0	Rs = 6.393	as = 0.35
Wso= 7.0	Rso= 5.893	aso= 0.62

Table 2 Level Density Parameters

Nuclide	SYST	a(/MeV)	T(MeV)	C(/MeV)	EX(MeV)	Pairing
38-Sr- 86		1.120E+01	8.900E-01	5.328E-01	8.599E+00	2.700E+00
38-Sr- 87		1.030E+01	8.610E-01	1.186E+00	5.938E+00	1.240E+00
38-Sr- 88		9.160E+00	7.510E-01	8.288E-02	4.550E+00	2.170E+00
38-Sr- 89		9.380E+00	8.200E-01	5.043E-01	4.642E+00	1.240E+00
39-Y - 87	*	1.388E+01	7.471E-01	2.541E+00	6.730E+00	1.460E+00
39-Y - 88		1.109E+01	7.450E-01	3.738E+00	3.570E+00	0.0
39-Y - 89		7.900E+00	8.500E-01	3.983E-01	3.440E+00	9.300E-01
39-Y - 90		1.027E+01	6.770E-01	1.716E+00	2.209E+00	0.0
40-Zr- 88	*	1.404E+01	7.386E-01	4.932E-01	7.870E+00	2.660E+00
40-Zr- 89		1.095E+01	8.260E-01	1.379E+00	5.864E+00	1.200E+00
40-Zr- 90		9.152E+00	8.222E-01	1.526E-01	5.383E+00	2.130E+00
40-Zr- 91		1.036E+01	8.000E-01	7.822E-01	5.057E+00	1.200E+00

SYST: * = LDP's were determined form systematics.

Spin cutoff params were calculated as 0.146*SQRT(a)*A**(2/3).
In the CASTHY calculation, spin cutoff factors at 0 MeV were assumed to be 10.12 for Zr- 90 and 12.04 for Zr- 91.

References

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3) Musgrove, A.R. de L. et al.: Aust. J. Phys., 30, 379 (1977).

4) Boldeman, J.W., et al.: Nucl. Phys., A246, 1 (1975).
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MAT number = 3402

40-Zr- 91 JNDC Eval-Aug89 JNDC FP Nuclear Data W.G.
Dist-Oct89

History
84-10 Evaluation for JENDL-2 was made by JNDC FPND W.G./1/
89-08 Modification for JENDL-3 was made/2/.

MF = 1 General information
MT=451 Comments and dictionary

MF = 2 Resonance parameters
MT=151 Resolved and unresolved resonance parameters
Resolved resonance region (MLBW formula) : below 30.16 keV
For JENDL-2, resonance energies recommended by Mughabghab et al. /3/ were adopted. Neutron and radiative capture widths were obtained by averaging the data of Musgrove et al. /4/ and of Brusegan et al. /5/. For the levels above 20 keV, capture areas by Boldeman et al. /6/ were also taken into account. Parameters of a negative resonance were adopted from Ref./3/. The effective scattering radius was also taken from Ref./3/.
Assumed capture width = 0.120 eV for s-wave res.
0.240 eV for p-wave res.
For JENDL-3, thus evaluated parameters were modified by taking account of the evaluation by Coceva/7/. After modification, radiative widths were determined so as to reproduce capture areas of JENDL-2.
Unresolved resonance region : 30.16 keV - 100 keV
The neutron strength functions, S0, S1 and S2 were calculated with optical model code CASTHY/8/. The observed level spacing was determined to reproduce the capture cross section calculated with CASTHY. The effective scattering radius was obtained from fitting to the calculated total cross section at 100 keV.

Typical values of the parameters at 70 keV:
S0 = 0.420E-4, S1 = 5.700E-4, S2 = 0.360E-4, GG = 0.205 eV
Do = 660.4 eV, R = 6.621 fm.

Calculated 2200-m/s cross sections and res. integrals (barns)

	2200 m/s	res. integ.
total	11.83	-
elastic	10.59	-
capture	1.247	6.95

MF = 3 Neutron cross sections
Below 100 keV, resonance parameters were given.
Above 100 keV, the spherical optical and statistical model calculation was performed with CASTHY/8/, by taking account of competing reactions, of which cross sections were calculated with PEGASUS/9/ standing on a preequilibrium and multi-step evaporation model. The OMP's for neutron given in Table 1 were determined by Iijima and Kawai/10/ to reproduce a systematic trend of the total cross section. The OMP's for charged particles are as follows:
Proton = Perey/11/
Alpha = Huizenga and Igo/12/

Deuteron = Lohr and Haeberli/13/
Helium-3 and triton = Becchetti and Greenlees/14/
Parameters for the composite level density formula of Girbert and Cameron/15/ were evaluated by Iijima et al./16/. More extensive determination and modification were made in the present work. Table 2 shows the level density parameters used in the present calculation. Energy dependence of spin cut-off parameter in the energy range below E-joint is due to Gruppelaar /17/.

MT = 1 Total
Spherical optical model calculation was adopted.

MT = 2 Elastic scattering
Calculated as (total - sum of partial cross sections).

MT = 4, 51 - 91 *Inelastic scattering*
Spherical optical and statistical model calculation was adopted. The level scheme was taken from Ref./18/.

No.	Energy(MeV)	Spin-parity
GR.	0.0	5/2 +
1	1.2049	1/2 +
2	1.4663	5/2 +
3	1.8818	7/2 +
4	2.0414	3/2 +
5	2.1315	9/2 +
6	2.1701	11/2 -
7	2.1890	5/2 +
8	2.2005	7/2 +
9	2.2610	13/2 -
10	2.2890	15/2 -
11	2.3220	11/2 -

Levels above 2.368 MeV were assumed to be overlapping.

MT = 102 Capture
Spherical optical and statistical model calculation with CASTHY/8/ was adopted. Direct and semi-direct capture cross sections were estimated according to the procedure of Benzi and Reffo/19/ and normalized to 1 milli-barn at 14 MeV.

The gamma-ray strength function (3.199E-04) was adjusted to reproduce the capture cross section of 25 milli-barns at 100 keV measured by Musgrove et al./20/

MT = 16 (n,2n) Cross Section
MT = 17 (n,3n) Cross Section
MT = 22 (n,n'a) Cross Section
MT = 28 (n,n'p) Cross Section
MT = 32 (n,n'd) Cross Section
MT =103 (n,p) Cross Section
MT =104 (n,d) Cross Section
MT =105 (n,t) Cross Section
MT =106 (n,He3) Cross Section
MT =107 (n,alpha) Cross Section
These reaction cross sections were calculated with the preequilibrium and multi-step evaporation model code

PEGASUS/9/.

The Kalbach's constant K (=269.1) was estimated by the formula derived from Kikuchi-Kawai's formalism/21/ and level density parameters.

Finally, (n,p) and (n,alpha) cross sections were normalized to the following values at 14.5 MeV:

(n,p)	29.00 mb	(recommendation by Forrest/22/)
(n,alpha)	8.51 mb	(systematics of by Forrest/22/)

MT = 251 Mu-bar
Calculated with CASTHY/8/.

MF = 4 Angular Distributions of Secondary Neutrons
Legendre polynomial coefficients for angular distributions are given in the center-of-mass system for MT=2 and discrete inelastic levels, and in the laboratory system for MT=91. They were calculated with CASTHY/8/. For other reactions, isotropic distributions in the laboratory system were assumed.

MF = 5 Energy Distributions of Secondary Neutrons
Energy distributions of secondary neutrons were calculated with PEGASUS/9/ for inelastic scattering from overlapping levels and for other neutron emitting reactions.

Table 1 Neutron Optical Potential Parameters

Depth (MeV)	Radius(fm)	Diffuseness(fm)
V = 46.0-0.25E	R0 = 5.893	a0 = 0.62
Ws = 7.0	Rs = 6.393	as = 0.35
Wso= 7.0	Rso= 5.893	aso= 0.62

Table 2 Level Density Parameters

Nuclide	a(/MeV)	T(MeV)	C(/MeV)	EX(MeV)	Pairing
38-Sr- 87	1.030E+01	8.610E-01	1.186E+00	5.938E+00	1.240E+00
38-Sr- 88	9.160E+00	7.510E-01	8.288E-02	4.550E+00	2.170E+00
38-Sr- 89	9.380E+00	8.200E-01	5.043E-01	4.642E+00	1.240E+00
38-Sr- 90	9.940E+00	8.530E-01	3.795E-01	6.252E+00	1.900E+00
39-Y - 88	1.109E+01	7.450E-01	3.738E+00	3.570E+00	0.0
39-Y - 89	7.900E+00	8.500E-01	3.983E-01	3.440E+00	9.300E-01
39-Y - 90	1.027E+01	6.770E-01	1.716E+00	2.209E+00	0.0
39-Y - 91	1.050E+01	7.140E-01	8.362E-01	3.521E+00	7.200E-01
40-Zr- 89	1.095E+01	8.260E-01	1.379E+00	5.864E+00	1.200E+00
40-Zr- 90	9.152E+00	8.222E-01	1.526E-01	5.383E+00	2.130E+00
40-Zr- 91	1.036E+01	8.000E-01	7.822E-01	5.057E+00	1.200E+00
40-Zr- 92	1.088E+01	8.192E-01	5.122E-01	6.429E+00	1.920E+00

Spin cutoff params were calculated as 0.146*SQRT(a)*A**(2/3).
In the CASTHY calculation, spin cutoff factors at 0 MeV were assumed to be 12.04 for Zr- 91 and 6.937 for Zr- 92.

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MAT number = 3403

40-Zr- 92 JNDC Eval-Aug89 JNDC FP Nuclear Data W.G.
Dist-Oct89

History
84-10 Evaluation for JENDL-2 was made by JNDC FPND W.G./1/
89-08 Modification for JENDL-3 was made/2/.

MF = 1 General information
MT=451 Comments and dictionary

MF = 2 Resonance parameters
MT=151 Resolved and unresolved resonance parameters
Resolved resonance region (MLBW formula) : below 71 keV
Evaluation was based on the measured data by Boldeman et al. /3/. Parameters of a negative resonance and the effective scattering radius were adopted from Ref./4/.
Assumed capture width = 0.180 eV for s-wave res.
0.270 eV for p-wave res.
Unresolved resonance region : 71 keV - 100 keV
The neutron strength functions S0 and S1 were based on the compilation of Mughabghab et al./4/, and S2 was calculated with optical model code CASTHY/5/. The observed level spacing was determined to reproduce the capture cross section calculated with CASTHY. The effective scattering radius was obtained from fitting to the calculated total cross section at 100 keV.

Typical values of the parameters at 80 keV:
S0 = 0.500E-4, S1 = 7.000E-4, S2 = 0.380E-4, GG(S)= 0.140 eV
GG(P)=0.36 eV, Do = 3229. eV, R = 5.964 fm.

Calculated 2200-m/s cross sections and res. integrals (barns)

	2200 m/s	res. integ.
total	5.087	-
elastic	4.869	-
capture	0.2175	0.702

MF = 3 Neutron cross sections
Below 100 keV, resonance parameters were given.
Above 100 keV, the spherical optical and statistical model calculation was performed with CASTHY/5/, by taking account of competing reactions, of which cross sections were calculated with PEGASUS/6/ standing on a preequilibrium and multi-step evaporation model. The OMP's for neutron given in Table 1 were determined by Iijima and Kawai/7/ to reproduce a systematic trend of the total cross section. The OMP's for charged particles are as follows:
Proton = Perey/8/
Alpha = Huizenga and Igo/9/
Deuteron = Lohr and Haeberli/10/
Helium-3 and triton = Becchetti and Greenlees/11/
Parameters for the composite level density formula of Girbert and Cameron/12/ were evaluated by Iijima et al./13/. More extensive determination and modification were made in the present work. Table 2 shows the level density parameters used in the present calculation. Energy dependence of spin cut-off

parameter in the energy range below E-joint is due to Gruppelaar /14/.

MT = 1 Total
Spherical optical model calculation was adopted.

MT = 2 Elastic scattering
Calculated as (total - sum of partial cross sections).

MT = 4, 51 - 91 Inelastic scattering
Spherical optical and statistical model calculation was adopted. The level scheme was taken from Ref./15/.

No.	Energy(MeV)	Spin-parity
GR.	0.0	0 +
1	0.9345	2 +
2	1.3830	0 +
3	1.4956	4 +
4	1.8473	2 +
5	2.0669	2 +
6	2.3399	3 -
7	2.3950	4 +
8	2.4790	5 -
9	2.7400	4 -
10	2.8120	2 +
11	2.8570	4 +
12	2.8900	3 +
13	2.9000	0 +
14	2.9540	6 +
15	3.0340	3 -
16	3.0490	2 +

Levels above 3.11 MeV were assumed to be overlapping.

MT = 102 Capture
Spherical optical and statistical model calculation with CASTHY/5/ was adopted. Direct and semi-direct capture cross sections were estimated according to the procedure of Benzi and Reffo/16/ and normalized to 1 milli-barn at 14 MeV.

The gamma-ray strength function (8.993E-05) was adjusted to reproduce the capture cross section of 30 milli-barns at 100 keV measured by Musgrove et al./17/

MT = 16 (n,2n) Cross Section
MT = 17 (n,3n) Cross Section
MT = 22 (n,n'a) Cross Section
MT = 28 (n,n'p) Cross Section
MT = 32 (n,n'd) Cross Section
MT = 33 (n,n't) Cross Section
MT =103 (n,p) Cross Section
MT =104 (n,d) Cross Section
MT =105 (n,t) Cross Section
MT =107 (n,alpha) Cross Section
These reaction cross sections were calculated with the preequilibrium and multi-step evaporation model code PEGASUS/6/.

The Kalbach's constant K (=163.7) was estimated by the formula derived from Kikuchi-Kawai's formalism/18/ and level density parameters.

Finally, (n,p) and (n,alpha) cross sections were normalized to the following values at 14.5 MeV:

(n,p)	22.00	mb (measured by Ikeda et al./19/)
(n,alpha)	9.50	mb (mean value of data measured by Qaim et al./20/ and Bayhurst et al./21/)

The (n,np) and (n,d) cross sections were increased by factor of 2 to fit the data of Ikeda et al./19/.

MT = 251 Mu-bar
Calculated with CASTHY/5/.

MF = 4 Angular Distributions of Secondary Neutrons
Legendre polynomial coefficients for angular distributions are given in the center-of-mass system for MT=2 and discrete inelastic levels, and in the laboratory system for MT=91. They were calculated with CASTHY/5/. For other reactions, isotropic distributions in the laboratory system were assumed.

MF = 5 Energy Distributions of Secondary Neutrons
Energy distributions of secondary neutrons were calculated with PEGASUS/6/ for inelastic scattering from overlapping levels and for other neutron emitting reactions.

Table 1 Neutron Optical Potential Parameters

Depth (MeV)	Radius(fm)	Diffuseness(fm)
V = 46.0-0.25E	R0 = 5.893	a0 = 0.62
Ws = 7.0	Rs = 6.393	as = 0.35
Wso= 7.0	Rso= 5.893	aso= 0.62

Table 2 Level Density Parameters

Nuclide	a(/MeV)	T(MeV)	C(/MeV)	EX(MeV)	Pairing
38-Sr- 88	9.160E+00	7.510E-01	8.288E-02	4.550E+00	2.170E+00
38-Sr- 89	9.380E+00	8.200E-01	5.043E-01	4.642E+00	1.240E+00
38-Sr- 90	9.940E+00	8.530E-01	3.795E-01	6.252E+00	1.960E+00
38-Sr- 91	1.090E+01	8.100E-01	1.103E+00	5.625E+00	1.240E+00
39-Y - 89	7.900E+00	8.500E-01	3.983E-01	3.440E+00	9.300E-01
39-Y - 90	1.027E+01	6.770E-01	1.716E+00	2.209E+00	0.0
39-Y - 91	1.050E+01	7.140E-01	8.362E-01	3.521E+00	7.200E-01
39-Y - 92	1.012E+01	7.629E-01	2.480E+00	3.191E+00	0.0
40-Zr- 90	9.152E+00	8.222E-01	1.526E-01	5.383E+00	2.130E+00
40-Zr- 91	1.036E+01	8.000E-01	7.822E-01	5.057E+00	1.200E+00
40-Zr- 92	1.088E+01	8.192E-01	5.122E-01	6.429E+00	1.920E+00
40-Zr- 93	1.298E+01	7.000E-01	1.273E+00	5.183E+00	1.200E+00

Spin cutoff params were calculated as 0.146*SQRT(a)*A**(2/3).
In the CASTHY calculation, spin cutoff factors at 0 MeV were

assumed to be 6.937 for Zr- 92 and 6.100 for Zr- 93.

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7) Iijima, S. and Kawai, M.: J. Nucl. Sci. Technol., 20, 77 (1983).
8) Perey, F.G: Phys. Rev. 131, 745 (1963).
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MAT number = 3405

40-Zr- 94 JNDC Eval-Aug89 JNDC FP Nuclear Data W.G.
Dist-Oct89

History
84-10 Evaluation for JENDL-2 was made by JNDC FPND W.G./1/
89-08 Modification for JENDL-3 was made/2/.

MF = 1 General information
MT=451 Comments and dictionary

MF = 2 Resonance parameters
MT=151 Resolved and unresolved resonance parameters
Resolved resonance region (MLBW formula) : below 53.5 keV
Parameters were determined on the basis of measured data by Boldeman et al./3/. A negative resonance was added to reproduce the capture cross section of 0.0499 barn and the elastic scattering of 6.1 barn at 0.0253 eV /4/.
Assumed capture width = 0.090 eV for s-wave res.
0.175 eV for p-wave res.

Unresolved resonance region : 53.5 keV - 100 keV
The neutron strength functions, S0, S1 and S2 were calculated with optical model code CASTHY/5/. The observed level spacing was determined to reproduce the capture cross section calculated with CASTHY. The effective scattering radius was obtained from fitting to the calculated total cross section at 100 keV.

Typical values of the parameters at 70 keV:
S0 = 0.370E-4, S1 = 5.500E-4, S2 = 0.360E-4, GG = 0.190 eV
Do = 3556. eV, R = 6.704 fm.

Calculated 2200-m/s cross sections and res. integrals (barns)

	2200 m/s	res. integ.
total	6.202	-
elastic	6.152	-
capture	0.04981	0.321

MF = 3 Neutron cross sections
Below 100 keV, resonance parameters were given.
Above 100 keV, the spherical optical and statistical model calculation was performed with CASTHY/5/, by taking account of competing reactions, of which cross sections were calculated with PEGASUS/6/ standing on a preequilibrium and multi-step evaporation model. The OMP's for neutron given in Table 1 were determined by Iijima and Kawai/7/ to reproduce a systematic trend of the total cross section. The OMP's for charged particles are as follows:
Proton = Perey/8/
Alpha = Huizenga and Igo/9/
Deuteron = Lohr and Haeberli/10/
Helium-3 and triton = Becchetti and Greenlees/11/
Parameters for the composite level density formula of Girbert and Cameron/12/ were evaluated by Iijima et al./13/. More extensive determination and modification were made in the present work. Table 2 shows the level density parameters used in the present calculation. Energy dependence of spin cut-off

parameter in the energy range below E-joint is due to Gruppelaar /14/.

MT = 1 Total
Spherical optical model calculation was adopted.

MT = 2 Elastic scattering
Calculated as (total - sum of partial cross sections).

MT = 4, 51 - 91 Inelastic scattering
Spherical optical and statistical model calculation was adopted. The level scheme was taken from Ref./15/.

No.	Energy(MeV)	Spin-parity
GR.	0.0	0 +
1	0.9182	2 +
2	1.3000	0 +
3	1.4683	4 +
4	1.6687	2 +
5	2.0574	3 -
6	2.1510	2 +
7	2.3360	4 +
8	2.3655	2 +
9	2.6050	5 -
10	2.8400	1 -

Levels above 2.882 MeV were assumed to be overlapping.

MT = 102 Capture
Spherical optical and statistical model calculation with CASTHY/5/ was adopted. Direct and semi-direct capture cross sections were estimated according to the procedure of Benzi and Reffo/16/ and normalized to 1 milli-barn at 14 MeV.

The gamma-ray strength function (4.886E-05) was adjusted to reproduce the capture cross section of 19 milli-barns at 100 keV measured by Musgrove et al./17/

MT = 16 (n,2n) Cross Section
MT = 17 (n,3n) Cross Section
MT = 22 (n,n'a) Cross Section
MT = 28 (n,n'p) Cross Section
MT = 32 (n,n'd) Cross Section
MT =103 (n,p) Cross Section
MT =104 (n,d) Cross Section
MT =105 (n,t) Cross Section
MT =107 (n,alpha) Cross Section
These reaction cross sections were calculated with the preequilibrium and multi-step evaporation model code PEGASUS/6/.

The Kalbach's constant K (=161.8) was estimated by the formula derived from Kikuchi-Kawai's formalism/18/ and level density parameters.

Finally, (n,p) and (n,alpha) cross sections were normalized to the following values at 14.5 MeV:
(n,p) 10.00 mb (recommended by Forrest/19/)

(n,alpha) 4.80 mb (measured by Ikeda et al./20/)

MT = 251 Mu-bar
Calculated with CASTHY/5/.

MF = 4 Angular Distributions of Secondary Neutrons
Legendre polynomial coefficients for angular distributions are given in the center-of-mass system for MT=2 and discrete inelastic levels, and in the laboratory system for MT=91. They were calculated with CASTHY/5/. For other reactions, isotropic distributions in the laboratory system were assumed.

MF = 5 Energy Distributions of Secondary Neutrons
Energy distributions of secondary neutrons were calculated with PEGASUS/6/ for inelastic scattering from overlapping levels and for other neutron emitting reactions.

Table 1 Neutron Optical Potential Parameters

Depth (MeV)	Radius(fm)	Diffuseness(fm)
V = 46.0-0.25E	R0 = 5.893	a0 = 0.62
Ws = 7.0	Rs = 6.393	as = 0.35
Wso= 7.0	Rso= 5.893	aso= 0.62

Table 2 Level Density Parameters

Nuclide	SYST	a(/MeV)	T(MeV)	C(/MeV)	EX(MeV)	Pairing
38-Sr- 90		9.940E+00	8.530E-01	3.795E-01	6.252E+00	1.960E+00
38-Sr- 91		1.090E+01	8.100E-01	1.103E+00	5.625E+00	1.240E+00
38-Sr- 92	*	1.288E+01	7.065E-01	2.515E-01	6.391E+00	2.360E+00
38-Sr- 93	*	1.386E+01	6.989E-01	1.878E+00	5.664E+00	1.240E+00
39-Y - 91		1.050E+01	7.140E-01	8.362E-01	3.521E+00	7.200E-01
39-Y - 92		1.012E+01	7.629E-01	2.480E+00	3.191E+00	0.0
39-Y - 93		1.150E+01	8.053E-01	1.740E+00	5.854E+00	1.120E+00
39-Y - 94		9.149E+00	7.385E-01	1.378E+00	2.222E+00	0.0
40-Zr- 92		1.088E+01	8.192E-01	5.122E-01	6.429E+00	1.920E+00
40-Zr- 93		1.298E+01	7.000E-01	1.273E+00	5.183E+00	1.200E+00
40-Zr- 94		1.275E+01	7.530E-01	4.411E-01	7.019E+00	2.320E+00
40-Zr- 95		1.331E+01	6.070E-01	5.453E-01	3.985E+00	1.200E+00

SYST: * = LDP's were determined from systematics.

Spin cutoff params were calculated as 0.146*SQRT(a)*A**(2/3).
In the CASTHY calculation, spin cutoff factors at 0 MeV were assumed to be 5.525 for Zr- 94 and 5.652 for Zr- 95.

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MAT number = 3407

40-Zr- 96 JNDC Eval-Aug89 JNDC FP Nuclear Data W.G.
Dist-Oct89

History
84-10 Evaluation for JENDL-2 was made by JNDC FPND W.G./1/
89-08 Modification for JENDL-3 was made/2/.

MF = 1 General information
MT=451 Comments and dictionary

MF = 2 Resonance parameters
MT=151 Resolved and unresolved resonance parameters
Resolved resonance region (MLBW formula) : below 100 keV
Resonance energies and neutron widths were based on the measured values by Coceva et al. /3/ below 41.5 keV and those by Musgrove et al. /4/ above 41.5 keV. The neutron widths of Musgrove et al. were multiplied by a factor of 1.79. The radiative capture widths were adopted from Brusegan et al. /5/. The parameters of the 301-eV level were taken from Salah et al. /6/. A negative resonance was adopted on the basis of recommended parameters in Ref./7/ by slightly modifying its radiative capture width so as to reproduce the capture cross section of 0.0229 +- 0.0010 barns at 0.0253 eV /7/.

Assumed capture width = 0.068 +- 0.010 eV for s-wave res.
0.170 +- 0.130 eV for p-wave res.

No unresolved resonance region

Calculated 2200-m/s cross sections and res. integrals (barns)

	2200 m/s	res. integ.
total	6.154	-
elastic	6.131	-
capture	0.02280	5.87

MF = 3 Neutron cross sections
Below 100 keV, resonance parameters were given.
Above 100 keV, the spherical optical and statistical model calculation was performed with CASTHY/8/, by taking account of competing reactions, of which cross sections were calculated with PEGASUS/9/ standing on a preequilibrium and multi-step evaporation model. The OMP's for neutron given in Table 1 were determined by Iijima and Kawai/10/ to reproduce a systematic trend of the total cross section. The OMP's for charged particles are as follows:

Proton = Perey/11/
Alpha = Huizenga and Igo/12/
Deuteron = Lohr and Haeberli/13/
Helium-3 and triton = Becchetti and Greenlees/14/

Parameters for the composite level density formula of Girbert and Cameron/15/ were evaluated by Iijima et al./16/. More extensive determination and modification were made in the present work. Table 2 shows the level density parameters used in the present calculation. Energy dependence of spin cut-off parameter in the energy range below E-joint is due to Gruppelaar /17/.

MT = 1 Total
Spherical optical model calculation was adopted.

MT = 2 Elastic scattering
Calculated as (total - sum of partial cross sections).

MT = 4, 51 - 91 Inelastic scattering
Spherical optical and statistical model calculation was adopted. The level scheme was taken from Ref./18/.

No.	Energy(MeV)	Spin-parity
GR.	0.0	0 +
1	1.5940	0 +
2	1.7580	2 +
3	1.9050	3 -
4	2.2100	3 -
5	2.4400	1 -
6	2.8400	3 -

Levels above 2.936 MeV were assumed to be overlapping.

MT = 102 Capture
Spherical optical and statistical model calculation with CASTHY/8/ was adopted. Direct and semi-direct capture cross sections were estimated according to the procedure of Benzi and Reffo/19/ and normalized to 1 milli-barn at 14 MeV.

The gamma-ray strength function (0.8245E-4) was adjusted to reproduce the capture cross section of 7 milli-barns at 200 keV measured by Lyon et al./20/

MT = 16 (n,2n) Cross Section
MT = 17 (n,3n) Cross Section
MT = 22 (n,n'a) Cross Section
MT = 28 (n,n'p) Cross Section
MT =103 (n,p) Cross Section
MT =104 (n,d) Cross Section
MT =105 (n,t) Cross Section
MT =107 (n,alpha) Cross Section
These reaction cross sections were calculated with the preequilibrium and multi-step evaporation model code PEGASUS/9/.

The Kalbach's constant K (=203.6) was estimated by the formula derived from Kikuchi-Kawai's formalism/21/ and level density parameters.

Finally, (n,2n), (n,p) and (n,alpha) cross sections were normalized to the following values at 14.5 MeV:

(n,2n)	1500 mb	(measured by Ikeda et al./22/)
(n,p)	3.79 mb	(systematics of Forrest/23/)
(n,alpha)	3.00 mb	(recommended by Forrest/23/)

MT = 251 Mu-bar
Calculated with CASTHY/8/.

MF = 4 Angular Distributions of Secondary Neutrons
Legendre polynomial coefficients for angular distributions are

given in the center-of-mass system for MT=2 and discrete inelastic levels, and in the laboratory system for MT=91. They were calculated with CASTHY/8/. For other reactions, isotropic distributions in the laboratory system were assumed.

MF = 5 Energy Distributions of Secondary Neutrons
Energy distributions of secondary neutrons were calculated with PEGASUS/9/ for inelastic scattering from overlapping levels and for other neutron emitting reactions.

Table 1 Neutron Optical Potential Parameters

Depth (MeV)	Radius(fm)	Diffuseness(fm)
V = 46.0-0.25E	R0 = 5.893	a0 = 0.62
Ws = 7.0	Rs = 6.393	as = 0.35
Wso= 7.0	Rso= 5.893	aso= 0.62

Table 2 Level Density Parameters

Nuclide	SYST	a(/MeV)	T(MeV)	C(/MeV)	EX(MeV)	Pairing
38-Sr- 92	*	1.288E+01	7.065E-01	2.515E-01	6.391E+00	2.360E+00
38-Sr- 93	*	1.386E+01	6.989E-01	1.878E+00	5.664E+00	1.240E+00
38-Sr- 94	*	1.485E+01	6.915E-01	4.495E-01	7.333E+00	2.530E+00
38-Sr- 95	*	1.586E+01	6.842E-01	4.531E+00	6.411E+00	1.240E+00
39-Y - 93		1.150E+01	8.053E-01	1.740E+00	5.854E+00	1.120E+00
39-Y - 94		9.149E+00	7.385E-01	1.378E+00	2.222E+00	0.0
39-Y - 95		1.070E+01	8.306E-01	1.082E+00	5.839E+00	1.290E+00
39-Y - 96	*	1.603E+01	6.771E-01	2.794E+01	5.117E+00	0.0
40-Zr- 94		1.275E+01	7.530E-01	4.411E-01	7.019E+00	2.320E+00
40-Zr- 95		1.331E+01	6.070E-01	5.453E-01	3.985E+00	1.200E+00
40-Zr- 96		1.320E+01	7.000E-01	2.235E-01	6.589E+00	2.490E+00
40-Zr- 97		1.259E+01	5.590E-01	2.497E-01	3.084E+00	1.200E+00

SYST: * = LDP's were determined from systematics.

Spin cutoff params were calculated as 0.146*SQRT(a)*A**(2/3).
In the CASTHY calculation, spin cutoff factors at 0 MeV were assumed to be 3.791 for Zr- 96 and 5 for Zr- 97.

References
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MAT number = 3411

```
 41-Nb- 93 NAIG        Eval-Nov88 M.Kawai, N.Yamamuro
                       Dist-Sep89
History
82-10  Evaluation of resonance parameters for JENDL-2 was made
       by Kawai.
88-10  Evaluation was performed for JENDL-3.
88-10  Compiled by K.Shibata (JAERI).

MF=1          General Information
  MT=451    Descriptive data and dictionary

MF=2          Resonance Parameters
  MT=151
  Resolved resonances: 1.0E-5 eV - 7 keV
     Parameters were taken from JENDL-2.
     Scattering radius: 7.10 fm
     Calculated 2200-m/s cross sections and res. integrals
                 2200-m/s          res. integ.
      elastic    6.322 b               -
      capture    1.152 b            9.488 b
      total      7.474 b               -
  Unresolved resonances: 7 keV - 100 keV
     Determined with the ASREP code/12/ so as to reproduce
     the evaluated sig-c and sig-t up to 100 keV.

MF=3          Neutron Cross Sections
     Slight background correction for sig-t and sig-c
     between 30 keV and 100 keV.
  MT=1      Total
       Below 100 keV   : Background cross sections given.
       100 keV to 20 MeV: Spline-function fitting to the
                          experimental data/1/.
  MT=2      Elastic scattering
       (Total) - (Reaction cross section)
  MT=3      Non elastic
       Sum of MT=4, 16, 17, 22, 28, 102, 103, 104, 107
  MT=4,51-62,91 Inelastic scattering
       The inelastic scattering cross sections to discrete
       levels were calculated with the statistical-model code
       CASTHY/2/, considering level fluctuation, using modified
       Walter-Guss potential parameters for neutrons.
       The components of the direct process were added to
       the levels of MT=53,54,56,57,58,60 by using the
       DWUCK code /3/.
       The cross section to continuum was calculated with the
       the GNASH code /6/ considering pre-equilibrium.

       The level scheme is given as follows:
         No.    Energy(MeV) Spin-Parity
          g.s   0.0         9/2 +
          1.    0.0304      1/2 -
          2.    0.6860      3/2 -
          3.    0.7440      7/2 +
          4.    0.8087      5/2 +
          5.    0.8101      3/2 -
```

6.	0.9499	13/2 +
7.	0.9791	11/2 +
8.	1.0826	9/2 +
9.	1.2900	3/2 -
10.	1.2974	9/2 +
11.	1.3156	5/2 +
12.	1.3351	17/2 +

Levels above 1.34 MeV were assumed to be overlapping.

Optical-model parameters are as follows:
V=52.56-0.30•En, Ws=3.233+0.271•En, Vso=6.004-0.015•En
Vsym=-16.5 , Wi=-0.963+0.153•En, Wso=0.291-0.018•En
r0=1.229 , rs=1.282 , ri=1.42, rso=1.103
a0=0.688 , b=0.512 , ai=0.509, aso=0.56

The level density parameters for GNASH and CASTHY calculations are as follows:

	a (1/MeV)	Ex (MeV)	T (MeV)	Ds (eV)	Gamma-g (eV)
Nb-94	14.4	4.059	0.719	30.0	0.052
NB-93	13.0	5.884	0.834	-	0.170
Nb-92	11.5	3.254	0.790	-	0.170
Nb-91	11.0	5.461	0.895	-	0.170
Zr-93	13.7	5.923	0.781	-	0.140
Zr-92	11.9	6.284	0.858	-	0.140
Y-90	11.1	1.441	0.721	1210.	0.130
Y-89	10.7	2.946	0.762	-	0.130

MT=16 (n,2n)
Based on the experimental data/4,5/.

MT=17,22,28,103,104,107 (n,3n),(n,n'a),(n,n'p),(n,p)
(n,d) and (n,a) cross sections
Calculated with GNASH/6/.
Optical potential parameters for proton, alpha-particle and deuteron were taken from the works of Perey/7/, Lemos/8/ and Lohr and Haeverli/9/, respectively.

MT=102 Radiative capture cross section
1.0E-5 eV to 100 keV: Resonance parameters given.
100 keV to 20 MeV: Calculated with the CASTHY code/2/.
T-gamma=0.0109; determined so as to reproduce sig-c=107mb at 100 keV, measured by Reffo et al./11/

MT=251 Mu-bar
Calculated from File-4.

MF=4 Angular Distributions of Secondary Neutrons
MT=2,51-62
Calculated with CASTHY for equilibrium process
The components of the direct process were added to the levels of MT=53,54,56,57,58,60 by using the DWUCK code /3/.
MT=16, 17, 22, 28
Assumed to be isotropic in the laboratory system
MT=91

The Kalbach-Mann systematics/10/ adopted at 14 MeV.

MF=5 Energy Distributions of Secondary Neutrons
MT=16, 17, 22, 28, 91
Calculated with GNASH.

MF=12 Photon Production Multiplicities
MT=16,17,22,28,52-62,91,102,103,104,107
Calculated with GNASH.

MF=14 Photon Angular Distributions
MT=16,17,22,28,52-62,91,102,103,104,107
Assumed to be isotropic.

MF=15 Photon Energy Distributions
MT=16,17,22,28,91,102,103,104,107
Calculated with GNASH.

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1 of Natural Molybdenum

MAT number = 3420

```
 42-Mo-  0 JNDC,JAERI Eval-Mar89 JNDC FPND W.G., M.Mizumoto
                      Dist-Oct89
History
84-10 Photon production data were evaluated by M.Mizumoto(JAERI).
89-03 Final data for JENDL-3 were compiled from isotope data.

MF = 1  General information
  MT=451 Comments and dictionary

MF = 2  Resonance parameters
  MT=151 Resolved and unresolved resonance parameters
  Resolved resonance region (MLBW formula)
    Evaluated by Kikuchi et al./1/ on the basis of the following
    experiments.
     Mo-92: below 50 keV
       Transmission : Wasson et al./2/
       Capture      : Wasson et al./2/, Weigmann et al./3/,
                      Musgrove et al./4/
     Mo-94: below 20 keV
       Capture      : Weigmann et al./3/, Musgrove et al./4/
     Mo-95: below 2 keV
       Transmission : Shwe et al./5/
       Capture      : Weigmann et al./3/
     Mo-96: below 19 keV
       Capture      : Weigmann et al./3/, Musgrove et al./4/
     Mo-97: below 1.8 keV
       Transmission : Shwe et al./5/
       Capture      : Weigmann et al./3/
     Mo-98: below 32 keV
       Transmission : Chrien et al./6/
       Capture      : Weigmann et al./3/, Musgrove et al./4/
     Mo-100: below 26 keV
       Transmission : Weigmann et al./7/
       Capture      : Weigmann et al./3/, Musgrove et al./4/
   Assumed radiative widths(eV)
                s-wave    p-wave                s-wave    p-wave
        Mo-92   0.02      0.425        Mo-94    0.135     0.175
        Mo-95   0.150     0.180        Mo-96    0.114     0.136
        Mo-97   0.130     0.150        Mo-98    0.085     0.12
        Mo-100  0.065     0.08
 Unresolved resonance region : up to 100 keV
   The neutron strength functions were calculated with optical
   model code CASTHY/8/.  The level spacing was determined to
   reproduce the capture cross section calculated with CASTHY.
   The scattering radius was obtained from fitting to the
   calculated total cross section at 100 keV.

 Typical values of the parameters at 70 keV:
             S0         S1         S2         GG(eV)    Do(eV)   R(fm)
   Mo-92     0.369E-4   5.479E-4   0.364E-4   0.226     2252     6.746
   Mo-94     0.369E-4   5.479E-4   0.365E-4   0.230     1101     6.699
   Mo-95     0.369E-4   5.479E-4   0.365E-4   0.232     76.12    6.680
   Mo-96     0.370E-4   5.480E-4   0.365E-4   0.162     93.33    6.698
   Mo-97     0.370E-4   5.479E-4   0.365E-4   0.180     58.76    6.687
   Mo-98     0.370E-4   5.479E-4   0.364E-4   0.133     765.9    6.675
```

Mo-100	0.370E-4	5.479E-4	0.365E-4	0.085	576.1	6.651

Calculated 2200-m/s cross sections and res. integrals (barns)

	2200 m/s	res. integ.
total	8.066	-
elastic	5.483	-
capture	2.58275	25.7

MF = 3 Neutron cross sections

Below 100 keV, resonance parameters were given. Above 100 keV, the spherical optical and statistical model calculation was performed with CASTHY/8/, by takinq account of competing reactions, of which cross sections were calculated with PEGASUS/9/ standing on a preequilibrium and multi-step evaporation model. The OMP's for neutron given in Table 1 were determined by Iijima et al./10/ to reproduce a systematic trend of the total cross section. The OMP's for charged particles are as follows:

Proton = Perey/11/
Alpha = Huizenga and Igo/12/
Deuteron = Lohr and Haeberli/13/
Helium-3 and triton = Becchetti and Greenlees/14/

Parameters for the composite level density formula of Girbert and Cameron/15/ were evaluated by Iijima et al./16/. More extensive determination and modification were made in the present work. Table 2 shows the level density parameters used in the present calculation. The energy dependence of spin cut-off parameter in the energy range below E-joint (EX) is due to Gruppelaar/17/.

MT = 1 Total

Below 500 keV, spherical optical model calculation was adopted. Above 500 keV, spline-fitting to the data measured by Foster and Glasgow /18/, Lambropoulos et al./19/ and Poenitz and Whalen/20/ was made.

MT = 2 Elastic scattering

Calculated as (total - sum of partial cross sections).

MT = 4, 51 - 91 Inelastic scattering

Spherical optical and statistical model calculation was adopted. The level schemes were taken from Ref./21/ for Mo-92 and -94 ,and from evaluated by Matsumoto et al./22/ for the other isotopes.

The inelastic scattering cross sections for each isotope were grouped in natural Mo data as follows:

MT	-Q(MEV)	MO-92	MO-94	MO-95	MO-96	MO-97	MO-98	MO-100
51	0.2039	-	-	51	-	-	-	-
52	0.4808	-	-	-	-	51	-	-
53	0.5354	-	-	-	-	-	-	51
54	0.6578	-	-	-	-	52,53	-	-
55	0.6941	-	-	-	-	-	-	52
56	0.7194	-	-	-	-	54,55	-	-
57	0.7347	-	-	-	-	-	51	-
58	0.7659	-	-	52	51	-	-	-
59	0.7863	-	-	53	-	-	52	-
60	0.8207	-	-	54	-	-	-	-

61	0.8712	-	51	-	-	56	-	-
62	0.9479	-	-	55	-	-	-	-
63	1.0244	-	-	56	-	57	-	-
64	1.0591	-	-	57,58	-	-	-	53
65	1.0925	-	-	-	-	58,59	-	-
66	1.1356	-	-	-	52	60	-	54
67	1.2226	-	-	59	-	-	-	-
68	1.2685	-	-	-	-	61,62 63,64	-	-
69	1.3101	-	-	60	-	-	-	-
70	1.3761	-	-	61	-	65	-	-
71	1.4320	-	-	62	-	66	53	-
72	1.4468	-	-	-	-	67	-	55
73	1.4978	51	-	-	53	68	54	-
74	1.5412	-	52	63,64	-	69,70	-	-
75	1.6204	-	-	65	54,55	-	-	-
76	1.6702	-	-	66,67,68	-	-	-	-
77	1.7424	-	53	-	-	-	55	56,57
78	1.8646	-	54	-	56	-	56	-
79	1.9073	-	-	69	-	-	-	58
80	1.9646	-	-	-	57	-	57,58	-
81	2.0172	-	55	-	-	-	59	59,60
82	2.0956	-	-	-	58	-	60	61
83	2.2064	-	-	-	59,60	-	61,62	-
84	2.2836	52	56	-	-	-	-	-
85	2.3329	-	-	-	-	-	63,64	62
86	2.3935	-	57,58	-	61	-	65	63
87	2.4384	-	-	-	62,63	-	66	64
88	2.4807	-	-	-	64	-	67,68	-
89	2.5208	53,54	59	-	-	-	-	65
90	2.5676	55	60,61	-	-	-	-	66
91	1.5798	56,57,91	91	91	91	91	91	91

MT = 102 Capture

Spherical optical and statistical model calculation with CASTHY/8/ was adopted. Direct and semi-direct capture cross sections were estimated according to the procedure of Benzi and Reffo/23/ and normalized to 1 milli-barn at 14 MeV. The gamma-ray strength functions were adjusted to reproduce the capture cross section measured by Musgrove et al./3/.

Mo-92: 0.941E-4, Mo-94: 1.966E-4, Mo-95: 29.76E-4,
Mo-96: 1.623E-4, Mo-97: 29.76E-4, Mo-98: 1.623E-4,
Mo-100: 1.432E-4,

MT = 16,17,22,28,32,103,104,105,106,107,111
(n,2n), (n,3n), (n,n'a), (n,n'p), (n,n'd), (n,p), (n,d), (n,t), (n,He3), (n,alpha) and (n,2p) Cross sections

These reaction cross sections were calculated with PEGASUS /9/. The Kalbach's constants were estimated by the formula derived from Kikuchi-Kawai's formalism/24/ and level density parameters. The (n,p) and (n,alpha) cross sections and (n,2n) cross section of Mo-100 were normalized to the experimental data or systematics at 14.5 MeV. For more details, see comment of each isotope.

MT = 251 Mu-bar

Calculated with CASTHY/8/.

MF = 4 Angular Distributions of Secondary Neutrons
Distributions of elastic and inelastic scattering neutrons were calculated with CASTHY/8/. In the case where more than 2 levels were grouped into 1 level, isotropic distribution in the center-of-mass system was assumed. For other reactions, isotropic distributions in the laboratory system were assumed.

MF = 5 Energy Distributions of Secondary Neutrons
Energy distributions of secondary neutrons were calculated with PEGASUS/9/ for inelastic scattering to overlapping levels and for other neutron emitting reactions.

MF =12 Photon Production Multiplicities
MT = 102 (below 420 keV)
Calculated with CASTHY/8/ for each isotope and constructed according to their abundances.

MF =13 Photon Production Cross Sections
MT = 3 (above 420 keV)
Fitted with the empirical formula by Howerton and Plechaty /25/ based on the experimental data/26/.

MF =14 Photon Angular Distributions
MT = 3,102
Assumed to be isotropic.

MF =15 Continuous Photon Energy Spectra
MT = 3
Fitted with the empirical formula by Howerton and Plechaty /25/ based on the experimental data/26/, and compared with experimental data measured by Yamamuro et al./27/.
MT = 102
Calculated with CASTHY/8/ for each isotope and constructed according to their abundances.

Table 1 Neutron Optical Potential Parameters

Depth (MeV)	Radius(fm)	Diffuseness(fm)
V = 46.0-0.25E	R0 = 5.893	a0 = 0.62
Ws = 7.0	Rs = 6.393	as = 0.35
Wso= 7.0	Rso= 5.893	aso= 0.62

Table 2 Level Density Parameters

NUCL.	SYST	a(/MeV)	T(MeV)	C(/MeV)	EX(MeV)	Pairing
40-Zr- 88	*	1.404E+01	7.386E-01	4.932E-01	7.870E+00	2.660E+00
40-Zr- 89		1.095E+01	8.260E-01	1.379E+00	5.864E+00	1.200E+00
40-Zr- 90		9.152E+00	8.222E-01	1.526E-01	5.383E+00	2.130E+00
40-Zr- 91		1.036E+01	8.000E-01	7.822E-01	5.057E+00	1.200E+00
40-Zr- 92		1.088E+01	8.192E-01	5.122E-01	6.429E+00	1.920E+00
40-Zr- 93		1.298E+01	7.000E-01	1.273E+00	5.183E+00	1.200E+00
40-Zr- 94		1.275E+01	7.530E-01	4.411E-01	7.019E+00	2.320E+00
40-Zr- 95		1.331E+01	6.070E-01	5.453E-01	3.985E+00	1.200E+00
40-Zr- 96		1.320E+01	7.000E-01	2.235E-01	6.589E+00	2.490E+00

40-Zr- 97		1.259E+01	5.590E-01	2.497E-01	3.084E+00	1.200E+00
40-Zr- 98	*	1.725E+01	6.633E-01	1.790E+00	7.555E+00	2.140E+00
40-Zr- 99	*	1.831E+01	6.586E-01	1.170E+01	6.957E+00	1.200E+00
41-Nb- 89	*	1.420E+01	7.303E-01	2.467E+00	6.611E+00	1.460E+00
41-Nb- 90	*	1.395E+01	7.222E-01	1.458E+01	4.869E+00	0.0
41-Nb- 91	*	9.464E+00	7.143E-01	3.924E-01	3.082E+00	9.300E-01
41-Nb- 92		1.040E+01	8.410E-01	4.607E+00	4.477E+00	0.0
41-Nb- 93		1.250E+01	7.120E-01	2.205E+00	4.629E+00	7.200E-01
41-Nb- 94		1.281E+01	7.230E-01	7.763E+00	4.250E+00	0.0
41-Nb- 95		1.277E+01	7.500E-01	2.121E+00	5.782E+00	1.120E+00
41-Nb- 96		1.331E+01	5.880E-01	3.406E+00	2.530E+00	0.0
41-Nb- 97		1.337E+01	6.710E-01	9.771E-01	5.026E+00	1.290E+00
41-Nb- 98		1.380E+01	5.110E-01	2.350E+00	1.731E+00	0.0
41-Nb- 99	*	1.742E+01	6.566E-01	1.085E+01	6.300E+00	9.400E-01
41-Nb-100	*	1.850E+01	6.500E-01	7.329E+01	5.699E+00	0.0
42-Mo- 90	*	1.436E+01	7.222E-01	4.129E-01	7.834E+00	2.740E+00
42-Mo- 91		1.168E+01	7.820E-01	1.284E+00	5.770E+00	1.280E+00
42-Mo- 92		1.064E+01	7.770E-01	2.062E-01	5.938E+00	2.210E+00
42-Mo- 93		1.125E+01	7.800E-01	9.792E-01	5.457E+00	1.280E+00
42-Mo- 94		1.301E+01	6.850E-01	3.417E-01	5.770E+00	2.000E+00
42-Mo- 95		1.360E+01	7.150E-01	1.847E+00	5.835E+00	1.280E+00
42-Mo- 96		1.403E+01	7.410E-01	6.991E-01	7.645E+00	2.400E+00
42-Mo- 97		1.517E+01	6.800E-01	2.769E+00	6.036E+00	1.280E+00
42-Mo- 98		1.594E+01	6.900E-01	7.358E-01	7.888E+00	2.570E+00
42-Mo- 99		1.774E+01	6.200E-01	4.294E+00	6.058E+00	1.280E+00
42-Mo-100		1.780E+01	6.000E-01	6.702E-01	6.645E+00	2.220E+00
42-Mo-101		2.085E+01	5.650E-01	7.153E+00	6.092E+00	1.280E+00

SYST: * = LDP's were determined from systematics.
Spin cut-off params were calculated as 0.146*SQRT(a)*A**(2/3).

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MAT number = 3421

42-Mo- 92 JNDC Eval-Aug89 JNDC FP Nuclear Data W.G.
Dist-Oct89

History
84-10 Evaluation for JENDL-2 was made by JNDC FPND W.G./1/
89-08 Modification for JENDL-3 was made/2/.

MF = 1 General information
MT=451 Comments and dictionary

MF = 2 Resonance parameters
MT=151 Resolved and unresolved resonance parameters
Resolved resonance region (MLBW formula) : below 50 keV
Resonance parameters were evaluated by Kikuchi et al./3/ on the basis of the following experiments.
Transmission : Wasson et al./4/
Capture : Wasson et al./4/, Weigmann et al./5/, Musgrove et al./6/
Average radiative widths of 0.02 eV for s-wave res. and 0.425 eV for p-wave res were adopted. Scattering radius was taken from Mughabghab et al./7/
Unresolved resonance region : 50 keV - 100 keV
The neutron strength functions, S0, S1 and S2 were calculated with optical model code CASTHY/8/. The observed level spacing was determined to reproduce the capture cross section calculated with CASTHY/8/. The effective scattering radius was obtained from fitting to the calculated total cross section at 100 keV.

Typical values of the parameters at 70 keV:
S0 = 0.369E-4, S1 = 5.479E-4, S2 = 0.364 E-4, GG = 0.226 eV
Do = 2252 eV, R = 6.746 fm.

Calculated 2200-m/s cross sections and res. integrals (barns)

	2200 m/s	res. integ.
total	5.566	-
elastic	5.545	-
capture	0.02075	0.968

MF = 3 Neutron cross sections
Below 100 keV, resonance parameters were given. Above 100 keV, the spherical optical and statistical model calculation was performed with CASTHY/8/, by taking account of competing reactions, of which cross sections were calculated with PEGASUS/9/ standing on a preequilibrium and multi-step evaporation model. The OMP's for neutron given in Table 1 were determined by Iijima et al./10/ to reproduce a systematic trend of the total cross section. The OMP's for charged particles are as follows:
Proton = Perey/11/
Alpha = Huizenga and Igo/12/
Deuteron = Lohr and Haeberli/13/
Helium-3 and triton = Becchetti and Greenlees/14/
Parameters for the composite level density formula of Girbert and Cameron/15/ were evaluated by Iijima et al./16/. More extensive determination and modification were made in the

present work. Table 2 shows the level density parameters used in the present calculation. The energy dependence of spin cut-off parameter in the energy range below E-joint (EX) is due to Gruppelaar/17/.

MT = 1 Total
Spherical optical model calculation was adopted.

MT = 2 Elastic scattering
Calculated as (total - sum of partial cross sections).

MT = 4, 51 - 91 Inelastic scattering
Spherical optical and statistical model calculation was adopted. The level scheme was taken from Ref./18/.

No.	Energy(MeV)	Spin-parity
GR.	0.0	0 +
1	1.5095	2 +
2	2.2826	4 +
3	2.5197	0 +
4	2.5270	5 -
5	2.6130	6 +
6	2.7600	8 +
7	2.8497	3 -

Levels above 3.0 MeV were assumed to be overlapping.

MT = 102 Capture
Spherical optical and statistical model calculation with CASTHY/8/ was adopted. Direct and semi-direct capture cross sections were estimated according to the procedure of Benzi and Reffo/19/ and normalized to 1 milli-barn at 14 MeV.

The gamma-ray strength function (9.406E-05) was adjusted to reproduce the experimental capture cross section measured by Musgrove et al./5/.

MT = 16 (n,2n) Cross Section
MT = 22 (n,n'a) Cross Section
MT = 28 (n,n'p) Cross Section
MT =103 (n,p) Cross Section
MT =104 (n,d) Cross Section
MT =105 (n,t) Cross Section
MT =106 (n,He3) Cross Section
MT =107 (n,alpha) Cross Section
MT =111 (n,2p) Cross Section
These reaction cross sections were calculated with the preequilibrium and multi-step evaporation model code PEGASUS/9/.

The Kalbach's constant K (= 251.4) was estimated by the formula derived from Kikuchi-Kawai's formalism/20/ and level density parameters.

Finally, (n,p) and (n,alpha) cross sections were normalized to the following values at 14.5 MeV:
(n,p) 116 mb (systematics of Forrest/21/)
(n,alpha) 24 mb (measured by Ikeda et al./22/)

The (n,2n) cross section was determined by eye-guiding of the data measured by Bormann et al./23/ and Brolley et al./24/.

MT = 251 Mu-bar
Calculated with CASTHY/8/.

MF = 4 Angular Distributions of Secondary Neutrons
Legendre polynomial coefficients for angular distributions are given in the center-of-mass system for MT=2 and discrete inelastic levels, and in the laboratory system for MT=91. They were calculated with CASTHY/8/.

MF = 5 Energy Distributions of Secondary Neutrons
Energy distributions of secondary neutrons were calculated with PEGASUS/9/ for inelastic scattering to overlapping levels and for other neutron emitting reactions.

Table 1 Neutron Optical Potential Parameters

Depth (MeV)	Radius(fm)	Diffuseness(fm)
V = 46.0-0.25E	R0 = 5.893	a0 = 0.62
Ws = 7.0	Rs = 6.393	as = 0.35
Wso= 7.0	Rso= 5.893	aso= 0.62

Table 2 Level Density Parameters

NUCL.	SYST	a(/MeV)	T(MeV)	C(/MeV)	EX(MeV)	Pairing
40-Zr- 88	*	1.404E+01	7.386E-01	4.932E-01	7.870E+00	2.660E+00
40-Zr- 89		1.095E+01	8.260E-01	1.379E+00	5.864E+00	1.200E+00
40-Zr- 90		9.152E+00	8.222E-01	1.526E-01	5.383E+00	2.130E+00
40-Zr- 91		1.036E+01	8.000E-01	7.822E-01	5.057E+00	1.200E+00
41-Nb- 89	*	1.420E+01	7.303E-01	2.467E+00	6.611E+00	1.460E+00
41-Nb- 90	*	1.395E+01	7.222E-01	1.458E+01	4.869E+00	0.0
41-Nb- 91	*	9.464E+00	7.143E-01	3.924E-01	3.082E+00	9.300E-01
41-Nb- 92		1.040E+01	8.410E-01	4.607E+00	4.477E+00	0.0
42-Mo- 90	*	1.436E+01	7.222E-01	4.129E-01	7.834E+00	2.740E+00
42-Mo- 91		1.168E+01	7.820E-01	1.284E+00	5.770E+00	1.280E+00
42-Mo- 92		1.064E+01	7.770E-01	2.062E-01	5.938E+00	2.210E+00
42-Mo- 93		1.125E+01	7.800E-01	9.792E-01	5.457E+00	1.280E+00

SYST: * = LDP's were determined from systematics.

Spin cut-off params were calculated as 0.146*SQRT(a)*A**(2/3).
In the CASTHY caluculation, spin cut-off factors at 0 MeV were assumed to be 13.13 for Mo-92 and 5.000 for Mo-93.

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MAT number = 3422

42-Mo- 94 JNDC Eval-Aug89 JNDC FP Nuclear Data W.G.
Dist-Oct89

History
84-10 Evaluation for JENDL-2 was made by JNDC FPND W.G./1/
89-08 Modification for JENDL-3 was made/2/.

MF = 1 General information
MT=451 Comments and dictionary

MF = 2 Resonance parameters
MT=151 Resolved and unresolved resonance parameters
Resolved resonance region (MLBW formula) : below 20 keV
Evaluation was made by Kikuchi et al./3/ on the basis of the following experimental data:
Capture : Weigmann et al./4/, Musgrove et al./5/
Average radiative widths were assumed to be 0.135 eV and 0.175 eV for s-wave and p-wave resonances, respectively.
Unresolved resonance region : 20 keV - 100 keV
The neutron strength functions, S0, S1 and S2 were calculated with optical model code CASTHY/6/.
The observed level spacing was determined to reproduce the capture cross section calculated with CASTHY. The effective scattering radiu was obtained from fitting to the calculated total cross section at 100 keV.

Typical values of the parameters at 70 keV:
S0 = 0.369E-4, S1 = 5.479E-4, S2 = 0.365 E-4, GG = 0.230 eV
Do = 1101 eV, R = 6.699 fm.

Calculated 2200-m/s cross sections and res. integrals (barns)

	2200 m/s	res. integ.
total	6.011	-
elastic	5.998	-
capture	0.01311	1.40

MF = 3 Neutron cross sections
Below 100 keV, resonance parameters were given. Above 100 keV, the spherical optical and statistical model calculation was performed with CASTHY/6/, by taking account of competing reactions, of which cross sections were calculated with PEGASUS/7/ standing on a preequilibrium and multi-step evaporation model. The OMP's for neutron given in Table 1 were determined by Iijima et al./8/ to reproduce a systematic trend of the total cross section. The OMP's for charged particles are as follows:
Proton = Perey/9/
Alpha = Huizenga and Igo/10/
Deuteron = Lohr and Haeberli/11/
Helium-3 and triton = Becchetti and Greenlees/12/
Parameters for the composite level density formula of Girbert-Cameron/13/ were evaluated by Iijima et al./14/. More extensive determination and modification were made in the present work. Table 2 shows the level density parameters used in the present calculation. The energy dependence of spin cut-off parameter in the energy range below E-joint (EX) is due

to Gruppelaar/15/.

MT = 1· Total
Spherical optical model calculation was adopted.

MT = 2 Elastic scattering
Calculated as (total - sum of partial cross sections).

MT = 4, 51 - 91 Inelastic scattering
Spherical optical and statistical model calculation was adopted. The level scheme was taken from Ref./16/.

No.	Energy(MeV)	Spin-parity
GR.	0.0	0 +
1	0.8710	2 +
2	1.5737	4 +
3	1.7420	0 +
4	1.8642	2 +
5	2.0674	2 +
6	2.2940	4 +
7	2.3930	2 +
8	2.4230	6 +
9	2.5337	3 -
10	2.5670	4 +
11	2.6100	5 -

Levels above 2.74 MeV were assumed to be overlapping.

MT = 102 Capture
Spherical optical and statistical model calculation with CASTHY/6/ was adopted. Direct and semi-direct capture cross sections were estimated according to the procedure of Benzi and Reffo/17/ and normalized to 1 milli-barn at 14 MeV.

The gamma-ray strength function (=1.966E-4) was adjusted to reproduce the experimental capture cross section of 54.5 milli-barns at 100 keV measured by Musgrove et al./5/.

MT = 16 (n,2n) Cross Section
MT = 17 (n,3n) Cross Section
MT = 22 (n,n'a) Cross Section
MT = 28 (n,n'p) Cross Section
MT = 32 (n,n'd) Cross Section
MT =103 (n,p) Cross Section
MT =104 (n,d) Cross Section
MT =105 (n,t) Cross Section
MT =106 (n,He3) Cross Section
MT =107 (n,alpha) Cross Section
MT =111 (n,2p) Cross Section
These reaction cross sections were calculated with the pre-equilibrium and multi-step evaporation model code PEGASUS /7/.

The Kalbach's constant K (= 151.7) was estimated by the formula derived from Kikuchi-Kawai's formalism/18/ and level density parameters.

Finally, (n,p) and (n,alpha) cross sections were normalized to

the following values at 14.5 MeV:
(n,p) 55.10 mb (systematics of Forrest/19/)
(n,alpha) 17.50 mb (recommended by Forrest/19/)

MT = 251 Mu-bar
Calculated with CASTHY/6/.

MF = 4 Angular Distributions of Secondary Neutrons
Legendre polynomial coefficients for angular distributions are given in the center-of-mass system for MT=2 and discrete inelastic levels, and in the laboratory system for MT=91. They were calculated with CASTHY/6/.

MF = 5 Energy Distributions of Secondary Neutrons
Energy distributions of secondary neutrons were calculated with PEGASUS/7/ for inelastic scattering from overlapping levels and for other neutron emitting reactions.

Table 1 Neutron Optical Potential Parameters

Depth (MeV)	Radius(fm)	Diffuseness(fm)
V = 46.0-0.25E	R0 = 5.893	a0 = 0.62
Ws = 7.0	Rs = 6.393	as = 0.35
Wso= 7.0	Rso= 5.893	aso= 0.62

Table 2 Level Density Parameters

Nucl.	SYST	a(/MeV)	T(MeV)	C(/MeV)	EX(MeV)	Pairing
40-Zr- 90		9.152E+00	8.222E-01	1.526E-01	5.383E+00	2.130E+00
40-Zr- 91		1.036E+01	8.000E-01	7.822E-01	5.057E+00	1.200E+00
40-Zr- 92		1.088E+01	8.192E-01	5.122E-01	6.429E+00	1.920E+00
40-Zr- 93		1.298E+01	7.000E-01	1.273E+00	5.183E+00	1.200E+00
41-Nb- 91	*	9.464E+00	7.143E-01	3.924E-01	3.082E+00	9.300E-01
41-Nb- 92		1.040E+01	8.410E-01	4.607E+00	4.477E+00	0.0
41-Nb- 93		1.250E+01	7.120E-01	2.205E+00	4.629E+00	7.200E-01
41-Nb- 94		1.281E+01	7.230E-01	7.763E+00	4.250E+00	0.0
42-Mo- 92		1.064E+01	7.770E-01	2.062E-01	5.938E+00	2.210E+00
42-Mo- 93		1.125E+01	7.800E-01	9.792E-01	5.457E+00	1.280E+00
42-Mo- 94		1.301E+01	6.850E-01	3.417E-01	5.770E+00	2.000E+00
42-Mo- 95		1.360E+01	7.150E-01	1.847E+00	5.835E+00	1.280E+00

SYST: * = LDP's were determined from systematics.

Spin cut-off params were calculated as 0.146*SQRT(a)*A**(2/3).
In the CASTHY caluculation, spin cut-off factors at 0 MeV were assumed to be 7.761 for Mo-94 and 6.184 for Mo-95.

References
1) Aoki, T. et al.: Proc. Int. Conf. on Nuclear Data for Basic and Applied Science, Santa Fe., Vol. 2, p.1627 (1985).
2) Kawai, M. et al.: Proc. Int. Conf. on Nuclear Data for Science and Technology, Mito, p. 569 (1988).
3) Kikuchi, Y. et al.: JAERI-M 86-030 (1986).

4) Weigmann H. et al.: 1971 Knoxville, 749 (1971).
5) Musgrove A.R.de L.: Nucl. Phys., A270, 108 (1976).
6) Igarasi, S.: J. Nucl. Sci. Technol., 12, 67 (1975).
7) Iijima, S. et al.: JAERI-M 87-025, p. 337 (1987).
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12) Becchetti, F.D., Jr. and Greenlees, G.W.: Polarization Phenomena in Nuclear Reactions ((eds) H.H. Barshall and W. Haeberli), p. 682, The university of Wisconsin Press. (1971).
13) Gilbert, A. and Cameron, A.G.W.: Can. J. Phys., 43, 1446 (1965).
14) Iijima, S., et al.: J. Nucl. Sci. Technol. 21, 10 (1984).
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19) Forrest, R.A.: AERE-R 12419 (1986).

MAT number = 3423

42-Mo- 95 JNDC Eval-Aug89 JNDC FP Nuclear Data W.G.
Dist-Oct89

History
84-10 Evaluation for JENDL-2 was made by JNDC FPND W.G./1/
89-08 Modification for JENDL-3 was made/2/.

MF = 1 General information
MT=451 Comments and dictionary

MF = 2 Resonance parameters
MT=151 Resolved and unresolved resonance parameters
Resolved resonance region (MLBW formula) : below 2 keV
Evaluation was made by Kikuchi et al./3/ on the basis of the following experimental data.
Transmission : Shwe et al./4/
Capture : Weigmann et al./5/
Assumed Gam-g : 0.150 eV for s-wave and 0.180 eV for p-wave resonance.
A negative resonance was added at -20 eV. Values of total spin J were assumed arbitrarily for levels whose J has not been determined.
Unresolved resonance region : 2 keV - 100 keV
The neutron strength functions, S0, S1 and S2 were calculated with optical model code CASTHY/6/. The observed level spacing was determined to reproduce the capture cross section calculated with CASTHY. The effective scattering radius was obtained from fitting to the calculated total cross section at 100 keV.

Typical values of the parameters at 70 keV:
S0 = 0.369E-4, S1 = 5.479E-4, S2 = 0.365 E-4, GG = 0.232 eV
Do = 76.12 eV, R = 6.680 fm.

Calculated 2200-m/s cross sections and res. integrals (barns)

	2200 m/s	res. integ.
total	19.560	-
elastic	5.566	-
capture	13.99	119

MF = 3 Neutron cross sections
Below 100 keV, resonance parameters were given. Above 100 keV, the spherical optical and statistical model calculation was performed with CASTHY/6/, by taking account of competing reactions, of which cross sections were calculated with PEGASUS/7/ standing on a preequilibrium and multi-step evaporation model. The OMP's for neutron given in Table 1 were determined by Iijima et al./8/ to reproduce a systematic trend of the total cross section. The OMP's for charged particles are as follows:
Proton = Perey/9/
Alpha = Huizenga and Igo/10/
Deuteron = Lohr and Haeberli/11/
Helium-3 and triton = Becchetti and Greenlees/12/
Parameters for the composite level density formula of Girbert and Cameron/13/ were evaluated by Iijima et al./14/. More

extensive determination and modification were made in the present work. Table 2 shows the level density parameters used in the present calculation. Energy dependence of spin cut-off parameter in the energy range below E-joint is due to Gruppelaar /15/.

MT = 1 Total
Spherical optical model calculation was adopted.

MT = 2 Elastic scattering
Calculated as (total - sum of partial cross sections).

MT = 4, 51 - 91 Inelastic scattering
Spherical optical and statistical model calculation was adopted. The level scheme was taken from Ref./16/.

No.	Energy(MeV)	Spin-parity
GR.	0.0	5/2 +
1	0.2039	3/2 +
2	0.7658	7/2 +
3	0.7862	1/2 +
4	0.8206	3/2 +
5	0.9478	9/2 +
6	1.0391	1/2 +
7	1.0590	5/2 +
8	1.0741	7/2 +
9	1.2225	5/2 +
10	1.3100	1/2 +
11	1.3760	3/2 +
12	1.4330	5/2 +
13	1.5410	11/2 +
14	1.5528	9/2 +
15	1.6202	3/2 +
16	1.6700	5/2 +
17	1.6830	9/2 +
18	1.7070	1/2 +
19	1.9380	11/2 -

Levels above 2.0 MeV were assumed to be overlapping.

MT = 102 Capture
Spherical optical and statistical model calculation with CASTHY/6/ was adopted. Direct and semi-direct capture cross sections were estimated according to the procedure of Benzi and Reffo/17/ and normalized to 1 milli-barn at 14 MeV.

The gamma-ray strength function (2.976E-03) was adjusted to reproduce the experimental capture cross section of 0.4 barn at 30 keV measured by Musgrove et al./18/

MT = 16 (n,2n) Cross Section
MT = 17 (n,3n) Cross Section
MT = 22 (n,n'a) Cross Section
MT = 28 (n,n'p) Cross Section
MT = 32 (n,n'd) Cross Section
MT =103 (n,p) Cross Section
MT =104 (n,d) Cross Section
MT =105 (n,t) Cross Section

MT =106 (n,He3) Cross Section
MT =107 (n,alpha) Cross Section
These reaction cross sections were calculated with the preequilibrium and multi-step evaporation model code PEGASUS/7/.

The Kalbach's constant K (= 142.6) was estimated by the formula derived from Kikuchi-Kawai's formalism/19/ and level density parameters.

Finally, (n,p) and (n,alpha) cross sections were normalized to the following values at 14.5 MeV:

(n,p)	38.00 mb	(recommended by Forrest/20/)
(n,alpha)	13.50 mb	(recommended by Forrest/20/)

MT = 251 Mu-bar
Calculated with CASTHY/6/.

MF = 4 Angular Distributions of Secondary Neutrons
Legendre polynomial coefficients for angular distributions are given in the center-of-mass system for MT=2 and discrete inelastic levels, and in the laboratory system for MT=91. They were calculated with CASTHY/6/.

MF = 5 Energy Distributions of Secondary Neutrons
Energy distributions of secondary neutrons were calculated with PEGASUS/7/ for inelastic scattering from overlapping levels and for other neutron emitting reactions.

Table 1 Neutron Optical Potential Parameters

Depth (MeV)	Radius(fm)	Diffuseness(fm)
V = 46.0-0.25E	R0 = 5.893	a0 = 0.62
Ws = 7.0	Rs = 6.393	as = 0.35
Wso= 7.0	Rso= 5.893	aso= 0.62

Table 2 Level Density Parameters

Nuclide	a(/MeV)	T(MeV)	C(/MeV)	EX(MeV)	Pairing
40-Zr- 91	1.036E+01	8.000E-01	7.822E-01	5.057E+00	1.200E+00
40-Zr- 92	1.088E+01	8.192E-01	5.122E-01	6.429E+00	1.920E+00
40-Zr- 93	1.298E+01	7.000E-01	1.273E+00	5.183E+00	1.200E+00
40-Zr- 94	1.275E+01	7.530E-01	4.411E-01	7.019E+00	2.320E+00
41-Nb- 92	1.040E+01	8.410E-01	4.607E+00	4.477E+00	0.0
41-Nb- 93	1.250E+01	7.120E-01	2.205E+00	4.629E+00	7.200E-01
41-Nb- 94	1.281E+01	7.230E-01	7.763E+00	4.250E+00	0.0
41-Nb- 95	1.277E+01	7.500E-01	2.121E+00	5.782E+00	1.120E+00
42-Mo- 93	1.125E+01	7.800E-01	9.792E-01	5.457E+00	1.280E+00
42-Mo- 94	1.301E+01	6.850E-01	3.417E-01	5.770E+00	2.000E+00
42-Mo- 95	1.360E+01	7.150E-01	1.847E+00	5.835E+00	1.280E+00
42-Mo- 96	1.403E+01	7.410E-01	6.991E-01	7.645E+00	2.400E+00

Spin cut-off params were calculated as 0.146*SQRT(a)*A**(2/3). *In the* CASTHY caluculation, spin cut-off factors at 0 MeV were assumed to be 6.184 for Mo-95 and 7.696 for Mo-96.

References

1) Aoki, T. et al.: Proc. Int. Conf. on Nuclear Data for Basic and Applied Science, Santa Fe., Vol. 2, p.1627 (1985).
2) Kawai, M. et al.: Proc. Int. Conf. on Nuclear Data for Science and Technology, Mito, p. 569 (1988).
3) Kikuchi Y. et al.: JAERI-M 86-030 (1986).
4) Shwe H. and Cote R.E.: Phys. Rev. 179, 1148 (1969).
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6) Igarasi, S.: J. Nucl. Sci. Technol., 12, 67 (1975).
7) Iijima, S. et al.: JAERI-M 87-025, p. 337 (1987).
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9) Perey, F.G: Phys. Rev. 131, 745 (1963).
10) Huizenga, J.R. and Igo, G.: Nucl. Phys. 29, 462 (1962).
11) Lohr, J.M. and Haeberli, W.: Nucl. Phys. A232, 381 (1974).
12) Becchetti, F.D., Jr. and Greenlees, G.W.: Polarization Phenomena in Nuclear Reactions ((eds) H.H. Barshall and W. Haeberli), p. 682, The university of Wisconsin Press. (1971).
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14) Iijima, S., et al.: J. Nucl. Sci. Technol. 21, 10 (1984).
15) Gruppelaar, H.: ECN-13 (1977).
16) Lederer, C.M., et al.: "Table of Isotopes, 7th Ed.", Wiley-Interscience Publication (1978).
17) Benzi, V. and Reffo, G.: CCDN-NW/10 (1969).
18) Musgrove A.R.de L. et al.: Nucl. Phys., A270, 108 (1976).
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MAT number = 3424

42-Mo- 96 JNDC Eval-Aug89 JNDC FP Nuclear Data W.G.
Dist-Oct89

History
84-10 Evaluation for JENDL-2 was made by JNDC FPND W.G./1/
89-08 Modification for JENDL-3 was made/2/.

MF = 1 General information
MT=451 Comments and dictionary

MF = 2 Resonance parameters
MT=151 Resolved and unresolved resonance parameters
Resolved resonance region (MLBW formula) : below 19 keV
Evaluation was made by Kikuchi et al./3/
Capture : Weigmann et al./4/, Musgrove et al./5/
Average radiative widths were assumed to be 0.114 eV and 0.136 eV for s-wave and p-wave resonances, respectively.
Unresolved resonance region : 19 keV - 100 keV
The neutron strength functions, S0, S1 and S2 were calculated with optical model code CASTHY/6/. The observed level spacing was determined to reproduce the capture cross section calculated with CASTHY. The effective scattering radius was obtained from fitting to the calculated total cross section at 100 keV.

Typical values of the parameters at 70 keV:
S0 = 0.370E-4, S1 = 5.480E-4, S2 = 0.365E-4, GG = 0.162 eV
Do = 93.33 eV, R = 6.698 fm.

Calculated 2200-m/s cross sections and res. integrals (barns)

	2200 m/s	res. integ.
total	5.322	-
elastic	4.727	-
capture	0.5954	17.5

MF = 3 Neutron cross sections
Below 100 keV, resonance parameters were given. Above 100 keV, the spherical optical and statistical model calculation was performed with CASTHY/6/, by taking account of competing reactions, of which cross sections were calculated with PEGASUS/7/ standing on a preequilibrium and multi-step evaporation model. The OMP's for neutron given in Table 1 were determined by Iijima et al./8/ to reproduce a systematic trend of the total cross section. The OMP's for charged particles are as follows:
Proton = Perey/9/
Alpha = Huizenga and Igo/10/
Deuteron = Lohr and Haeberli/11/
Helium-3 and triton = Becchetti and Greenlees/12/
Parameters for the composite level density formula of Girbert and Cameron/13/ were evaluated by Iijima et al./14/. More extensive determination and modification were made in the present work. Table 2 shows the level density parameters used in the present calculation. Energy dependence of spin cut-off parameter in the energy range below E-joint is due to Gruppelaar /15/.

MT = 1 Total
Spherical optical model calculation was adopted.

MT = 2 Elastic scattering
Calculated as (total - sum of partial cross sections).

MT = 4, 51 - 91 Inelastic scattering
Spherical optical and statistical model calculation was adopted. The level scheme was taken from Ref./16/.

No.	Energy(MeV)	Spin-parity
GR.	0.0	0 +
1	0.7783	2 +
2	1.1479	0 +
3	1.4978	2 +
4	1.6260	2 +
5	1.6280	4 +
6	1.8695	4 +
7	1.9783	3 +
8	2.0956	2 +
9	2.2193	4 +
10	2.2345	3 -
11	2.4262	3 +
12	2.4384	5 +
13	2.4406	6 +
14	2.4807	4 +

Levels above 2.5 MeV were assumed to be overlapping.

MT = 102 Capture
Spherical optical and statistical model calculation with CASTHY/6/ was adopted. Direct and semi-direct capture cross sections were estimated according to the procedure of Benzi and Reffo/17/ and normalized to 1 milli-barn at 14 MeV.

The gamma-ray strength function (1.623E-04) was adjusted to reproduce the experimental capture cross section measured by Musgrove et al./5/

MT = 16 (n,2n) Cross Section
MT = 17 (n,3n) Cross Section
MT = 22 (n,n'a) Cross Section
MT = 28 (n,n'p) Cross Section
MT = 32 (n,n'd) Cross Section
MT =103 (n,p) Cross Section
MT =104 (n,d) Cross Section
MT =105 (n,t) Cross Section
MT =107 (n,alpha) Cross Section
These reaction cross sections were calculated with the preequilibrium and multi-step evaporation model code PEGASUS/7/.

The Kalbach's constant K (=116.4) was estimated by the formula derived from Kikuchi-Kawai's formalism/18/ and level density parameters.

Finally, (n,p) and (n,alpha) cross sections were normalized to

the following values at 14.5 MeV:
(n,p) 23.00 mb (measured by Ikeda et al./19/)
(n,alpha) 10.00 mb (recommended by Forrest/20/)

MT = 251 Mu-bar
Calculated with CASTHY/6/.

MF = 4 Angular Distributions of Secondary Neutrons
Legendre polynomial coefficients for angular distributions are given in the center-of-mass system for MT=2 and discrete inelastic levels, and in the laboratory system for MT=91. They were calculated with CASTHY/6/.

MF = 5 Energy Distributions of Secondary Neutrons
Energy distributions of secondary neutrons were calculated with PEGASUS/7/ for inelastic scattering from overlapping levels and for other neutron emitting reactions.

Table 1 Neutron Optical Potential Parameters

Depth (MeV)	Radius(fm)	Diffuseness(fm)
V = 46.0-0.25E	R0 = 5.893	a0 = 0.62
Ws = 7.0	Rs = 6.393	as = 0.35
Wso= 7.0	Rso= 5.893	aso= 0.62

Table 2 Level Density Parameters

Nuclide	a(/MeV)	T(MeV)	C(/MeV)	EX(MeV)	Pairing
40-Zr- 92	1.088E+01	8.192E-01	5.122E-01	6.429E+00	1.920E+00
40-Zr- 93	1.298E+01	7.000E-01	1.273E+00	5.183E+00	1.200E+00
40-Zr- 94	1.275E+01	7.530E-01	4.411E-01	7.019E+00	2.320E+00
40-Zr- 95	1.331E+01	6.070E-01	5.453E-01	3.985E+00	1.200E+00
41-Nb- 93	1.250E+01	7.120E-01	2.205E+00	4.629E+00	7.200E-01
41-Nb- 94	1.281E+01	7.230E-01	7.763E+00	4.250E+00	0.0
41-Nb- 95	1.277E+01	7.500E-01	2.121E+00	5.782E+00	1.120E+00
41-Nb- 96	1.331E+01	5.880E-01	3.406E+00	2.530E+00	0.0
42-Mo- 94	1.301E+01	6.850E-01	3.417E-01	5.770E+00	2.000E+00
42-Mo- 95	1.360E+01	7.150E-01	1.847E+00	5.835E+00	1.280E+00
42-Mo- 96	1.403E+01	7.410E-01	6.991E-01	7.645E+00	2.400E+00
42-Mo- 97	1.517E+01	6.800E-01	2.769E+00	6.036E+00	1.280E+00

Spin cut-off params were calculated as 0.146*SQRT(a)*A**(2/3). In the CASTHY caluculation, spin cut-off factors at 0 MeV were assumed to be 7.696 for Mo- 96 and 7.075 for Mo- 97.

References
1) Aoki, T. et al.: Proc. Int. Conf. on Nuclear Data for Basic and Applied Science, Santa Fe., Vol. 2, p.1627 (1985).
2) Kawai, M. et al.: Proc. Int. Conf. on Nuclear Data for Science and Technology, Mito, p. 569 (1988).
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4) Weigmann H. et al.: 1971 Knoxville, 749 (1971).

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7) Iijima, S. et al.: JAERI-M 87-025, p. 337 (1987).
8) Iijima, S. and Kawai, M.: J. Nucl. Sci. Technol., 20, 77 (1983).
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MAT number = 3425

42-Mo- 97 JNDC Eval-Aug89 JNDC FP Nuclear Data W.G.
Dist-Oct89

History
84-10 Evaluation for JENDL-2 was made by JNDC FPND W.G./1/
89-08 Modification for JENDL-3 was made/2/.

MF = 1 General information
MT=451 Comments and dictionary

MF = 2 Resonance parameters
MT=151 Resolved and unresolved resonance parameters
Resolved resonance region (MLBW formula) : below 1.8 keV
Evaluation was made by Kikuchi et al./3/ on the basis of the following experimental data.
Transmission : Shwe et al./4/
Capture : Weigmann et al./5/
Assumed Gamma-g : 0.130 eV for s-wave and 0.150 eV for p-wave resonances.
A negative resonance added at -20 eV. Values of total spin J were assumed arbitrarily for levels whose j has not been determined.
Unresolved resonance region : 1.8 keV - 100 keV
The neutron strength functions, S0, S1 and S2 were calculated with optical model code CASTHY/6/. The observed level spacing was determined to reproduce the capture cross section calculated with CASTHY. The effective scattering radius was obtained from fitting to the calculated total cross section at 100 keV.

Typical values of the parameters at 70 keV:
S0 = 0.370E-4, S1 = 5.479E-4, S2 = 0.365E-4, GG = 0.180 eV
Do = 58.76 eV, R = 6.687 fm.

Calculated 2200-m/s cross sections and res. integrals (barns)

	2200 m/s	res. integ.
total	7.957	-
elastic	5.857	-
capture	2.100	17.1

MF = 3 Neutron cross sections
Below 100 keV, resonance parameters were given. Above 100 keV, the spherical optical and statistical model calculation was performed with CASTHY/6/, by taking account of competing reactions, of which cross sections were calculated with PEGASUS/7/ standing on a preequilibrium and multi-step evaporation model. The OMP's for neutron given in Table 1 were determined by Iijima et al./8/ to reproduce a systematic trend of the total cross section. The OMP's for charged particles are as follows:
Proton = Perey/9/
Alpha = Huizenga and Igo/10/
Deuteron = Lohr and Haeberli/11/
Helium-3 and triton = Becchetti and Greenlees/12/
Parameters for the composite level density formula of Girbert and Cameron/13/ were evaluated by Iijima et al./14/. More

extensive determination and modification were made in the present work. Table 2 shows the level density parameters used in the present calculation. Energy dependence of spin cut-off parameter in the energy range below E-joint is due to Gruppelaar /15/.

MT = 1 Total
Spherical optical model calculation was adopted.

MT = 2 Elastic scattering
Calculated as (total - sum of partial cross sections).

MT = 4, 51 - 91 Inelastic scattering
Spherical optical and statistical model calculation was adopted. The level scheme was taken from Ref./16/.

No.	Energy(MeV)	Spin-parity
GR.	0.0	5/2 +
1	0.4809	3/2 +
2	0.6579	7/2 +
3	0.6796	1/2 +
4	0.7195	5/2 +
5	0.7211	3/2 +
6	0.8882	1/2 +
7	1.0245	7/2 +
8	1.0926	3/2 +
9	1.1167	9/2 +
10	1.1486	7/2 -
11	1.2686	7/2 +
12	1.2730	3/2 +
13	1.2840	13/2 +
14	1.2846	3/2 +
15	1.4095	11/2 +
16	1.4373	11/2 -
17	1.4470	3/2 +
18	1.5156	9/2 +
19	1.5452	5/2 -
20	1.5651	3/2 +

Levels above 1.58 MeV were assumed to be overlapping.

MT = 102 Capture
Spherical optical and statistical model calculation with CASTHY/6/ was adopted. Direct and semi-direct capture cross sections were estimated according to the procedure of Benzi and Reffo/17/ and normalized to 1 milli-barn at 14 MeV.

The gamma-ray strength function (2.976E-03) was adjusted to reproduce the experimental capture cross section measured by Musgrove et al./18/

MT = 16 (n,2n) Cross Section
MT = 17 (n,3n) Cross Section
MT = 22 (n,n'a) Cross Section
MT = 28 (n,n'p) Cross Section
MT = 32 (n,n'd) Cross Section
MT =103 (n,p) Cross Section
MT =104 (n,d) Cross Section

MT =105 (n,t) Cross Section
MT =106 (n,He3) Cross Section
MT =107 (n,alpha) Cross Section

These reaction cross sections were calculated with the preequilibrium and multi-step evaporation model code PEGASUS/7/.

The Kalbach's constant K (=103.4) was estimated by the formula derived from Kikuchi-Kawai's formalism/19/ and level density parameters.

Finally, (n,p) and (n,alpha) cross sections were normalized to the following values at 14.5 MeV:

(n,p)	17.00 mb	(measured by Ikeda et al./20/)
(n,alpha)	7.50 mb	(recommended by Forrest/21/)

MT = 251 Mu-bar
Calculated with CASTHY/6/.

MF = 4 Angular Distributions of Secondary Neutrons
Legendre polynomial coefficients for angular distributions are given in the center-of-mass system for MT=2 and discrete inelastic levels, and in the laboratory system for MT=91. They were calculated with CASTHY/6/.

MF = 5 Energy Distributions of Secondary Neutrons
Energy distributions of secondary neutrons were calculated with PEGASUS/7/ for inelastic scattering from overlapping levels and for other neutron emitting reactions.

Table 1 Neutron Optical Potential Parameters

Depth (MeV)	Radius(fm)	Diffuseness(fm)
V = 46.0-0.25E	R0 = 5.893	a0 = 0.62
Ws = 7.0	Rs = 6.393	as = 0.35
Wso= 7.0	Rso= 5.893	aso= 0.62

Table 2 Level Density Parameters

Nuclide	a(/MeV)	T(MeV)	C(/MeV)	EX(MeV)	Pairing
40-Zr- 93	1.298E+01	7.000E-01	1.273E+00	5.183E+00	1.200E+00
40-Zr- 94	1.275E+01	7.530E-01	4.411E-01	7.019E+00	2.320E+00
40-Zr- 95	1.331E+01	6.070E-01	5.453E-01	3.985E+00	1.200E+00
40-Zr- 96	1.320E+01	7.000E-01	2.235E-01	6.589E+00	2.490E+00
41-Nb- 94	1.281E+01	7.230E-01	7.763E+00	4.250E+00	0.0
41-Nb- 95	1.277E+01	7.500E-01	2.121E+00	5.782E+00	1.120E+00
41-Nb- 96	1.331E+01	5.880E-01	3.406E+00	2.530E+00	0.0
41-Nb- 97	1.337E+01	6.710E-01	9.771E-01	5.026E+00	1.290E+00
42-Mo- 95	1.360E+01	7.150E-01	1.847E+00	5.835E+00	1.280E+00
42-Mo- 96	1.403E+01	7.410E-01	6.991E-01	7.645E+00	2.400E+00
42-Mo- 97	1.517E+01	6.800E-01	2.769E+00	6.036E+00	1.280E+00
42-Mo- 98	1.594E+01	6.900E-01	7.358E-01	7.888E+00	2.570E+00

Spin cutoff params were calculated as 0.146·SQRT(a)·A··(2/3).
In the CASTHY calculation, spin cutoff factors at 0 MeV were assumed to be 7.075 for Mo- 97 and 5.291 for Mo- 98.

References

1) Aoki, T. et al.: Proc. Int. Conf. on Nuclear Data for Basic and Applied Science, Santa Fe., Vol. 2, p.1627 (1985).
2) Kawai, M. et al.: Proc. Int. Conf. on Nuclear Data for Science and Technology, Mito, p. 569 (1988).
3) Kikuchi, Y. et al.: JAERI-M 86-030 (1986).
4) Shwe H. and Cote R.E.: Phys. Rev. 179, 1148 (1969).
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6) Igarasi, S.: J. Nucl. Sci. Technol., 12, 67 (1975).
7) Iijima, S. et al.: JAERI-M 87-025, p. 337 (1987).
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12) Becchetti, F.D., Jr. and Greenlees, G.W.: Polarization Phenomena in Nuclear Reactions ((eds) H.H. Barshall and W. Haeberli), p. 682, The university of Wisconsin Press. (1971).
13) Gilbert, A. and Cameron, A.G.W.: Can. J. Phys., 43, 1446 (1965).
14) Iijima, S., et al.: J. Nucl. Sci. Technol. 21, 10 (1984).
15) Gruppelaar, H.: ECN-13 (1977).
16) Matsumoto, J., et al.: JAERI-M 7734 (1978).
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MAT number = 3426

42-Mo- 98 JNDC Eval-Aug89 JNDC FP Nuclear Data W.G.
Dist-Oct89

History
84-10 Evaluation for JENDL-2 was made by JNDC FPND W.G./1/
89-08 Modification for JENDL-3 was made/2/.

MF = 1 General information
MT=451 Comments and dictionary

MF = 2 Resonance parameters
MT=151 Resolved and unresolved resonance parameters
Resolved resonance region (MLBW formula) : below 32 keV
Evaluation was made by Kikuchi et al./3/ on the basis of the following experimental data.
Transmission : Chrien et al./4/
Capture : Weigmann et al./5/, Musgrove et al./6/
Assumed gamma-g : 0.085 eV for s-wave and 0.12 eV for p-wave resonances.
A negative resonance was added at -980 eV.
Unresolved resonance region : 32 keV - 100 keV
The neutron strength functions, S0, S1 and S2 were calculated with optical model code CASTHY/7/. The observed level spacing was determined to reproduce the capture cross section calculated with CASTHY. The effective scattering radius was obtained from fitting to the calculated total cross section at 100 keV.

Typical values of the parameters at 70 keV:
S0 = 0.370E-4, S1 = 5.479E-4, S2 = 0.364E-4, GG = 0.133 eV
Do = 765.9 eV, R = 6.675 fm.

Calculated 2200-m/s cross sections and res. integrals (barns)

	2200 m/s	res. integ.
total	5.772	-
elastic	5.642	-
capture	0.1300	6.56

MF = 3 Neutron cross sections
Below 100 keV, resonance parameters were given. Above 100 keV, the spherical optical and statistical model calculation was performed with CASTHY/7/, by taking account of competing reactions, of which cross sections were calculated with PEGASUS/8/ standing on a preequilibrium and multi-step evaporation model. The OMP's for neutron given in Table 1 were determined by Iijima et al./9/ to reproduce a systematic trend of the total cross section. The OMP's for charged particles are as follows:
Proton = Perey/10/
Alpha = Huizenga and Igo/11/
Deuteron = Lohr and Haeberli/12/
Helium-3 and triton = Becchetti and Greenlees/13/
Parameters for the composite level density formula of Girbert and Cameron/14/ were evaluated by Iijima et al./15/. More extensive determination and modification were made in the present work. Table 2 shows the level density parameters used

in the present calculation. Energy dependence of spin cut-off parameter in the energy range below E-joint is due to Gruppelaar /16/.

MT = 1 Total
Spherical optical model calculation was adopted.

MT = 2 Elastic scattering
Calculated as (total - sum of partial cross sections).

MT = 4, 51 - 91 Inelastic scattering
Spherical optical and statistical model calculation was adopted. The level scheme was taken from Ref./17/.

No.	Energy(MeV)	Spin-parity
GR.	0.0	0 +
1	0.7349	0 +
2	0.7874	2 +
3	1.4323	2 +
4	1.5101	4 +
5	1.7585	2 +
6	1.8809	3 +
7	1.9650	0 +
8	1.9855	1 +
9	2.0176	3 -
10	2.1049	2 +
11	2.2069	2 +
12	2.2240	2 +
13	2.3334	2 +
14	2.3437	6 +
15	2.4198	3 -
16	2.4500	4 +
17	2.4854	3 +
18	2.5063	3 -

Levels above 2.53 MeV were assumed to be overlapping.

MT = 102 Capture
Spherical optical and statistical model calculation with CASTHY/7/ was adopted. Direct and semi-direct capture cross sections were estimated according to the procedure of Benzi and Reffo/18/ and normalized to 1 milli-barn at 14 MeV.

The gamma-ray strength function (1.623E-04) was adjusted to reproduce the capture cross section measured by Musgrove et al./6/.

MT = 16 (n,2n) Cross Section
MT = 17 (n,3n) Cross Section
MT = 22 (n,n'a) Cross Section
MT = 28 (n,n'p) Cross Section
MT = 32 (n,n'd) Cross Section
MT =103 (n,p) Cross Section
MT =104 (n,d) Cross Section
MT =105 (n,t) Cross Section
MT =107 (n,alpha) Cross Section
These reaction cross sections were calculated with the preequilibrium and multi-step evaporation model code

PEGASUS/8/.

The Kalbach's constant K (=77.4) was estimated by the formula derived from Kikuchi-Kawai's formalism/19/ and level density parameters.

Finally, (n,p) and (n,alpha) cross sections were normalized to the following values at 14.5 MeV:

(n,p) 5.80 mb (measured by Ikeda et al./20/)
(n,alpha) 5.70 mb (measured by Ikeda et al./20/)

MT = 251 Mu-bar
Calculated with CASTHY/7/.

MF = 4 Angular Distributions of Secondary Neutrons
Legendre polynomial coefficients for angular distributions are given in the center-of-mass system for MT=2 and discrete inelastic levels, and in the laboratory system for MT=91. They were calculated with CASTHY/7/.

MF = 5 Energy Distributions of Secondary Neutrons
Energy distributions of secondary neutrons were calculated with PEGASUS/8/ for inelastic scattering from overlapping levels and for other neutron emitting reactions.

Table 1 Neutron Optical Potential Parameters

Depth (MeV)	Radius(fm)	Diffuseness(fm)
V = 46.0-0.25E	R0 = 5.893	a0 = 0.62
Ws = 7.0	Rs = 6.393	as = 0.35
Wso= 7.0	Rso= 5.893	aso= 0.62

Table 2 Level Density Parameters

Nuclide	a(/MeV)	T(MeV)	C(/MeV)	EX(MeV)	Pairing
40-Zr- 94	1.275E+01	7.530E-01	4.411E-01	7.019E+00	2.320E+00
40-Zr- 95	1.331E+01	6.070E-01	5.453E-01	3.985E+00	1.200E+00
40-Zr- 96	1.320E+01	7.000E-01	2.235E-01	6.589E+00	2.490E+00
40-Zr- 97	1.259E+01	5.590E-01	2.497E-01	3.084E+00	1.200E+00
41-Nb- 95	1.277E+01	7.500E-01	2.121E+00	5.782E+00	1.120E+00
41-Nb- 96	1.331E+01	5.880E-01	3.406E+00	2.530E+00	0.0
41-Nb- 97	1.337E+01	6.710E-01	9.771E-01	5.026E+00	1.290E+00
41-Nb- 98	1.380E+01	5.110E-01	2.350E+00	1.731E+00	0.0
42-Mo- 96	1.403E+01	7.410E-01	6.991E-01	7.645E+00	2.400E+00
42-Mo- 97	1.517E+01	6.800E-01	2.769E+00	6.036E+00	1.280E+00
42-Mo- 98	1.594E+01	6.900E-01	7.358E-01	7.888E+00	2.570E+00
42-Mo- 99	1.774E+01	6.200E-01	4.294E+00	6.058E+00	1.280E+00

Spin cutoff params were calculated as 0.146*SQRT(a)*A**(2/3). In the CASTHY calculation, spin cutoff factors at 0 MeV were assumed to be 5.291 for Mo- 98 and 2.875 for Mo- 99.

References

1) Aoki, T. et al.: Proc. Int. Conf. on Nuclear Data for Basic and Applied Science, Santa Fe., Vol. 2, p.1627 (1985).
2) Kawai, M. et al.: Proc. Int. Conf. on Nuclear Data for Science and Technology, Mito, p. 569 (1988).
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7) Igarasi, S.: J. Nucl. Sci. Technol., 12, 67 (1975).
8) Iijima, S. et al.: JAERI-M 87-025, p. 337 (1987).
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10) Perey, F.G: Phys. Rev. 131, 745 (1963).
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13) Becchetti, F.D., Jr. and Greenlees, G.W.: Polarization Phenomena in Nuclear Reactions ((eds) H.H. Barshall and W. Haeberli), p. 682, The university of Wisconsin Press. (1971).
14) Gilbert, A. and Cameron, A.G.W.: Can. J. Phys., 43, 1446 (1965).
15) Iijima, S., et al.: J. Nucl. Sci. Technol. 21, 10 (1984).
16) Gruppelaar, H.: ECN-13 (1977).
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18) Benzi, V. and Reffo, G.: CCDN-NW/10 (1969).
19) Kikuchi, K. and Kawai, M.: "Nuclear Matter and Nuclear Reactions", North Holland (1968).
20) Ikeda, Y. et al.: JAERI 1312 (1988).

MAT number = 3428

42-Mo-100 JNDC Eval-Aug89 JNDC FP Nuclear Data W.G.
Dist-Oct89

History
84-10 Evaluation for JENDL-2 was made by JNDC FPND W.G./1/
89-08 Modification for JENDL-3 was made/2/.

MF = 1 General information
MT=451 Comments and dictionary

MF = 2 Resonance parameters
MT=151 Resolved and unresolved resonance parameters
Resolved resonance region (MLBW formula) : below 26 keV
Evaluation was made by Kikuchi et al./3/ on the basis of the following experimental data.
Transmission : Weigmann et al./4/
Capture : Weigmann et al./5/, Musgrove et al./6/
Assumed gamma-g : 0.065 eV for s-wave and 0.08 eV for p-wave resonances.
A negative resonance was added at -172 eV.
Unresolved resonance region : 26 keV - 100 keV
The neutron strength functions, S0, S1 and S2 were calculated with optical model code CASTHY/7/. The observed level spacing was determined to reproduce the capture cross section calculated with CASTHY. The effective scattering radius was obtained from fitting to the calculated total cross section at 100 keV.

Typical values of the parameters at 50 keV:
S0 = 0.370E-4, S1 = 5.479E-4, S2 = 0.365E-4, GG = 0.085 eV
Do = 576.1 eV, R = 6.651 fm.

Calculated 2200-m/s cross sections and res. integrals (barns)

	2200 m/s	res. integ.
total	5.499	-
elastic	5.300	-
capture	0.1990	3.91

MF = 3 Neutron cross sections
Below 100 keV, resonance parameters were given. Above 100 keV, the spherical optical and statistical model calculation was performed with CASTHY/7/, by taking account of competing reactions, of which cross sections were calculated with PEGASUS/8/ standing on a preequilibrium and multi-step evaporation model. The OMP's for neutron given in Table 1 were determined by Iijima et al./9/ to reproduce a systematic trend of the total cross section. The OMP's for charged particles are as follows:
Proton = Perey/10/
Alpha = Huizenga and Igo/11/
Deuteron = Lohr and Haeberli/12/
Helium-3 and triton = Becchetti and Greenlees/13/
Parameters for the composite level density formula of Girbert and Cameron/14/ were evaluated by Iijima et al./15/. More extensive determination and modification were made in the present work. Table 2 shows the level density parameters used

in the present calculation. Energy dependence of spin cut-off parameter in the energy range below E-joint is due to Gruppelaar /16/.

MT = 1 Total
Spherical optical model calculation was adopted.

MT = 2 Elastic scattering
Calculated as (total - sum of partial cross sections).

MT = 4, 51 - 91 Inelastic scattering
Spherical optical and statistical model calculation was adopted. The level scheme was taken from Ref./17/.

No.	Energy(MeV)	Spin-parity
GR.	0.0	0 +
1	0.5356	2 +
2	0.6944	0 +
3	1.0637	2 +
4	1.1361	4 +
5	1.4633	2 +
6	1.7657	1 +
7	1.7704	3 +
8	1.9081	3 -
9	2.0330	0 +
10	2.0400	2 +
11	2.1014	4 +
12	2.3400	2 +
13	2.4156	3 -
14	2.4700	4 +
15	2.5632	3 +
16	2.5900	4 +

Levels above 2.62 MeV were assumed to be overlapping.

MT = 102 Capture
Spherical optical and statistical model calculation with CASTHY/7/ was adopted. Direct and semi-direct capture cross sections were estimated according to the procedure of Benzi and Reffo/18/ and normalized to 1 milli-barn at 14 MeV.

The gamma-ray strength function (1.432E-04) w s adjusted to reproduce the capture cross section measured by Musgrove et al./6/.

MT = 16 (n,2n) Cross Section
MT = 17 (n,3n) Cross Section
MT = 22 (n,n'a) Cross Section
MT = 28 (n,n'p) Cross Section
MT = 32 (n,n'd) Cross Section
MT =103 (n,p) Cross Section
MT =104 (n,d) Cross Section
MT =105 (n,t) Cross Section
MT =107 (n,alpha) Cross Section
These reaction cross sections were calculated with the preequilibrium and multi-step evaporation model code PEGASUS/8/.

The Kalbach's constant K (=50.6) was estimated by the formula derived from Kikuchi-Kawai's formalism/19/ and level density parameters.

Finally, (n,2n), (n,p) and (n,alpha) cross sections were normalized to the following values at 14.5 MeV:

(n,2n)	1540 mb	(measured by Ikeda et al./20/)
(n,p)	2.50 mb	(recommended by Forrest/21/)
(n,alpha)	2.80 mb	(measured by Ikeda et al./20/)

MT = 251 Mu-bar
Calculated with CASTHY/7/.

MF = 4 Angular Distributions of Secondary Neutrons
Legendre polynomial coefficients for angular distributions are given in the center-of-mass system for MT=2 and discrete inelastic levels, and in the laboratory system for MT=91. They were calculated with CASTHY/7/.

MF = 5 Energy Distributions of Secondary Neutrons
Energy distributions of secondary neutrons were calculated with PEGASUS/8/ for inelastic scattering from overlapping levels and for other neutron emitting reactions.

Table 1 Neutron Optical Potential Parameters

Depth (MeV)	Radius(fm)	Diffuseness(fm)
V = 46.0-0.25E	R0 = 5.893	a0 = 0.62
Ws = 7.0	Rs = 6.393	as = 0.35
Wso= 7.0	Rso= 5.893	aso= 0.62

Table 2 Level Density Parameters

Nuclide	SYST	a(/MeV)	T(MeV)	C(/MeV)	EX(MeV)	Pairing
40-Zr- 96		1.320E+01	7.000E-01	2.236E-01	6.589E+00	2.490E+00
40-Zr- 97		1.259E+01	5.590E-01	2.497E-01	3.084E+00	1.200E+00
40-Zr- 98	*	1.725E+01	6.633E-01	1.790E+00	7.555E+00	2.140E+00
40-Zr- 99	*	1.831E+01	6.566E-01	1.170E+01	6.957E+00	1.200E+00
41-Nb- 97		1.337E+01	6.710E-01	9.771E-01	5.026E+00	1.290E+00
41-Nb- 98		1.380E+01	5.110E-01	2.350E+00	1.731E+00	0.0
41-Nb- 99	*	1.742E+01	6.566E-01	1.085E+01	6.300E+00	9.400E-01
41-Nb-100	*	1.850E+01	6.500E-01	7.329E+01	5.699E+00	0.0
42-Mo- 98		1.594E+01	6.900E-01	7.358E-01	7.888E+00	2.570E+00
42-Mo- 99		1.774E+01	6.200E-01	4.294E+00	6.058E+00	1.280E+00
42-Mo-100		1.780E+01	6.000E-01	6.702E-01	6.645E+00	2.220E+00
42-Mo-101		2.085E+01	5.650E-01	7.153E+00	6.092E+00	1.280E+00

SYST: * = LDP's were determined from systematics.

Spin cutoff params were calculated as 0.146*SQRT(a)*A**(2/3).
In the CASTHY calculation, spin cutoff factors at 0 MeV were assumed to be 5.125 for Mo-100 and 5.000 for Mo-101.

References

1) Aoki, T. et al.: Proc. Int. Conf. on Nuclear Data for Basic and Applied Science, Santa Fe., Vol. 2, p.1627 (1985).
2) Kawai, M. et al.: Proc. Int. Conf. on Nuclear Data for Science and Technology, Mito, p. 569 (1988).
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7) Igarasi, S.: J. Nucl. Sci. Technol., 12, 67 (1975).
8) Iijima, S. et al.: JAERI-M 87-025, p. 337 (1987).
9) Iijima, S. and Kawai, M.: J. Nucl. Sci. Technol., 20, 77 (1983).
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14) Gilbert, A. and Cameron, A.G.W.: Can. J. Phys., 43, 1446 (1965).
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20) Ikeda, Y. et al.: JAERI 1312 (1988).
21) Forrest, R.A.: AERE-R 12419 (1986).

MAT number = 3470

47-Ag- 0 JAERI Eval-Mar87 Liu T.J.,T.Nakagawa,K.Shibata
Dist-Sep89

History
87-03 New evaluation for JENDL-3
87-07 Compiled by K.Shibata

MF=1 General Information
MT=451 Comments and dictionary.

MF=2 Resonance Parameters
MT=151 Resolved and unresolved resonance parameters
This file was made of Ag-107 and Ag-109 data.
Resolved resonance parameters (below 7.0095keV)
Resolved resonance parameters (below 7.0095keV) are the same as those of JENDL-2, which were made by Nakajima /1/ on the basis of experimental data by Moxon and Rae /2/, Garg et al./3/, Asghar et al./4/,Pattenden /5/, Muradjan and Adamchuk /6/, de Barros et al./7/, Pattenden and Jolly /8/, Macklin /9/ and Mizumoto et al./10/. There are no new experimental data available since then.
Unresolved resonance parameters (7.0095 - 100 keV)
The parameters were determined with the code ASREP /11/ to reproduce the capture and total cross sections, which were based on experimental data /12,13/ and adjusted for consistence between the data of the natural element and its isotopes.

Calculated 2200-m/s cross sections and res. integrals (barns):

	2200 m/s	res. integ.
total	68.81	-
elastic	5.19	-
capture	63.62	762.30

MF=3 Neutron Cross Sections

MT=1,102 Total, capture
Below 100 keV, resonance parameters were given. No background cross sections are adopted. Above 100 keV, cross sections were evaluated on the basis of experimental data and theoretical calculations. The main data were taken from the works of Poenitz and Whalen /12/, Foster and Glasgow /14/ for total cross sectoin and Mizumoto et al. /13/, Poenitz/15/ for capture cross section. The data were fitted with spline function /16/,and were adjusted for consistence between the natural element and its isotopes.

MT=2 Elastic
Elastic = Total - Nonelastic

MT=3 Nonelastic
Sum of MT=4,16,17,22,28,102,103,107

MT=4 Total inelastic
Sum of MT=51-80,91

MT=16,17,22,28,51-80,91,103,107 (n,2n),(n,3n),(n,na),(n,np), inelastic,(n,p),(n,a)
They were made of Ag-107 and Ag-109 data. For these two isotopes, the cross sections were calculated with the multistep

Hauser-Feshbach code TNG /17, 18/. At first, the optical model and level density parameters were taken from the works of Smith et al. /19/ and Iijima et al. /20/, respectively and then they were adjusted to reproduce available experimental data.

The optical model parameters are:

	Depth (MeV)	Radius(fm)	Diffuseness(fm)
Neutron	V = 48.25-0.3E	r0 = 1.249	a0 = 0.603
	Ws = 8.501-0.15E	rs = 1.270	as = 0.575
	Vso= 6.0	rso= 1.249	aso= 0.603
Proton	V = 66.061-0.550E	r0 = 1.150	a0 = 0.650
	Ws = 12.50-0.10E	rs = 1.250	as = 0.470
		rc = 1.150	
Alpha	V = 193.0-0.15E	r0 = 1.370	a0 = 0.560
	Ws = 21.00+0.25E	rs = 1.370	as = 0.560
		rc = 1.370	

The level density parameters are:

	Ecut(MeV)	Ejo(MeV)	T(MeV)	a(1/MeV)	C(MeV)	Cspin	Epair
Rh-103	0.990	5.409	0.655	15.50	3.884	49.725	0.94
Rh-104	0.230	4.351	0.650	15.43	17.72	49.820	0.00
Rh-105	0.770	5.700	0.630	16.80	4.000	54.591	1.24
Rh-106	0.150	3.869	0.575	17.50	17.18	57.230	0.00
Pd-106	2.380	8.004	0.666	17.17	0.920	56.147	2.59
Pd-107	0.700	7.693	0.769	14.98	6.956	49.293	1.35
Pd-108	1.900	7.957	0.646	17.90	0.884	59.268	2.60
Pd-109	0.360	7.380	0.687	17.50	9.479	58.301	1.35
Ag-105	1.230	5.530	0.609	18.57	2.750	60.343	0.94
Ag-106	0.400	3.549	0.563	17.16	12.92	56.110	0.00
Ag-107	1.420	5.918	0.693	14.55	2.412	47.878	1.24
Ag-108	0.270	3.014	0.576	15.04	6.004	49.799	0.00
Ag-109	1.180	6.112	0.705	14.50	2.666	48.306	1.25
Ag-110	0.320	3.150	0.454	17.01	2.513	57.015	0.00

The level scheme is given as follows:

Ag-107:

No.	Energy(MeV)	Spin-parity
GR.	0.0	1/2 -
1	0.0930	7/2 +
2	0.1260	(9/2)+
3	0.3250	3/2 -
4	0.4230	5/2 -
5	0.7730	(11/2)+
6	0.7870	3/2 -
7	0.9220	5/2 +
8	0.9500	5/2 -
9	0.9730	(7/2)-
10	0.9910	(13/2)+
11	1.0610	(1/2 -)
12	1.1420	1/2 +
13	1.1470	7/2 -
14	1.2230	5/2 +
15	1.2590	(3/2)+

16	1.3260	(3/2)+

Ag-109:

No.	Energy(MeV)	Spin-parity
GR.	0.0	1/2 -
1	0.0880	7/2 +
2	0.1330	9/2 +
3	0.3110	3/2 -
4	0.4150	5/2 -
5	0.7020	3/2 -
6	0.7070	3/2 +
7	0.7240	(3/2)+
8	0.7360	5/2 +
9	0.8630	5/2 -
10	0.8700	(5/2)+
11	0.9110	7/2 +
12	0.9120	7/2 -
13	1.0910	9/2 -
14	1.0990	(5/2 +)

MT=251
Calculated from MF=4,MT=2.

MF=4 Angular Distributions of Secondary Neutrons
MT=2
Calculated with the CASTHY code /21/.
MT=51-80
Calculated with TNG.
MT=16,17,22,28,91
Assumed to be isotropic in the laboratory system.

MF=5 Energy Distributions of Secondary Neutrons
MT=16,17,22,28,91
Calculated with TNG.

MF=12,14,15 Gamma-Production Data
MT=4,16,17,22,28,102,103,107
Calculated with TNG.

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MAT number = 3471

47-Ag-107 JAERI Eval-Mar87 Liu T.J.,T.Nakagawa.,K.Shibata
Dist-Sep89

History
87-03 New evaluation for JENDL-3
87-07 Compiled by K.Shibata

MF=1 General Information
MT=451 Comments and dictionary

MF=2 Resonance Parameters
MT=151
Resolved resonance parameters (below 7.0095 keV)
Resolved resonance parameters (below 7.0095keV) are the same as those of JENDL-2, which were made by Nakajima /1/ on the basis of experimental data by Moxon and Rae /2/, Garg et al./3/, Asghar et al. /4/, Mur jan and Adamchuk /5/, de Barros et al./6/, Pattenden and Jolly /7/, Macklin /8/ and Mizumoto et al. /9/. There are no new experimental data available since then.
Unresolved resonance parameters (7.0095 - 100 keV)
The parameters were determined with the ASREP code /10/ to reproduce the capture and total cross sections, which were based on experimental data /11, 12/ and adjusted for consistence between the data of the natural element and its isotopes. The typical parameters are :

S0 = (0.344-0.516)E-4, S1 = (3.5-4.5)E-4, S2= 0.53E-4,
D-obs= (18.5-22.8)eV, R=6.54fm

Calculated 2200-m/s cross sections and res. integrals (barns):

	2200 m/s	res. integ.
total	46.29	-
elastic	7.66	-
capture	38.62	103.24

MF=3 Neutron Cross Sections

MT=1,102 Total, capture
Below 100 keV, resonance parameters were given. No background cross sections are adopted. Above 100 keV, cross sections were evaluated on the basis of experimental data and theoretical calculations. The main data were taken from the works of Dukerevich et al. /13/, Smith et al. /14/ for total cross sectoin and Mizumoto et al. /12/, Macklin et al. /15/ for capture cross section. The data were fitted with spline function /16/,and were adjusted for consistence between the natural element and its isotopes.
MT=2 Elastic
Elastic = Total - Nonelastic
MT=3 Nonelastic
Sum of MT=4,16,17,22,28,102,103,107
MT=4 Total inelastic
Sum of MT=51-66,91
MT=16,17,22,28,51-66,91,103,107 (n,2n),(n,3n),(n,na),(n,np), inelastic,(n,p),(n,a)

For these reactions the cross sections were calculated with the multi-step Hauser-Feshbach code TNG /17, 18/. At first, the optical model and level density parameters were taken from the works of Smith et al./19/ and Iijima et al. /20/, respectively and then they were adjusted to reproduce the available experimental data.

The optical model parameters are:

	Depth (MeV)	Radius(fm)	Diffuseness(fm)
Neutron	V = 48.25-0.3E	r0 = 1.249	a0 = 0.603
	Ws = 8.501-0.15E	rs = 1.270	as = 0.575
	Vso= 6.000	rso= 1.249	aso= 0.603
Proton	V = 66.061-0.550E	r0 = 1.150	a0 = 0.650
	Ws = 12.50-0.10E	rs = 1.250	as = 0.470
		rc = 1.150	
Alpha	V = 193.0-0.15E	r0 = 1.370	a0 = 0.560
	Ws = 21.00+0.25E	rs = 1.370	as = 0.560
		rc = 1.370	

The level density parameters are:

	Ecut(MeV)	Ejo(MeV)	T(MeV)	a(1/MeV)	C(MeV)	Cspin	Epair
Rh-103	0.990	5.409	0.655	15.50	3.884	49.725	0.94
Rh-104	0.230	4.351	0.650	16.43	17.72	49.820	0.00
Pd-106	2.380	8.004	0.666	17.17	0.920	56.147	2.59
Pd-107	0.700	7.693	0.769	14.98	6.956	49.293	1.35
Ag-105	1.230	5.830	0.609	18.57	2.750	60.343	0.94
Ag-106	0.400	3.549	0.563	17.16	12.92	56.110	0.00
Ag-107	1.420	5.918	0.693	14.55	2.412	47.878	1.24
Ag-108	0.270	3.014	0.576	15.04	6.004	49.799	0.00

The level scheme is given as follows:

No.	Energy(MeV)	Spin-parity
GR.	0.0	1/2 -
1	0.0930	7/2 +
2	0.1260	(9/2)+
3	0.3250	3/2 -
4	0.4230	5/2 -
5	0.7730	(11/2)+
6	0.7870	3/2 -
7	0.9220	5/2 +
8	0.9500	5/2 -
9	0.9730	(7/2)-
10	0.9910	(13/2)+
11	1.0610	(1/2 -)
12	1.1420	1/2 +
13	1.1470	7/2 -
14	1.2230	5/2 +
15	1.2590	(3/2)+
16	1.3260	(3/2)+

Continuum levels were assumed above 1.42 MeV.

MT=251
Calculated from MF=4,MT=2.

MF=4 Angular Distributions of Secondary Neutrons
MT=2
Calculated with the CASTHY code /21/.
MT=51-66
Calculated with the TNG code.
MT=16,17,22,28,91
Assumed to be isotropic in the laboratory system.

MF=5 Energy Distributions of Secondary Neutrons
MT=16,17,22,28,91
Calculated with TNG.

MF=12,14,15 Gamma-Production Data
MT=4,16,17,22,28,102,103,107
Calculated with TNG.

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MAT number = 3472

47-Ag-109 JAERI Eval-Mar87 Liu T.J.,T.Nakagawa,K.Shibata
Dist-Sep89

History
87-03 New evaluation for JENDL-3
87-07 Compiled by K.Shibata

MF=1 General Information
MT=451 Comments and dictionary.

MF=2 Resonance Parameters
MT=151 Resolved and unresolved resonance parameters
Resolved resonance parameters (below 7.0095keV)
Resolved resonance parameters (below 7.0095keV) are the same as those of JENDL-2, which were made by Nakajima /1/ on the basis of experimental data by Moxon and Rae /2/, Garg et al./3/, Asghar et al. /4/,Pattenden /5/, Muradjan and Adamchuk /6/, de Barros et al./7/, Pattenden and Jolly /8/, Macklin /9/ and Mizumoto et al. /10/. There are no new experimental data available since then.
Unresolved resonance parameters (7.0095 - 100 keV)
The parameters were determined with code ASREP /11/ to reproduce the capture and total cross sections, which were based on experimental data /12-13/ and adjusted for consistence between the data of the natural element and its isotopes.
The typical parameters are :

S0 = (0.315-0.540)E-4, S1 = (3.61-4.34)E-4, S2= 0.53E-4,
D-obs= (17.5-20.2)eV, R=6.18fm

Calculated 2200-m/s cross sections and res. integrals (barns):

	2200 m/s	res. integ.
total	93.04	-
elastic	2.51	-
capture	90.53	1471.7

MF=3 Neutron Cross Sections

MT=1,102 Total, capture
Below 100 keV, resonance parameters were given. No background cross sections are adopted. Above 100 keV, cross sections were evaluated on the basis of experimental data and theoretical calculations. The main data were taken from the works of Mizumoto et al. /13/, Macklin et al. /14/ for capture cross section. The data were fitted with spline function /15/,and were adjusted for consistence between the natural element and its isotopes.
MT=2 Elastic
Elastic = Total - Nonelastic
MT=3 Nonelastic
Sum of MT=4,16,17,22,28,102,103,107
MT=4 Total inelastic
Sum of MT=51-64,91
MT=16,17,22,28,51-64,91,103,107 (n,2n),(n,3n),(n,na),(n,np), inelastic,(n,p),(n,a)

For these reactions the cross sections were calculated with the multistep Hauser-Feshbach code TNG /16,17/. At first, the optical model and level density parameters were taken from the works of Smith et al. /18/ and Iijima et al. /19/, respectively and then they were adjusted to reproduce the available experimental data.

The optical model parameters are:

	Depth (MeV)	Radius(fm)	Diffuseness(fm)
NEUTRON	V = 48.25-0.3E	r0 = 1.249	a0 = 0.603
	Ws = 8.501-0.15E	rs = 1.270	as = 0.575
	Vso= 6.0	rso= 1.249	aso= 0.603
PROTON	V = 66.061-0.550E	r0 = 1.150	a0 = 0.650
	Ws = 12.50-0.10E	rs = 1.250	as = 0.470
		rc = 1.150	
ALPHA	V = 193.0-0.15E	r0 = 1.370	a0 = 0.560
	Ws = 21.00+0.25E	rs = 1.370	as = 0.560
		rc = 1.370	

The level density parameters are:

	Ecut(MeV)	Ejo(MeV)	T(MeV)	a(1/MeV)	C(MeV)	Cspin	Epair
Rh-105	0.770	5.700	0.630	16.80	4.000	54.591	1.24
Rh-106	0.150	3.869	0.575	17.50	17.18	57.230	0.00
Pd-108	1.900	7.957	0.646	17.90	0.884	59 268	2.60
Pd-109	0.360	7.380	0.687	17.50	9.479	58.301	1.35
Ag-107	1.420	5.918	0.693	14.55	2.412	47.878	1.24
Ag-108	0.270	3.014	0.576	15.04	6.004	49.799	0.00
Ag-109	1.180	6.112	0.705	14.50	2.666	48.306	1.25
Ag-110	0.320	3.150	0.454	17.01	2.513	57.015	0.00

The level scheme used is given as follows:

No.	Energy(MeV)	Spin-parity
GR.	0.0	1/2 -
1	0.0880	7/2 +
2	0.1330	9/2 +
3	0.3110	3/2 -
4	0.4150	5/2 -
5	0.7020	3/2 -
6	0.7070	3/2 +
7	0.7240	(3/2)+
8	0.7360	5/2 +
9	0.8630	5/2 -
10	0.8700	(5/2)+
11	0.9110	7/2 +
12	0.9120	7/2 -
13	1.0910	9/2 -
14	1.0990	(5/2 +)

Continuum levels were assumed above 1.18 MeV.

MT=251
Calculated from MF=4,MT=2.

MF=4 Angular Distributions of Secondary neutrons

MT=2
Calculated with the CASTHY code /20/.
MT=51-64
Calculated with TNG.
MT=16,17,22,28,91
Assumed to be isotropic in the laboratory system.

MF=5 Energy Distributions of Secondary Neutrons
MT=16,17,22,28,91
Calculated with TNG.

MF=12,14,15 Gamma-Production Data
MT=4,16,17,22,28,102,103,107
Calculated with TNG.

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MAT number = 3480

48-Cd- 0 JNDC Eval-Mar89 JNDC FP ND W.G., N.Yamamuro
Dist-Oct89

History
89-03 Evaluation of Cd isotopes for JENDL-3 was made by JNDC FP Nuclear Data W.G./1/, and data for natural Cd were constructed from them by T.Nakagawa(JAERI).
89-03 Photon production data were calculated by N.Yamamuro (Data Engineering)

MF = 1 General information
MT=451 Comments and dictionary

MF = 2 Resonance parameters
MT=151 Resolved and unresolved resonance parameters
Resolved resonance region (MLBW formula)
Evaluation was made on the basis of the following data for each isotope.
Cd-106 : below 0.7 keV
Mughabghab et al./2/
Assumed capture width = 0.153 eV
Cd-108 : below 0.38 keV
Anufriev et al./3/
Assumed capture width = 0.110 eV
Cd-110 : below 7.0 keV
Liou et al./4/, Musgrove et al./5/, Alfimenkov et al./6/.
Assumed capture width = 0.102 eV
Cd-112 : below 7.0 keV
Liou et al./4/, Musgrove et al./5/.
Assumed capture width = 0.1 eV/4/ below 2.0 keV, and
0.077 eV above 2.0 keV for s-wave res.
0.096 eV/5/ for p-wave res.
Cd-113 : below 2.0 keV
Liou et al./4/.
Assumed capture width = 0.101 eV/4/
Cd-114 : below 8.0 keV
Liou et al./1/, Musgrove et al./5/.
Assumed capture width = 0.11 eV /4/ below 2.0 keV, and
0.053 eV above 2.0 keV for s-wave res.
0.082 eV/5/ for p-wave res.
Cd-116 : below 9.0 keV
Liou et al./4/, Musgrove et al./5/.
Assumed capture width = 0.047 eV for s-wave res. and
0.085 eV for p-wave res/5/.

In order to reproduce well measured total cross sections, effective scattering radius of 5.42 fm was assumed for the all isotopes.

Unresolved resonance region : up to 100 keV
The neutron strength functions for L=0 and 1 were taken from Mughabghab et al./2/, and those for L=2 were calculated with optical model code CASTHY/7/. Average radiative capture widths were also taken from Ref./2/. The observed level spacings were determined to reproduce the capture cross sections calculated with CASTHY for Cd-110, Cd-112, Cd-113, Cd-114 and Cd-116, and the capture cross sections determined

from experimental data for the other isotopes. The effective scattering radius was obtained from fitting to the calculated total cross section at 100 keV. Finally, background cross section was given to the capture to reproduce the experimental data/8,9/

Unresolved resonance parameters (at 70 keV)

Nuclide	S0	S1	S2	GG(s,d) (eV)	GG(p) (eV)	D-obs (eV)	R (fm)
Cd-106	1.00E-4	5.00E-4	0.97E-4	0.155	0.175	131	4.70
Cd-108	1.20E-4	4.80E-4	0.95E-4	0.105	0.125	147	4.59
Cd-110	0.44E-4	3.00E-4	0.93E-4	0.071	0.080	155	6.25
Cd-111	0.80E-4	3.00E-4	0.92E-4	0.096	0.096	22	5.76
Cd-112	0.50E-4	4.40E-4	0.91E-4	0.077	0.090	212	5.44
Cd-113	0.31E-4	2.20E-4	0.90E-4	0.160	0.160	27	6.74
Cd-114	0.64E-4	3.50E-4	0.89E-4	0.063	0.070	250	5.80
Cd-116	0.16E-4	2.80E-4	0.87E-4	0.047	0.070	432	6.49

Calculated 2200-m/s cross sections and res. integrals (barns)

	2200 m/s	res. integ.
total	2536	-
elastic	8.274	-
capture	2528	67.9

MF = 3 Neutron cross sections

Below 100 keV, resonance parameters were given.
Above 100 keV, the spherical optical and statistical model calculation was performed with CASTHY/7/, by taking account of competing reactions, of which cross sections were calculated with PEGASUS/10/ standing on a preequilibrium and multi-step evaporation model. The OMP's for neutron given in Table 1 were determined to reproduce the Cd-111 total cross section. The OMP's for charged particles are as follows:

Proton = Perey/11/
Alpha = Huizenga and Igo/12/
Deuteron = Lohr and Haeberli/13/
Helium-3 and triton = Becchetti and Greenlees/14/

Parameters for the composite level density formula of Girbert and Cameron/15/ were evaluated by Iijima et al./16/. More extensive determination and modification were made in the present work. Table 2 shows the level density parameters used in the present calculation. Energy dependence of spin cut-off parameter in the energy range below E-joint is due to Gruppelaar /17/.

MT = 1 Total

Spherical optical model calculation was adopted. In the energy region from 100 keV to 2.5 MeV, cross section was determined from the data measured by Whalen et al./18/, Green et al./19/ and Poenitz and Whalen/20/.

MT = 2 Elastic scattering

Calculated as (total - sum of partial cross sections).

MT = 3 Non-elastic scattering

Sum of partial cross sections except MT=2.

MT = 4, 51 - 91 Inelastic scattering
Spherical optical and statistical model calculation was adopted. The level schemes were taken from Ref./21/ for Cd-106 and 108, Ref./22/ for Cd-110, 111, 112 1nd 113, and Ref./23/ for Cd-114 and 116. The inelastic scattering cross sections were grouped as follows:

MT	-Q(MEV)	106	108	110	111	112	113	114	116
51	-0.2454	-	-	-	51	-	51	-	-
52	-0.2986	-	-	-	-	-	52,53	-	-
53	-0.3419	-	-	-	52,53	-	-	-	-
54	-0.4166	-	-	-	54	-	54,55	-	-
55	-0.5131	-	-	-	-	-	56	-	51
56	-0.5583	-	-	-	-	-	57	51	-
57	-0.6174	51	51	-	55	51	-	-	-
58	-0.6577	-	-	51	56	-	58,59	-	-
59	-0.754	-	-	-	57	-	-	-	-
60	-0.8553	-	-	-	58	-	60	-	-
61	-0.8836	-	-	-	-	-	61	-	-
62	-0.9884	-	-	-	-	-	62,63	-	-
63	-1.02	-	-	-	59	-	-	-	-
64	-1.1261	-	-	-	60	-	64	-	-
65	-1.1342	-	-	-	-	-	-	52	-
66	-1.19	-	-	-	61	-	65	-	-
67	-1.2093	-	-	-	-	-	-	53	52,53
68	-1.223	-	-	-	-	52	-	-	-
69	-1.283	-	-	-	-	-	-	54	54
70	-1.3052	-	-	-	-	53	-	55	-
71	-1.361	-	-	-	-	-	-	-	55
72	-1.3639	-	-	-	-	54	-	56	-
73	-1.4317	-	-	-	-	55,56	-	-	-
74	-1.4732	52	52	52,53	-	-	-	-	-
75	-1.5424	53	53,54	54	-	-	-	-	-
76	-1.7318	-	-	55	-	-	-	57,58	-
77	-1.7833	-	-	56,57	-	-	-	-	-
78	-1.971	-	55,56	-	-	57	-	-	-
79	-1.971	-	-	58	58,59	-	-	-	-
80	-2.0788	54	-	59,60	-	-	-	-	-
81	-2.1627	-	57,58	61	-	-	-	-	-
82	-2.22	55-57	59	62	-	-	-	-	-
83	-2.355	58	60	63	-	-	-	-	-
84	-2.4641	59-61	61	64,65	-	-	-	-	-
85	-2.538	-	62	66	-	-	-	-	-
86	-2.5612	-	63-69	67	-	-	-	-	-
87	-2.7864	-	70	68	-	-	-	-	-
88	-2.868	-	-	69,70	-	-	-	-	-
89	-2.9266	-	71-77	71	-	-	-	-	-
91	-1.1948	91	91	91	91	91	91	91	91

MT = 102 Capture
Spherical optical and statistical model calculation with CASTHY/7/ was adopted. Direct and semi-direct capture cross sections were estimated according to the procedure of Benzi and Reffo/24/ and normalized to 1 milli-barn at 14 MeV. The gamma-ray strength functions were adjusted to reproduce the following capture cross sections.

Nuclide cross section(b) strength function

Cd-106	0.34 at 70 keV	14.2E-4
Cd-108	0.23 at 70 keV	8.63E-4
Cd-110	0.245 at 30 keV	4.65E-4
Cd-111	0.9 at 30 keV	68.8E-4
Cd-112	0.22 at 30 keV	4.04E-4
Cd-113	0.72 at 30 keV	46.5E-4
Cd-114	0.15 at 30 keV	2.50E-4
Cd-116	0.09 at 30 keV	1.35E-4

At the energies from 9 keV to 10 MeV, the cross section was modified to well reproduce the data measured by Kompe/8/ and Poenitz/9/.

MT = 16, 17, 22, 28, 32, 103, 104, 105, 106, 107, 111
(n,2n), (n,3n), (n,n'a), (n,n'p), (n,n'd), (n,p), (n,d), (n,t), (n,He3), (n,alpha) and (n,2p) Cross Sections
These reaction cross sections were calculated with the pre-equilibrium and multi-step evaporation model code PEGASUS /10/. The Kalbach's constants were estimated by the formula derived from Kikuchi-Kawai's formalism/25/ and level density parameters. The (n,2n), (n,p) and (n,alpha) cross sections were normalized to the following values(mb) at 14.5 MeV:

Nuclide	(n,2n)/26/	(n,p)/27/	(n,alpha)/26/
Cd-106	900	130	100
Cd-108	1000	57.6	12.1
Cd-110	1170	29.7	6.34
Cd-111	(1582)	50	4.52
Cd-112	(1583)	16	3.1
Cd-113	(1632)	10.9	2.23
Cd-114	(1631)	10	0.7
Cd-116	(1632)	2.5	(0.108)

Values in ( ) were calculated ones (not normalized).

MT = 251 Mu-bar
Calculated with CASTHY/7/.

MF = 4 Angular Distributions of Secondary Neutrons
Distributions of elastic and inelastic scattering neutrons were calculated with CASTHY/7/. In the case where more than 2 levels were grouped into 1 level, isotropic distribution in the center-of-mass system was assumed. For other reactions, isotropic distributions in the laboratory system were assumed.

MF = 5 Energy Distributions of Secondary Neutrons
Energy distributions of secondary neutrons were calculated with PEGASUS/10/ for inelastic scattering from overlapping levels and for other neutron emitting reactions.

MF = 12 Photon Production Multiplicities
MT = 3 (above 100 keV), and 102 (below 100 keV)
Calculated with GNASH/28/ modified by Yamamuro/29/

MF = 14 Photon Angular Distributions
MT = 3, 102
Isotropic distributions were assumed.

MF = 15 Photon Energy Distributions
MT = 3, 102

Calculated with GNASH/28/ modified by Yamamuro/29/

Table 1 Neutron Optical Potential Parameters

	Depth (MeV)	Radius(fm)	Diffuseness(fm)
V	= 50.01-0.5528E	R0 = 5 872	a0 = 0.56
Ws	= 8.165	Rs = 6.594	as = 0.44
Wso	= 5.261	Rso= 5.97	aso= 0.267

Table 2 Level Density Parameters of Cd Isotopes

Nuclide	SYST	a(/MeV)	T(MeV)	C(/MeV)	EX(MeV)	Pairing
48-Cd-104	*	1.643E+01	6.403E-01	3.532E-01	7.266E+00	2.650E+00
48-Cd-105		1.600E+01	6.850E-01	4.000E+00	6.612E+00	1.360E+00
48-Cd-106		1.468E+01	6.950E-01	5.785E-01	7.078E+00	2.300E+00
48-Cd-107		1.647E+01	6.740E-01	4.374E+00	6.626E+00	1.360E+00
48-Cd-108		1.541E+01	6.900E-01	5.114E-01	7.655E+00	2.600E+00
48-Cd-109		1.812E+01	6.120E-01	3.856E+00	6.132E+00	1.360E+00
48-Cd-110		1.750E+01	6.300E-01	5.212E-01	7.482E+00	2.610E+00
48-Cd-111		1.874E+01	5.930E-01	3.762E+00	6.000E+00	1.360E+00
48-Cd-112		1.797E+01	6.190E-01	6.327E-01	7.351E+00	2.500E+00
48-Cd-113		1.973E+01	5.760E-01	4.397E+00	6.018E+00	1.360E+00
48-Cd-114		1.910E+01	6.010E-01	5.651E-01	7.611E+00	2.680E+00
48-Cd-115		2.072E+01	5.570E-01	4.805E+00	5.966E+00	1.360E+00
48-Cd-116		1.990E+01	5.750E-01	6.265E-01	7.206E+00	2.510E+00
48-Cd-117		2.107E+01	5.620E-01	6.164E+00	6.181E+00	1.360E+00

SYST: * = LDP's were determined from systematics.

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MAT number = 3510

51-Sb- 0 JNDC Eval-Mar89 JNDC FP Nuclear Data W.G.
Dist-Oct89

History
89-03 Data were constructed with those for Sb-121 and Sb-123 which were evaluated by JNDC FP Nuclear Data W.G./1/.

MF = 1 General information
MT=451 Comments and dictionary

MF = 2 Resonance parameters
MT=151 Resolved and unresolved resonance parameters
Resolved resonance parameters (MLBW formula)
1) Sb-121 : below 2 keV
Evaluation was made on the basis of data measured by Ohkubo/2/, Ohkubo et al./3/, Bolotin and Chrien/4/, Wynchank et al./5/, Muradjan et al./6/ and Adamchuk et al./7/. Angular momentum l and spin J were based on the data by Belyaev et al./8/, Baht et al./9/ and Cauvin et al./10/. The average radiative capture width of 0.089 eV was assumed.
2) Sb-123 : below 2.5 keV
Evaluation was made on the basis of the data measured by Ohkubo/2/, Ohkubo et al./11/, Stolvy and Harvey/12/, Bolotin and Chrien/4/, Wynchank et al./5/, Muradjan et al./6/ and Adamchuk et al./7/. Angular momentum l and spin J were based on the data by Baht et al./9/ and Cauvin et al./10/. The average radiative capture width of 0.098 eV was assumed.

Unresolved resonance region : up to 100 keV
The neutron strength functions, S0, S1 and S2 were calculated with optical model code CASTHY/13/. The observed level spacing was determined to reproduce the capture cross section calculated with CASTHY. The effective scattering radius was obtained from fitting to the calculated total cross section at 100 keV.

Calculated 2200-m/s cross sections and res. integrals (barns)

	2200 m/s	res. integ.
total	8.943	-
elastic	3.722	-
capture	5.221	175

MF = 3 Neutron cross sections
Below 100 keV, resonance parameters were given.
Above 100 keV, the spherical optical and statistical model calculation was performed with CASTHY/13/, by taking account of competing reactions, of which cross sections were calculated with PEGASUS/14/ standing on a preequilibrium and multi-step evaporation model. The OMP's for neutron given in Table 1 were adopted from Iijima and Kawai/15/ by modifying radius parameter of the spin-orbit term. The OMP's for charged particles are as follows:

Proton = Perey/16/
Alpha = Huizenga and Igo/17/
Deuteron = Lohr and Haeberli/18/

Helium-3 and triton = Becchetti and Greenlees/19/
Parameters for the composite level density formula of Girbert and Cameron/20/ were evaluated by Iijima et al./21/. More extensive determination and modification were made in the present work. Table 2 shows the level density parameters used in the present calculation. Energy dependence of spin cut-off parameter in the energy range below E-joint is due to Gruppelaar /22/.

MT = 1 Total
Spherical optical model calculation was adopted in the energy ranges below 500 keV and above 11.5 MeV. Between 500 keV and 11.5 MeV, spline fitting to the experimental data /23,24/ was performed.

MT = 2 Elastic scattering
Calculated as (total - sum of partial cross sections).

MT = 4, 51 - 91 Inelastic scattering
Spherical optical and statistical model calculation was adopted. The level scheme was taken from Ref./25/.

--- Sb-121 ---				--- Sb-123 ---			
No.	MT	Energy(MeV)	J-parity	No.	MT	Energy(MeV)	J-parity
GR.		0.0	5/2 +	GR.		0.0	7/2 +
1	51	0.0371	7/2 +	1	52	0.1603	5/2 +
2	53	0.5076	3/2 +	2	54	0.5421	3/2 +
3	55	0.5731	1/2 +	3	56	0.7125	1/2 +
4	57	0.9470	9/2 +	4	59	1.0302	9/2 +
5	58	1.0240	7/2 +	5	61	1.0886	9/2 +
6	60	1.0355	9/2 +				
7	62	1.1393	11/2 +				
8	63	1.1447	9/2 +				

Overlapping levels were assumed above 1.15 MeV for Sb-121 and above 1.18 MeV for Sb-123. In the data file, Q-values of levels were slightly shifted to be consistent with their threshold energies.

MT = 102 Capture
Spherical optical and statistical model calculation with CASTHY/13/ was adopted. Direct and semi-direct capture cross sections were estimated according to the procedure of Benzi and Reffo/26/ and normalized to 1 milli-barn at 14 MeV.

The gamma-ray strength functions were adjusted to reproduce the capture cross sections.

	cross section (30 keV)	strength function
Sb-121	0.55 barn	49.8E-4
Sb-123	0.34 barn	25.7E-4

MT = 16, 17, 22, 28, 32, 33, 103, 104, 105, 107
(n,2n), (n,3n), (n,n'a), (n,n'p), (n,n'd), (n,n't), (n,p), (n,d), (n,t) and (n,alpha) Cross Sections
These reaction cross sections were calculated with the preequilibrium and multi-step evaporation model code PEGASUS/14/.

The Kalbach's constants were estimated by the formula derived from Kikuchi-Kawai's formalism/27/ and level density parameters.
Sb-121: 145.3, Sb-123: 174.0

Finally, the (n,2n), (n,p) and (n,alpha) cross sections were modified as follows.
Sb-121:
(n,2n) based on experimental data by Bormann et al./28/
(n,alpha) normalized to 4.51 mb/29/ at 14.5 MeV.
Sb-123:
(n,p) normalized to 4.70 mb/29/ at 14.5 MeV.
(n,alpha) normalized to 2.53 mb/29/ at 14.5 MeV.

MT = 251 Mu-bar
Calculated with CASTHY/13/.

MF = 4 Angular Distributions of Secondary Neutrons
Legendre polynomial coefficients for angular distributions are given in the center-of-mass system for MT=2 and discrete inelastic levels, and in the laboratory system for MT=91. They were calculated with CASTHY/13/. For other reactions, isotropic distributions in the laboratory system were assumed.

MF = 5 Energy Distributions of Secondary Neutrons
Energy distributions of secondary neutrons were calculated with PEGASUS/14/ for inelastic scattering from overlapping levels and for other neutron emitting reactions.

Table 1 Neutron Optical Potential Parameters

Depth (MeV)	Radius(fm)	Diffuseness(fm)
V = 47.64-0.473E	R0 = 6.256	a0 = 0.62
Ws = 9.744	Rs = 6.469	as = 0.35
Wso= 7.0	Rso= 6.241	aso= 0.62

Table 2 Level Density Parameters

Nuclide	SYST	a(/MeV)	T(MeV)	C(/MeV)	EX(MeV)	Pairing
49-In-117		1.678E+01	6.010E-01	2.387E+00	5.208E+00	1.150E+00
49-In-118	*	1.804E+01	6.064E-01	3.111E+01	4.636E+00	0.0
49-In-119		1.940E+01	5.340E-01	2.195E+00	4.999E+00	1.240E+00
49-In-120	*	1.757E+01	6.016E-01	2.330E+01	4.366E+00	0.0
49-In-121		1.601E+01	6.060E-01	1.119E+00	5.277E+00	1.430E+00
49-In-122	*	1.707E+01	5.968E-01	1.737E+01	4.092E+00	0.0
50-Sn-118		1.633E+01	6.140E-01	3.341E-01	6.448E+00	2.340E+00
50-Sn-119		1.635E+01	5.990E-01	1.772E+00	5.050E+00	1.190E+00
50-Sn-120		1.595E+01	6.540E-01	4.691E-01	7.083E+00	2.430E+00
50-Sn-121		1.630E+01	6.100E-01	2.010E+00	5.217E+00	1.190E+00
50-Sn-122		1.434E+01	7.060E-01	3.423E-01	7.416E+00	2.620E+00
50-Sn-123		1.509E+01	6.870E-01	3.062E+00	6.032E+00	1.190E+00
51-Sb-119	*	1.858E+01	6.040E-01	5.801E+00	5.944E+00	1.150E+00
51-Sb-120	*	1.834E+01	6.016E-01	3.366E+01	4.659E+00	0.0

51-Sb-121	1.730E+01	5.740E-01	1.715E+00	5.022E+00	1.240E+00
51-Sb-122	1.772E+01	5.500E-01	1.346E+01	3.517E+00	0.0
51-Sb-123	1.585E+01	6.213E-01	1.285E+00	5.469E+00	1.430E+00
51-Sb-124	1.696E+01	5.600E-01	1.090E+01	3.433E+00	0.0

SYST: * = LDP's were determined from systematics.

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MAT number = 3511

51-Sb-121 JNDC Eval-Mar89 JNDC FP Nuclear Data W.G.
Dist-Oct89

History
84-10 Evaluation for JENDL-2 was made by JNDC FPND W.G./1/
89-03 Modification was made/2/, and stored in JENDL-3.

MF = 1 General information
MT=451 Comments and dictionary

MF = 2 Resonance parameters
MT=151 Resolved and unresolved resonance parameters
Resolved resonance region (MLBW formula) : below 2 keV
Evaluation was made on the basis of the data measured by Ohkubo et al./3,4/, Bolotin and Chrien/5/, Wynchank et al./6/, Muradjan et al./7/ and Adamchuk et al./8/.
Angular momentum l and spin J were based on the data by Belyaev et al./9/, Baht et al./10/ and Cauvin et al./11/.
The average radiative capture width of 0.089 eV was assumed.
Unresolved resonance region : 2 keV - 100 keV
The neutron strength functions, S0, S1 and S2 were calculated with optical model code CASTHY/12/. The observed level spacing was determined to reproduce the capture cross section calculated with CASTHY. The effective scattering radius was obtained from fitting to the calculated total cross section at 100 keV.

Typical values of the parameters at 70 keV:
S0 = 0.300E-4, S1 = 2.700E-4, S2 = 0.760E-4, GG = 0.100 eV
Do = 10.51 eV, R = 5.837 fm.

Calculated 2200-m/s cross sections and res. integrals (barns)

	2200 m/s	res. integ.
total	9.582	-
elastic	3.590	-
capture	5.991	215

MF = 3 Neutron cross sections
Below 100 keV, resonance parameters were given.
Above 100 keV, the spherical optical and statistical model calculation was performed with CASTHY/12/, by taking account of competing reactions, of which cross sections were calculated with PEGASUS/13/ standing on a preequilibrium and multi-step evaporation model. The OMP's for neutron given in Table 1 were taken from Iijima and Kawai/14/ and rso was modified to reproduce the measured total cross sections. The OMP's for charged particles are as follows:
Proton = Perey/15/
Alpha = Huizenga and Igo/16/
Deuteron = Lohr and Haeberli/17/
Helium-3 and triton = Becchetti and Greenlees/18/
Parameters for the composite level density formula of Girbert and Cameron/19/ were evaluated by Iijima et al./20/. More extensive determination and modification were made in the present work. Table 2 shows the level density parameters used in the present calculation. Energy dependence of spin cut-off

parameter in the energy range below E-joint is due to Gruppelaar /21/.

MT = 1 Total
Spherical optical model calculation was adopted.

MT = 2 Elastic scattering
Calculated as (total - sum of partial cross sections).

MT = 4, 51 - 91 Inelastic scattering
Spherical optical and statistical model calculation was adopted. The level scheme was taken from Ref./22/.

No.	Energy(MeV)	Spin-parity
GR.	0.0	5/2 +
1	0.0371	7/2 +
2	0.5076	3/2 +
3	0.5731	1/2 +
4	0.9470	9/2 +
5	1.0240	7/2 +
6	1.0355	9/2 +
7	1.1393	11/2 +
8	1.1447	9/2 +

Levels above 1.15 MeV were assumed to be overlapping.

MT = 102 Capture
Spherical optical and statistical model calculation with CASTHY/12/ was adopted. Direct and semi-direct capture cross sections were estimated according to the procedure of Benzi and Reffo/23/ and normalized to 1 milli-barn at 14 MeV.

The gamma-ray strength function (49.8E-4) was adjusted to reproduce the capture cross section of 550 milli-barns at 30 keV which was derived from natural Sb data/24/ and CFRMF activation rate measurement (Sb-121/Sb-123=1.6)/25/.

MT = 16 (n,2n) Cross Section
MT = 17 (n,3n) Cross Section
MT = 22 (n,n'a) Cross Section
MT = 28 (n,n'p) Cross Section
MT = 32 (n,n'd) Cross Section
MT = 33 (n,n't) Cross Section
MT =103 (n,p) Cross Section
MT =104 (n,d) Cross Section
MT =105 (n,t) Cross Section
MT =107 (n,alpha) Cross Section
These reaction cross sections were calculated with the preequilibrium and multi-step evaporation model code PEGASUS/13/.

The Kalbach's constant K (=145.3) was estimated by the formula derived from Kikuchi-Kawai's formalism/26/ and level density parameters.

Finally, the (n,alpha) cross sections were normalized to the following values at 14.5 MeV:
(n,alpha) 4.51 mb (systematics of Forrest/27/)

The (n,2n) cross section was determined by eye-guiding of the data measured by Bormann/28/.

MT = 251 Mu-bar
Calculated with CASTHY/12/.

MF = 4 Angular Distributions of Secondary Neutrons
Legendre polynomial coefficients for angular distributions are given in the center-of-mass system for MT=2 and discrete inelastic levels, and in the laboratory system for MT=91. They were calculated with CASTHY/12/. For other reactions, isotropic distributions in the laboratory system were assumed.

MF = 5 Energy Distributions of Secondary Neutrons
Energy distributions of secondary neutrons were calculated with PEGASUS/13/ for inelastic scattering from overlapping levels and for other neutron emitting reactions.

Table 1 Neutron Optical Potential Parameters

Depth (MeV)	Radius(fm)	Diffuseness(fm)
V = 47.64-0.473E	R0 = 6.256	a0 = 0.62
Ws = 9.744	Rs = 6.469	as = 0.35
Wso= 7.0	Rso= 6.241	aso= 0.62

Table 2 Level Density Parameters

Nuclide	SYST	a(/MeV)	T(MeV)	C(/MeV)	EX(MeV)	Pairing
49-In-117		1.678E+01	6.010E-01	2.387E+00	5.208E+00	1.150E+00
49-In-118	*	1.804E+01	6.064E-01	3.111E+01	4.636E+00	0.0
49-In-119		1.940E+01	5.340E-01	2.195E+00	4.999E+00	1.240E+00
49-In-120	*	1.757E+01	6.016E-01	2.330E+01	4.366E+00	0.0
50-Sn-118		1.633E+01	6.140E-01	3.341E-01	6.448E+00	2.340E+00
50-Sn-119		1.635E+01	5.990E-01	1.772E+00	5.050E+00	1.190E+00
50-Sn-120		1.595E+01	6.540E-01	4.691E-01	7.083E+00	2.430E+00
50-Sn-121		1.630E+01	6.100E-01	2.010E+00	5.217E+00	1.190E+00
51-Sb-119	*	1.858E+01	6.040E-01	5.801E+00	5.944E+00	1.150E+00
51-Sb-120	*	1.834E+01	6.016E-01	3.366E+01	4.659E+00	0.0
51-Sb-121		1.730E+01	5.740E-01	1.715E+00	5.022E+00	1.240E+00
51-Sb-122		1.772E+01	5.500E-01	1.346E+01	3.517E+00	0.0

SYST: * = LDP's were determined from systematics.

Spin cutoff params were calculated as 0.146*SQRT(a)*A**(2/3).
In the CASTHY calculation, spin cutoff factors at 0 MeV were assumed to be 9.25 for Sb-121 and 5.0 for Sb-122.

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MAT number = 3512

51-Sb-123 JNDC Eval-Mar89 JNDC FP Nuclear Data W.G.
Dist-Oct89

History
84-10 Evaluation for JENDL-2 was made by JNDC FPND W.G./1/
89-03 Modification was made and stored in JENDL-3.

MF = 1 General information
MT=451 Comments and dictionary

MF = 2 Resonance parameters
MT=151 Resolved and unresolved resonance parameters
Resolved resonance region (MLBW formula) : below 2.5 keV
Evaluation was made on the basis of the data measured by Ohkubo/2/, Ohkubo et al./3/, Stolvy and Harvey/4/, Bolotin and Chrien/5/, Wynchank et al./6/, Muradjan et al./7/ and Adamchuk et al./8/. Angular momentum l and spin J were based on the data by Baht et al./9/ and Cauvin et al./10/. The average radiative capture width of 0.098 eV was assumed.
Unresolved resonance region : 2.5 keV - 100 keV
The neutron strength functions, S0, S1 and S2 were calculated with optical model code CASTHY/11/. The observed level spacing was determined to reproduce the capture cross section calculated with CASTHY. The effective scattering radius was obtained from fitting to the calculated total cross section at 100 keV.

Typical values of the parameters at 70 keV:
S0 = 0.250E-4, S1 = 2.700E-4, S2 = 0.760E-4, GG = 0.100 eV
Do = 23.28 eV, R = 5.856 fm.

Calculated 2200-m/s cross sections and res. integrals (barns)

	2200 m/s	res. integ.
total	8.086	-
elastic	3.899	-
capture	4.187	123

MF = 3 Neutron cross sections
Below 100 keV, resonance parameters were given.
Above 100 keV, the spherical optical and statistical model calculation was performed with CASTHY/11/, by taking account of competing reactions, of which cross sections were calculated with PEGASUS/12/ standing on a preequilibrium and multi-step evaporation model. The OMP's for neutron given in in Table 1 were taken from Iijima and Kawai/13/ and rso was modified to reproduce the measured total cross sections. The OMP's for charged particles are as follows:
Proton = Perey/14/
Alpha = Huizenga and Igo/15/
Deuteron = Lohr and Haeberli/16/
Helium-3 and triton = Becchetti and Greenlees/17/
Parameters for the composite level density formula of Girbert and Cameron/18/ were evaluated by Iijima et al./19/. More extensive determination and modification were made in the present work. Table 2 shows the level density parameters used in the present calculation. Energy dependence of spin cut-off

parameter in the energy range below E-joint is due to Gruppelaar /20/.

MT = 1 Total
Spherical optical model calculation was adopted.

MT = 2 Elastic scattering
Calculated as (total - sum of partial cross sections).

MT = 4, 51 - 91 Inelastic scattering
Spherical optical and statistical model calculation was adopted. The level scheme was taken from Ref./21/.

No.	Energy(MeV)	Spin-parity
GR.	0.0	7/2 +
1	0.1603	5/2 +
2	0.5421	3/2 +
3	0.7125	1/2 +
4	1.0302	9/2 +
5	1.0886	9/2 +

Levels above 1.18 MeV were assumed to be overlapping.

MT = 102 Capture
Spherical optical and statistical model calculation with CASTHY/11/ was adopted. Direct and semi-direct capture cross sections were estimated according to the procedure of Benzi and Reffo/22/ and normalized to 1 milli-barn at 14 MeV.

The gamma-ray strength function (25.7E-4) was adjusted to reproduce the capture cross section of 340 milli-barns at 30 keV which was derived from natural Sb data /23/ and CFRMF activation rate measurement (Sb-121/Sb-123=1.6) /24/.

MT = 16 (n,2n) Cross Section
MT = 17 (n,3n) Cross Section
MT = 22 (n,n'a) Cross Section
MT = 28 (n,n'p) Cross Section
MT = 32 (n,n'd) Cross Section
MT = 33 (n,n't) Cross Section
MT =103 (n,p) Cross Section
MT =104 (n,d) Cross Section
MT =105 (n,t) Cross Section
MT =107 (n,alpha) Cross Section
These reaction cross sections were calculated with the preequilibrium and multi-step evaporation model code PEGASUS/12/.

The Kalbach's constant K (=174) was estimated by the formula derived from Kikuchi-Kawai's formalism/25/ and level density parameters.

Finally, the (n,p) and (n,alpha) cross sections were normalized to the following values at 14.5 MeV:

(n,p)	4.70 mb	(recommended by Forrest/26/)
(n,alpha)	2.53 mb	(systematics of Forrest/26/)

MT = 251 Mu-bar

Calculated with CASTHY/11/.

MF = 4 Angular Distributions of Secondary Neutrons
Legendre polynomial coefficients for angular distributions are given in the center-of-mass system for MT=2 and discrete inelastic levels, and in the laboratory system for MT=91. They were calculated with CASTHY/11/. For other reactions, isotropic distributions in the laboratory system were assumed.

MF = 5 Energy Distributions of Secondary Neutrons
Energy distributions of secondary neutrons were calculated with PEGASUS/12/ for inelastic scattering from overlapping levels and for other neutron emitting reactions.

Table 1 Neutron Optical Potential Parameters

Depth (MeV)	Radius(fm)	Diffuseness(fm)
V = 47.64-0.473E	R0 = 6.256	a0 = 0.62
Ws = 9.744	Rs = 6.469	as = 0.35
Wso= 7.0	Rso= 6.241	aso= 0.62

Table 2 Level Density Parameters

Nuclide	SYST	a(/MeV)	T(MeV)	C(/MeV)	EX(MeV)	Pairing
49-In-119		1.940E+01	5.340E-01	2.196E+00	4.999E+00	1.240E+00
49-In-120	*	1.757E+01	6.016E-01	2.330E+01	4.366E+00	0.0
49-In-121		1.601E+01	6.060E-01	1.119E+00	5.277E+00	1.430E+00
49-In-122	*	1.707E+01	5.968E-01	1.737E+01	4.092E+00	0.0
50-Sn-120		1.595E+01	6.540E-01	4.691E-01	7.083E+00	2.430E+00
50-Sn-121		1.630E+01	6.100E-01	2.010E+00	5.217E+00	1.190E+00
50-Sn-122		1.434E+01	7.060E-01	3.423E-01	7.416E+00	2.620E+00
50-Sn-123		1.509E+01	6.870E-01	3.062E+00	6.032E+00	1.190E+00
51-Sb-121		1.730E+01	5.740E-01	1.715E+00	5.022E+00	1.240E+00
51-Sb-122		1.772E+01	5.500E-01	1.346E+01	3.517E+00	0.0
51-Sb-123		1.585E+01	6.213E-01	1.285E+00	5.469E+00	1.430E+00
51-Sb-124		1.696E+01	5.600E-01	1.090E+01	3.433E+00	0.0

SYST: * = LDP's were determined from systematics.

Spin cutoff params were calculated as 0.146*SQRT(a)*A**(2/3). In the CASTHY calculation, spin cutoff factors at 0 MeV were assumed to be 6.4 for Sb-123 and 5.0 for Sb-124.

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13) Iijima, S. and Kawai, M.: J. Nucl. Sci. Technol., 20, 77 (1983).
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MAT number = 3630

63-Eu- 0 JAERI,JNDC Eval-Mar89 T.Asami, JNDC FP ND W.G.
Dist-Oct89

History

89-03 Evaluation for each isotope was made by T.Asami(JAERI) and JNDC FP Nuclear Data W.G. Data for natural Eu were constructed from the isotope data by T.Asami and T.Nakagawa(JAERI).

MF = 1 General information
MT=451 Comments and dictionary

MF = 2 Resonance parameters
MT=151 Resolved and unresolved resonance parameters
Resolved resonance region (MLBW formula)
Evaluation for each isotope was made by Kikuchi /1/.

1) Eu-151: below 98.2 eV
Parameters were mainly based on the data of Rahn et al. /2/, and for the lowest 2 levels, the data of Tassan et al./3/. The capture width of 0.093 eV /2/ was assumed for the levels whose radiative capture width was not measured. A negative resonance was added so as to reproduce the capture cross section of 9200 barns at 0.0253 eV/4/.

2)Eu-153: below 97.2 eV
Neutron widths were obtained from the data of Rahn et al. /2/ and Anufriev et al./5/. Radiative capture widths were adopted from the data of Rahn et al. The parameters of 1.73-, 2.46-, 3.29- and 3.94-eV levels were taken from Maghabghab /6/ so as to reproduce the capture resonance integral of 1420 barns/6/. A negative resonance was added so as to reproduce the capture cross section of 390 barns and the elastic scattering of 8.0 +- 0.2 barns at 0.0253 eV/4/.

Unresolved resonance region : up to 100 keV
The parameters were adjusted to reproduce the capture cross sections. The effective scattering radius was obtained from fitting to the calculated total cross section at 100 keV.

Typical values of the parameters at 70 keV:

1) Eu-151
S0 = 3.699E-4, S1 = 0.100E-4, S2 = 3.000E-4, GG = 0.091 eV
Do = 0.408 eV, R = 6.870 fm.

2) Eu-153
S0 = 2.602E-4, S1 = 1.394E-4, S2 = 2.946E-4, GG = 0.094 eV
Do = 1.489 eV, R = 6.421 fm.

Calculated 2200-m/s cross sections and res. integrals (barns)

	2200 m/s	res. integ.
total	4606	-
elastic	5.248	-
capture	4601	2210
(n,alpha)	4.637E-06	

MF = 3 Neutron cross sections
Below 100 keV, resonance parameters were given.

MT = 1 Total
Below 10 MeV, calculated with the CASTHY code/7/. The optical potential parameters listed in Table 1 used. Above 10 MeV, cross section was determined from the data of Foster and Glasgow/8/ for natural Eu.

MT = 2 Elastic scattering
Calculated as (total - sum of partial cross sections).

MT = 4, 51-71, 91 Inelastic scattering
Calculated with the CASTHY code/7/. The level scheme used in the calculations was taken from Ref./9/

		Eu-151				Eu-153	
No	MT	energy(MeV)	J-parity	No.	MT	energy(MeV)	J-parity
g.s		0.0	5/2+	g.s		0.0	5/2+
1	51	0.02150	7/2+	1	52	0.0834	7/2+
2	58	0.19620	11/2-	2	53	0.0974	5/2-
3	59	0.19650	3/2+	3	54	0.1032	3/2+
4	61	0.2432	7/2-	4	55	0.1516	7/2-
5	62	0.2604	5/2+	5	56	0.1729	5/2+
6	64	0.3070	7/2+	6	57	0.1931	9/2+
7	65	0.3075	5/2+	7	60	0.2353	9/2-
8	68	0.3498	9/2-	8	63	0.2697	7/2+
9	69	0.3536	7/2-	9	66	0.3219	11/2-
10	71	0.4160	7/2+	10	67	0.3251	11/2+
				11	70	0.3964	9/2+
cont	91	0.420		cont	91	0.400	

Q-values of excited levels were shifted a little so as to be consistent with threshold energies.

MT = 102 Capture
Calculated from Eu-151 and -153 capture cross sections. The Eu-151 capture cross section below 2 MeV was determined by eye-guiding the data measured by Macklin and Young/10/, and above 2 MeV, JENDL-2 data calculated with CASTHY was normalized to Macklin and Young at 2 MeV. For Eu-153, evaluation for JENDL-2 was adopted. Direct and semi-direct capture cross sections were added, which were estimated according to the procedure of Benzi and Reffo/11/ and normalized to 1 milli-barn at 14 MeV.

MT=16, 17, 22, 28, 103, 107 (n,2n), (n,3n), (n,na), (n,np), (n,p) and (n,a) cross sections
Calculated with the GNASH code/12/ using the optical model parameters in Table 2, which were determined so as to reproduce well the total cross section measured by Foster and Glasgow/8/ for natural Eu. The level scheme data were taken from Ref/9/. The calculated (n,2n) and (n,3n) cross sections were modified on the basis of the experimental data of Frehaut et al./13/ and Bayhurt/14/, respectively.

The (n,alpha) cross section in the resonance region was calculated from resonance parameters, by assuming a mean alpha width of 9.0E-11 eV for Eu-151 and 2.0E-10 eV for Eu-153 so as to reproduce the thermal cross section/6/. The cross section was averaged in suitable energy intervals. Above the resolved resonance region, the cross section was connected smoothly to the GNASH calculation.

MT = 251 Mu-bar
Calculated with CASTHY/7/.

MF = 4 Angular Distributions of Secondary Neutrons
Legendre polynomial coefficients for angular distributions are given in the center-of-mass system for MT=2 and discrete inelastic levels, and in the laboratory system for MT=91. They were calculated with CASTHY/7/. For other reactions, the isotropic distributions in the laboratory system were assumed.

MF = 5 Energy Distributions of Secondary Neutrons
Energy distributions of secondary neutrons were calculated with GNASH/12/.

MF = 12 Photon Production Multiplicities
MT=102, 107 (below 21.6437 keV)
Calculuated with GNASH code/12/.

MF = 13 Photon Production Cross Sections
MT=3 (above 21.6437 keV)
Calculuated with GNASH code/12/.

MF = 14 Photon Angular Distributions
MT=3, 102
Assumed to be isotropic.

MF = 15 Continuous Photon Energy Spectra
MT=3, 102, 107
Calculated with GNASH code/12/.

Table 1 Neutron Optical Potential Parameters (for CASTHY)

V = 43.71 - 0.0566*En,		Vso = 7.9	(MeV)
Ws = 7.696,		Wv = 0.0	(MeV)
r = 1.270,	rs = 1.440,	rso = 1.280	(fm)
a = 0.60,	b = 0.45,	aso = 0.60	(fm)

Table 2 Neutron Optical Potential Parameters (for GNASH)

V = 43.71 - 0.05655*En,		Vso = 0.0	(MeV)
Ws = 7.696,		Wv = 0.0	(MeV)
r = 1.272,	rs = 1.440,	rso = 1.270	(fm)
a = 0.48,	b = 0.45,	aso = 0.48	(fm)

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1) Kikuchi, Y., et al.: JAERI-M 86-030 (1986).
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12) Young, P.G. and Arthur, E.D.: LA-6947 (1977).
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14) Bayhurst, B.P. et al.: Phys. Rev., C12, 451 (1975).

MAT number = 3631

63-Eu-151 JAERI,JNDC Eval-Mar89 T.Asami, JNDC FP ND W.G.
Dist-Oct89

History
84-10 Evaluation for JENDL-2 was made by JNDC FPND W.G./1/
89-03 Evaluation for JENDL-3 was made by T.Asami(JAERI) and JNDC FP Nuclear Data W.G.

MF = 1 General information
MT=451 Comments and dictionary

MF = 2 Resonance parameters
MT=151 Resolved and unresolved resonance parameters
Resolved resonance region (MLBW formula) : below 0.0982 keV
Evaluation was made by Kikuchi /2/. Parameters were adopted mainly from the data measured by Rahn et al./3/. For the lowest 2 levels, the data of Tassan et al./4/ were adopted. The average capture width of 0.093 eV /3/ was assumed for the levels whose radiative capture width was not measured. A negative resonance was added at -0.00361 eV so as to reproduce the capture cross section of 9200 +- 100 barns at 0.0253 eV/5/.
Unresolved resonance region : 0.0982 keV - 100 keV
The neutron strength functions S0, S1, S2 were based on the compilation of Mughabghab/6/. The observed level spacing was adjusted to reproduce the capture cross section measured by Macklin and Young/7/. The effective scattering radius was obtained from fitting to the calculated total cross section at 100 keV.

Typical values of the parameters at 70 keV:
S0 = 3.699E-4, S1 = 0.100E-4, S2 = 3.000E-4, GG = 0.091 eV
Do = 0.408 eV, R = 6.870 fm.

Calculated 2200-m/s cross sections and res. integrals (barns)

	2200 m/s	res. integ.
total	9201	-
elastic	3.207	-
capture	9198	3070
(n,alpha)	8.806E-06	

MF = 3 Neutron cross sections
Below 100 keV, resonance parameters were given.

MT = 1 Total
Below 10 MeV, calculated with the CASTHY code/8/. The optical potential parameters listed in Table 1 used. Above 10 MeV, determined from the data of Foster and Glasgow/9/ for natural Eu.

MT = 2 Elastic scattering
Calculated as (total - sum of partial cross sections).

MT = 4, 51-60, 91 Inelastic scattering
Calculated with the CASTHY code/8/. The level scheme used in the calculations was taken from Ref./10/

No	level energy(MeV)	spin-parity
g.s	0.0	5/2+
1	0.02150	7/2+
2	0.19620	11/2-
3	0.19650	3/2+
4	0.2432	7/2-
5	0.2604	5/2+
6	0.3070	7/2+
7	0.3075	5/2+
8	0.3498	9/2-
9	0.3536	7/2-
10	0.4160	7/2+

Levels above 0.420 MeV were assumed to be overlapping.

MT = 102 Capture
Below 2 MeV, cross section was determined by eye-guiding the data measured by Macklin and Young/7/. Above 2 MeV, JENDL-2 data calculated with CASTHY was normalized to Macklin and Young at 2 MeV. Direct and semi-direct capture cross sections were added, which were estimated according to the procedure of Benzi and Reffo/11/ and normalized to 1 milli-barn at 14 MeV.

MT=16, 17, 22, 28, 103, 107 (n,2n), (n,3n), (n,na), (n,np), (n,p) and (n,a) cross sections
Calculated with the GNASH code/12/ using the optical model parameters in Table 2, which were determined so as to reproduce well the total cross section measured by Foster and Glasgow/9/ for natural Eu. The level scheme data were taken from Ref/10/. The calculated (n,2n) and (n,3n) cross sections were modified on the basis of the experimental data of Frehaut et al./13/ and Bayhurt/14/, respectively.

The (n,alpha) cross section in the resonance region was calculated from resonance parameters, by assuming a mean alpha width of 9.0E-11 eV so as to reproduce the thermal cross section/6/. The cross section was averaged in suitable energy intervals. Above 98.2 eV, the cross section was connected smoothly to the GNASH calculation.

MT = 251 Mu-bar
Calculated with CASTHY/8/.

MF = 4 Angular Distributions of Secondary Neutrons
Legendre polynomial coefficients for angular distributions are given in the center-of-mass system for MT=2 and discrete inelastic levels, and in the laboratory system for MT=91. They were calculated with CASTHY/8/. For other reactions, the isotropic distributions in the laboratory system were assumed.

MF = 5 Energy Distributions of Secondary Neutrons
Energy distributions of secondary neutrons were calculated with GNASH/12/.

Table 1 Neutron Optical Potential Parameters (for CASTHY)

V = 43.71 - 0.0566•En,		Vso = 7.9	(MeV)
Ws = 7.696,		Wv = 0.0	(MeV)
r = 1.270,	rs = 1.440,	rso = 1.280	(fm)
a = 0.60,	b = 0.45,	aso = 0.60	(fm)

Table 2 Neutron Optical Potential Parameters (for GNASH)

V = 43.71 - 0.05655•En,		Vso = 0.0	(MeV)
Ws = 7.696,		Wv = 0.0	(MeV)
r = 1.272,	rs = 1.440,	rso = 1.270	(fm)
a = 0.48,	b = 0.45,	aso = 0.48	(fm)

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10) ENSDF: Evaluated Nuclear Structure Data File (June 1987).
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MAT number = 3633

63-Eu-153 JEARI,JNDC Eval-Mar89 T.Asami, JNDC FP ND W.G.
Dist-Oct89

History
84-10 Evaluation for JENDL-2 was made by JNDC FPND W.G./1/
89-03 Evaluation for JENDL-3 was made by T.Asami(JAERI) and
JNDC FP Nuclear Data W.G.

MF = 1 General information
MT=451 Comments and dictionary

MF = 2 Resonance parameters
MT=151 Resolved and unresolved resonance parameters
Evaluation was made by Kikuchi /2/. Neutron widths were obtained by averaging the data of Rahn et al./3/ and Anufriev et al./4/. Radiative capture widths were adopted from the data measured by Rahn et al. The parameters of 1.73-, 2.46-, 3.29- and 3.94-eV levels were taken from Mughabghab /5/ so as to reproduce the capture resonance integral of 1420 +- 100 barns recommended in Ref./5/. A negative resonance was added at -0.5 eV so as to reproduce the capture cross section of 390 +- 20 barns and the elastic scattering of 8.0 +- 0.2 barns at 0.0253 eV /6/.

Unresolved resonance region : 0.0972 keV - 100 keV
Initial values of neutron strength functions were the same as JENDL-2 calculated with optical and statistiacl model code CASTHY/7/. They were adjusted to the capture cross section calculated with CASTHY for JENDL-2 which was in good agreement with experimental data by Macklin and Young/8/. The observed level spacing was determined to reproduce the capture cross section at 30 keV. The effective scattering radius was obtained from fitting to the calculated total cross section at 100 keV.

Typical values of the parameters at 70 keV:
S0 = 2.602E-4, S1 = 1.394E-4, S2 = 2.946E-4, GG = 0.094 eV
Do = 1.489 eV, R = 6.421 fm.

Calculated 2200-m/s cross sections and res. integrals (barns)

	2200 m/s	res. integ.
total	399.2	-
elastic	7.118	-
capture	392.1	1420
(n,alpha)	8.187E-07	

MF = 3 Neutron cross sections
Below 100 keV, resonance parameters were given.

MT = 1 Total
Below 10 MeV, calculated with the CASTHY code/7/. The optical potential parameters listed in Table 1 used. Above 10 MeV, determined from the data of Foster and Glasgow/9/ for natural Eu.

MT = 2 Elastic scattering
Calculated as (total - sum of partial cross sections).

MT = 4, 51 – 91 *Inelastic scattering*
Calculated with the CASTHY code/7/. The level scheme used in the calculations was taken from Ref./10/

No	level energy(MeV)	spin-parity
g.s.	0.0	5/2+
1	0.0834	7/2+
2	0.0974	5/2-
3	0.1032	3/2+
4	0.1516	7/2-
5	0.1729	5/2+
6	0.1931	9/2+
7	0.2353	9/2-
8	0.2697	7/2+
9	0.3219	11/2-
10	0.3251	11/2+
11	0.3964	9/2+

Levels above 0.400 MeV were assumed to be overlapping.

MT = 102 *Capture*
Calculation for JENDL-2 with CASTHY/7/ was adopted. The following potential parameters were determined by Iijima et al. /11/ to reproduce a systematic trend of the total cross section.

Depth (MeV)	Radius(fm)	Diffuseness(fm)
V = 49.61	R0 = 6.7926	a0 = 0.6
Ws = 10.595	Rs = 7.6483	as = 0.45
Wso= 7.0	Rso= 6.8461	'so= 0.6

Parameters for the composite level density formula of Girbert-Cameron were evaluated as follows/12/. The coefficient of spin cut-off parameter C1 was taken as 0.146. The energy dependence of spin cut-off parameter in the energy range below E-joint is due to Gruppelaar /13/.

	Eu-153	Eu-154
Pairing energy (MeV)	1.100	0.0
a (1/MeV)	27.860	22.670
Spin cut-off param.	19.567	19.972
Nuclear temp.(MeV)	0.455	0.432
C (1/MeV)	13.410	16.440
E-joint (MeV)	5.399	2.784

The gamma-ray strength function (= 809.E-4) was adjusted to reproduce the experimental capture cross section of 680 milli-barns at 250 keV measured by Macklin and Young/8/. Direct and semi-direct capture cross sections were estimated according to the procedure of Benzi and Reffo/14/ and normalized to 1 milli-barn at 14 MeV.

MT=16, 17, 22, 28, 103, 107 (n,2n), (n,3n), (n,na), (n,np), (n,p) and (n,a) cross sections
Calculated with the GNASH code/15/ using the optical model parameters in Table 2, which were determined so as to

reproduce well the total cross section measured by Foster and Glasgow/9/ for natural Eu. The level scheme data were taken from Ref/10/. The calculated (n,p) cross section was normalized at 14.5 MeV to an average value of the experimental data around 14.5 MeV/16,17,18,19/.

The (n,alpha) cross section in the resonance region was calculated from resonance parameters, by assuming a mean alpha width of 2.0E-10 eV so as to reproduce the thermal cross section/5/. The cross section was averaged in suitable energy intervals. Above 97.2 eV, the cross section was connected smoothly to the GNASH calculation.

MT = 251 Mu-bar
Calculated with CASTHY/7/.

MF = 4 Angular Distributions of Secondary Neutrons
Legendre polynomial coefficients for angular distributions are given in the center-of-mass system for MT=2 and discrete inelastic levels, and in the laboratory system for MT=91. They were calculated with CASTHY/7/. For other reactions, isotropic distributions in the laboratory system were assumed.

MF = 5 Energy Distributions of Secondary Neutrons
Energy distributions of secondary neutrons were calculated with GNASH/15/.

Table 1 Neutron Optical Potential Parameters (for CASTHY)

V = 43.71 - 0.0566•En,		Vso = 7.9	(MeV)
Ws = 7.696,		Wv = 0.0	(MeV)
r = 1.270,	rs = 1.440,	rso = 1.280	(fm)
a = 0.60,	b = 0.45,	aso = 0.60	(fm)

Table 2 Neutron Optical Potential Parameters (for GNASH)

V = 43.71 - 0.05655•En,		Vso = 0.0	(MeV)
Ws = 7.696,		Wv = 0.0	(MeV)
r = 1.272,	rs = 1.440,	rso = 1.270	(fm)
a = 0.48,	b = 0.45,	aso = 0.48	(fm)

References

1) Aoki, T. et al.: Proc. Int. Conf. on Nuclear Data for Basic and Applied Science, Santa Fe., Vol. 2, p.1627 (1985).
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4) Anufriev, V.A., et al.: Sov. At. Energy, 46, 182 (1979).
5) Mughabghab, S.F.: "Neutron Cross Sections, Vol. I, Part B", Academic Press (1984).
6) Mughabghab, S.F. and Garber, D.I.: "Neutron Cross Sections, Vol.1, Resonance Parameters", BNL 325, 3rd Ed., Vol. 1, (1973).
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9) Foster Jr.D.G. and Glasgow D.W.: Phys. Rev., C3, 576 (1971).
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11) Iijima, S. and Kawai, M.: J. Nucl. Sci. Technol., 20, 77

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15) Young, P.G. and Arthur, E.D.: LA-6947 (1977).
16) Coleman, R.F. et al.: Proc. Phys. Soc., 73, 215 (1959).
17) Qaim, S.M.: data in the EXFOR file (1974).
18) Pruys, H.S. et al.: J. Inorg. Nucl. Chem., 37, 1587 (1975).
19) Bari, A.: J. Radioanal. Chem., 75, 189 (1982).

MAT number = 3720

72-Hf- 0 NAIG+ Eval-Jul89 Hida, Yoshida and Shibata(JAERI)
Dist-Sep89

History
89-07 New evaluation for JENDL-3 was made by K.Hida, T.Yoshida (NAIG) and K.Shibata (JAERI).

MF=1 General Information
MT=451 Descriptive data and dictionary

MF=2 Resonance Parameters
MT=151 Resolved and unresolved resonance parameters
Resonance region: 1.0E-5 eV to 50 keV
Resolved resonances for MLBW formula
Made up of isotopic files.
Unresolved resonances
Made up of isotopic files.

2200 m/sec cross sections and calculated res. integrals.

	2200 m/sec	res. integ.
total	114.9 b	-
elastic	9.9 b	-
capture	105.0 b	1995.7 b

MF=3 Neutron Cross Sections
Below 50 keV :
No background was given.
Above 50 keV :
MT=1 Total
50 keV - 110 keV : Made up of isotopic files.
110 keV - 7.5 MeV: Spline-function fitting to the experimental data/1/-/3/.
7.5 MeV - 20 MeV : Made up of isotopic files.
MT=2 Elastic
Obtained by subtracting a sum of partial reaction cross sections from the total cross section.
MT=3 Nonelastic
Sum of MT=4, 16, 17, 102, 103, 107.
MT=4 Total inelastic
Sum of MT=51-79, 91.
MT=51-79, 91 Inelastic
Made up of isotopic files.
The discrete levels were lumped.
MT=16,17,102,103,107 (n,2n),(n,3n),(n,gamma),(n,p),(n,alpha)
Made up of isotopic files.
MT=251 Mu-bar
Calculated from MF/MT=4/2.

MF=4 Angular Distributions of Secondary Neutrons
MT=2,51-79,91
Made up of isotopic files.
MT=16,17
Isotropic in the laboratory system.

MF=5 Energy Distributions of Secondary Neutrons
MT=16,17,91

Made up of isotopic files.

MF=12 Photon Production Multiplicities and
MT=3,102
Made up isotopic files.

MF=14 Photon Angular Distributions
MT=3,102
Isotropic.

MF=15 Continuous Photon Energy Spectra
MT=3,102
Made up of isotopic files.

References

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2) Foster Jr. D.G. and Glasgow D.W.: Phys. Rev. C3, 576 (1971).
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MAT number = 3721

```
72-Hf-174 NAIG+       Eval-Jul89 Hida, Yoshida and Shibata(JAERI)
                      Dist-Sep89
History
89-07 New evaluation for JENDL-3 was made by K.Hida, T.Yoshida
      (NAIG) and K.Shibata (JAERI).

MF=1  General Information
 MT=451  Descriptive data and dictionary

MF=2  Resonance Parameters
 MT=151 Resolved and unresolved resonance parameters
 Resolved resonances for MLBW formula
    Energy range               : 1.0E-5 eV to 220 eV.
    Res. energies and Gam-n : BNL-325 /1/.
    Gam-gamma                  : 0.060 eV assumed if unknown.
    Radius                     : 7.5 fm
 Unresolved resonances
    Energy range               : 220 eV to 50 keV.
    S0, S1, R and Gam-gamma : Adjusted so that the calculated
                               total and capture cross sections
                               were reproduced well.
    Results are D-obs = 13.4 eV, S0 = 2.8E-4, S1 = 1.00E-4,
    R = 7.9 fm and Gam-gamma = 0.054 eV.

    2200 m/sec cross sections and calculated res. integrals.
                  2200 m/sec     res. integ.
        total      576.4 b          -
        elastic     15.0 b          -
        capture    561.5 b        363.8 b

MF=3  Neutron Cross Sections
Below 50 keV :
 No background was given.
Above 50 keV :
 MT=1,2,4,51-68,91,102  Total,elastic,inelastic and capture
  Calculated with ECIS /2/ and CASTHY /3/.  Deformed optical
  potential for ECIS calculation was determined so as to reproduce
  the experimental total cross section of natural hafnium,
  starting with the Haouat potential /4/.
    V0 = 47.05-0.3*En, Ws = 3.92+0.4*En (En<10), Vso = 6.2 (MeV),
                            7.92        (En>10)
    a0 = 0.63,         as = 0.52,                  aso = 0.47 (fm),
    r0 = 1.24,         rs = 1.24,                  rso = 1.12 (fm),
    Beta-2 = 0.266,    Beta-4 = 0.0.
  The deformation parameter Beta-2 was determined from the
  measured E2 transition probability data /5/.  The lowest three
  levels belonging to the ground state rotational band were
  coupled in the calculation.  The spherical optical potential for
  CASTHY calculation is the same as that of JENDL-2.
    V0 = 38.0, Ws = 8.0+0.5*SQRT(En), Vso = 7.0 (MeV),
    a0 = 0.47, as = 0.52            , aso = 0.47 (fm),
    r0 = 1.32, rs = 1.32            , rso = 1.32 (fm).
  Competing processes (n,2n) and (n,3n) were
  calculated with GNASH /6/ and fed to ECIS-CASTHY calculation.
  The level fluctuation and interference effects were considered.
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Level scheme was taken from Table of Isotopes /7/.

No.	Energy(MeV)	Spin-Parity
g.s.	0.0	0 +
1	0.0910	2 +
2	0.2975	4 +
3	0.6084	6 +
4	0.8282	0 +
5	0.9002	2 +
6	1.0622	4 +
7	1.2268	2 +
8	1.3034	3 +
9	1.3087	2 -
10	1.3194	2 +
11	1.3365	3 +
12	1.3947	4 +
13	1.4253	4 -
14	1.4429	5 -
15	1.4489	4 +
16	1.4964	2 +
17	1.5034	3 +
18	1.6261	4 +

Continuum levels assumed above 1.6487 MeV.

The level density parameters for Gilbert and Cameron's formula /8/ are the same as those of JENDL-2.

	a(1/MeV)	C(1/MeV)	T(MeV)	Ex(MeV)	sigma**2
Hf-174	23.09	2.31	0.477	5.01	7.47
Hf-175	22.93	10.0	0.484	4.42	6.00

MT=3 Nonelastic
Sum of MT=4,16,17,102.

MT=16,17 (n,2n), (n,3n)
Calculated with GNASH /6/. The transmission coefficients for the incident channel were generated with ECIS /4/, while those for the exit channels with ELIESE-3 /9/. The preequilibrium parameter F2 was adjusted to reproduce the measured (n,2n) cross section at 14.5 MeV and resulted in F2=5.0.

MT=251 Mu-bar
Calculated with ECIS /2/ and CASTHY /3/.

MF=4 Angular Distributions of Secondary Neutrons
MT=2,51-68,91
Calculated with ECIS /2/ and CASTHY /3/.
MT=16,17
Isotropic in the laboratory system.

MF=5 Energy Distributions of Secondary Neutrons
MT=16,17,91
Calculated with GNASH /6/.

MF=12 Photon Production Multiplicities
MT=16,17,91,102
Calculated with GNASH /6/ and stored under Option-1 (photon production multiplicities). The photon strength functions for most nuclei were taken from /1/, while those for some hafnium isotopes were determined from capture cross section normalization to the experimental data. The photon profile function is a superposition of the Berman-type giant dipole

resonance /10/ and the pygmy resonance whose parameter values were cited from the neighbouring nucleus Ta /11/.

EG1 = 15.23, EG2 = 12.3 , Ep = 5.2 (MeV),
GG1 = 4.48, GG2 = 2.43, Gp = 2.5 (MeV),
sig-pygmy/sig-GDR = 0.0245.

MT=51-68
Stored under Option-2 (transition probability array). Data were taken from /7/.

MF=14 Photon Angular Distributions
MT=16,17,51-68,91,102
Isotropic.

MF=15 Continuous Photon Energy Spectra
MT=16,17,91,102
Calculated with GNASH /6/.

References
1) Mughabghab S.F.: Neutron Cross Sections, vol.1, Part B (1984).
2) Raynal J.: IAEA SMR-9/8 (1970).
3) Igarasi S.: J. Nucl. Sci. Technol., 12, 67 (1975).
4) Haouat G. et al.: Nucl. Sci. Eng., 81, 491 (1982).
5) Raman S. et al.: At. Data Nucl. Data Tables, 36, 1 (1987).
6) Young P.G. and Arthur E.D.: LA-6947 (1977).
7) Lederer C.M. and Shirley V.S.: Table of Isotopes 7th Edition (1978).
8) Gilbert A. and Cameron A.G.W.: Can. J. Phys., 43, 1446 (1965).
9) Igarasi S.: JAERI-1224 (1972).
10) Berman B.L.: At. Data Nucl. Data Tables, 15, 319 (1975).
11) Igashira M. et al.: Int. Symp. Capture Gamma-ray Specroscopy and Related Topics - 1984, 523 (1985).

MAT number = 3722

72-Hf-176 NAIG+ Eval-Jul89 Hida, Yoshida and Shibata(JAERI)
Dist-Sep89

History
89-07 New evaluation for JENDL-3 was made by K.Hida, T.Yoshida (NAIG) and K.Shibata (JAERI).

MF=1 General Information
MT=451 Descriptive data and dictionary

MF=2 Resonance Parameters
MT=151 Resolved and unresolved resonance parameters
Resolved resonances for MLBW formula
Energy range : 1.0E-5 eV to 700 eV.
Res. energies and Gam-n : BNL-325 /1/.
Gam-gamma : 0.060 eV assumed if unknown.
Radius : 7.6 fm
Unresolved resonances
Energy range : 700 eV to 50 keV.
S0, S1, R and Gam-gamma : Adjusted so that the calculated total and capture cross sections were reproduced well.
Results are D-obs = 55.2 eV, S0 = 2.00E-4, S1 = 1.00E-4, R = 9.1 fm and Gam-gamma = 0.054 eV.

2200 m/sec cross sections and calculated res. integrals.

	2200 m/sec	res. integ.
total	29.03 b	-
elastic	5.54 b	-
capture	23.48 b	894.1 b

MF=3 Neutron Cross Sections
Below 50 keV :
No background was given.
Above 50 keV :
MT=1,2,4,51-73,91,102 Total,elastic,inelastic and capture
Calculated with ECIS /2/ and CASTHY /3/. Deformed optical potential for ECIS calculation was determined so as to reproduce the experimental total cross section of natural hafnium, starting with the Haouat potential /4/.

V0 = 46.89-0.3*En, Ws = 3.84+0.4*En (En<10), Vso = 6.2 (MeV),
7.84 (En>10)
a0 = 0.63, as = 0.52, aso = 0.47 (fm),
r0 = 1.24, rs = 1.24, rso = 1.12 (fm),
Beta-2 = 0.276, Beta-4 = 0.0.

The deformation parameter Beta-2 was determined from the measured E2 transition probability data /5/. The lowest three levels belonging to the ground state rotational band were coupled in the calculation. The spherical optical potential for CASTHY calculation is the same as that of JENDL-2.

V0 = 38.0, Ws = 8.0+0.5*SQRT(En), Vso = 7.0 (MeV),
a0 = 0.47, as = 0.52 , aso = 0.47 (fm),
r0 = 1.32, rs = 1.32 , rso = 1.32 (fm).

Capture cross section was normalized to the measured data of Beer et al. /6/ at 30 keV.
Competing processes (n,2n), (n,3n), (n,p), and (n,alpha) were

calculated with GNASH /7/ and fed to ECIS-CASTHY calculation.
The level fluctuation and interference effects were considered.
Level scheme was taken from Table of Isotopes /8/.

No.	Energy(MeV)	Spin-Parity
g.s.	0.0	0 +
1	0.0883	2 +
2	0.2902	4 +
3	0.5970	6 +
4	0.9980	8 +
5	1.1499	0 +
6	1.2266	2 +
7	1.2477	2 -
8	1.2932	0 +
9	1.3133	3 -
10	1.3413	2 +
11	1.3794	2 +
12	1.4046	4 -
13	1.4458	3 +
14	1.5777	3 +
15	1.6434	1 -
16	1.6723	1 +
17	1.7046	2 +
18	1.7102	3 -
19	1.7221	1 -
20	1.7675	2 -
21	1.7861	3 +
22	1.7937	3 -
23	1.8190	0 -

Continuum levels assumed above 1.8400 MeV.
The level density parameters for Gilbert and Cameron's formula /9/ are the same as those of JENDL-2.

	a(1/MeV)	C(1/MeV)	T(MeV)	Ex(MeV)	sigma**2
Hf-176	22.77	1.74	0.454	4.38	6.09
Hf-177	22.61	9.06	0.486	4.38	9.45

MT=3 Nonelastic
Sum of MT=4,16,17,102,103,107.

MT=16,17,103,107 (n,2n), (n,3n), (n,p) and (n,alpha)
Calculated with GNASH /7/. The transmission coefficients for the incident channel were generated with ECIS /2/, while those for the exit channels with ELIESE-3 /10/. The preequilibrium parameter F2 was adjusted to reproduce the measured (n,2n) cross section at 14.5 MeV and resulted in F2=5.0.

MT=251 Mu-bar
Calculated with ECIS /2/ and CASTHY /3/.

MF=4 Angular Distributions of Secondary Neutrons
MT=2,51-73,91
Calculated with ECIS /2/ and CASTHY /3/.
MT=16,17
Isotropic in the laboratory system.

MF=5 Energy Distributions of Secondary Neutrons
MT=16,17,91
Calculated with GNASH /7/.

MF=12 Photon Production Multiplicities

MT=16,17,91,102,103,107
Calculated with GNASH /7/ and stored under Option-1 (photon production multiplicities). The photon strength functions for most nuclei were taken from /1/, while those for some hafnium isotopes were determined from capture cross section normalization to the experimental data. The photon profile function is a superposition of the Berman-type giant dipole resonance /11/ and the pygmy resonance whose parameter values were cited from the neighbouring nucleus Ta /12/.

EG1 = 15.23, EG2 = 12.3 , Ep = 5.2 (MeV),
GG1 = 4.48, GG2 = 2.43, Gp = 2.5 (MeV),
sig-pygmy/sig-GDR = 0.0245.

MT=51-73
Stored under Option-2 (transition probability array). Data were taken from /8/.

MF=14 Photon Angular Distributions
MT=16,17,51-68,91,102,103,107
Isotropic.

MF=15 Continuous Photon Energy Spectra
MT=16,17,91,102,103,107
Calculated with GNASH /7/.

References

1) Mughabghab S.F.: Neutron Cross Sections, vol.1, Part B (1984).
2) Raynal J.: IAEA SMR-9/8 (1970).
3) Igarasi S.: J. Nucl. Sci. Technol., 12, 67 (1975).
4) Haouat G. et al.: Nucl. Sci. Eng., 81, 491 (1982).
5) Raman S. et al.: At. Data Nucl. Data Tables, 36, 1 (1987).
6) Beer H. et al.: Phys. Rev., C30, 464 (1984).
7) Young P.G. and Arthur E.D.: LA-6947 (1977).
8) Lederer C.M. and Shirley V.S.: Table of Isotopes 7th Edition (1979).
9) Gilbert A. and Cameron A.G.W.: Can. J. Phys., 43, 1446 (1965).
10) Igarasi S.: JAERI-1224 (1972).
11) Berman B.L.: At. Data Nucl. Data Tables, 15, 319 (1975).
12) Igashira M. et al.: Int. Symp. Capture Gamma-ray Specroscopy and Related Topics - 1984, 523 (1985).

MAT number = 3723

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 72-Hf-177 NAIG+       Eval-Jul89 Hida, Yoshida and Shibata(JAERI)
                       Dist-Sep89
History
89-07 New evaluation for JENDL-3 was made by K.Hida, T.Yoshida
      (NAIG) and K.Shibata (JAERI).

MF=1  General Information
 MT=451  Descriptive data and dictionary

MF=2  Resonance Parameters
 MT=151 Resolved and unresolved resonance parameters
  Resolved resonances for MLBW formula
   Energy range             : 1.0E-5 eV to 250 eV.
   Res. energies and Gam-n  : BNL-325 /1/.
   Gam-gamma                : 0.065 eV assumed if unknown.
   Radius                   : 7.0 fm
  Unresolved resonances
   Energy range             : 250 eV to 50 keV.
   S0, S1, R and Gam-gamma  : Adjusted so that the calculated total
                              and capture cross sections were
                              reproduced well.
   Results are D-obs = 3.58 eV, S0 = 2.50E-4, S1 = 1.00E-4,
   R = 7.3 fm and Gam-gamma = 0.065 eV.

      2200 m/sec cross sections and calculated res. integrals.
                    2200 m/sec    res. integ.
          total      373.7 b          -
          elastic      0.2 b          -
          capture    373.5 b       7213.7 b

MF=3  Neutron Cross Sections
Below 50 keV :
 No background was given.
Above 50 keV :
 MT=1,2,4,51-66,91,102  Total,elastic,inelastic and capture
  Calculated with ECIS /2/ and CASTHY /3/.  Deformed optical
  potential for ECIS calculation was determined so as to reproduce
  the experimental total cross section of natural hafnium,
  starting with the Haouat potential /4/.
     V0 = 46.82-0.3*En, Ws = 3.81+0.4*En (En<10), Vso = 6.2 (MeV),
                             7.81        (En>10)
     a0 = 0.63,        as = 0.52,                aso = 0.47 (fm),
     r0 = 1.24,        rs = 1.24,                rso = 1.12 (fm),
     Beta-2 = 0.273,   Beta-4 = 0.0.
  The deformation parameter Beta-2 was determined from the
  measured E2 transition probability data /5/.  The lowest three
  levels belonging to the ground state rotational band were
  coupled in the calculation.  The spherical optical potential for
  CASTHY calculation is the same as that of JENDL-2.
     V0 = 38.0, Ws = 8.0+0.5*SQRT(En), Vso = 7.0 (MeV),
     a0 = 0.47, as = 0.52          , aso = 0.47 (fm),
     r0 = 1.32, rs = 1.32          , rso = 1.32 (fm).
  Capture cross section was normalized to the measured data of
  Beer et al. /6/ at 30 keV.
  Competing processes (n,2n), (n,3n), (n,p), and (n,alpha) were
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calculated with GNASH /7/ and fed to ECIS-CASTHY calculation. The level fluctuation and interference effects were considered. Level scheme was taken from Table of Isotopes /8/.

No.	Energy(MeV)	Spin-Parity
g.s.	0.0	7/2 -
1	0.1130	9/2 -
2	0.2497	11/2 -
3	0.3213	9/2 +
4	0.4095	13/2 -
5	0.4267	11/2 +
6	0.5081	5/2 -
7	0.5552	13/2 +
8	0.5913	15/2 -
9	0.6044	7/2 -
10	0.7085	15/2 +
11	0.7459	7/2 +
12	0.7945	17/2 -
13	0.8057	3/2 -
14	0.8474	9/2 +
15	0.8730	5/2 -
16	0.8828	17/2 +

Continuum levels assumed above 0.9480 MeV.

The level density parameters for Gilbert and Cameron's formula /9/ are the same as those of JENDL-2.

	a(1/MeV)	C(1/MeV)	T(MeV)	Ex(MeV)	sigma**2
Hf-177	22.61	9.06	0.486	4.38	9.45
Hf-178	22.36	2.22	0.451	4.08	12.94

MT=3 Nonelastic
Sum of MT=4,16,17,102,103,107.

MT=16,17,103,107 (n,2n), (n,3n), (n,p) and (n,alpha)
Calculated with GNASH /7/. The transmission coefficients for the incident channel were generated with ECIS /2/, while those for the exit channels with ELIESE-3 /10/. The preequilibrium parameter F2 was F2=5.0.

MT=251 Mu-bar
Calculated with ECIS /2/ and CASTHY /3/.

MF=4 Angular Distributions of Secondary Neutrons
MT=2,51-66,91
Calculated with ECIS /2/ and CASTHY /3/.
MT=16,17
Isotropic in the laboratry system.

MF=5 Energy Distributions of Secondary Neutrons
MT=16,17,91
Calculated with GNASH /7/.

MF=12 Photon Production Multiplicities
MT=16,17,91,102,103,107
Calculated with GNASH /7/ and stored under Option-1 (photon production multiplicities). The photon strength functions for most nuclei were taken from /1/, while those for some hafnium isotopes were determined from capture cross section normalization to the experimental data. The photon profile function is a superposition of the Berman-type giant dipole resonance /11/ and the pygmy resonance whose parameter values

were cited from the neighbouring nucleus Ta /12/.
EG1 = 15.23, EG2 = 12.3 , Ep = 5.2 (MeV),
GG1 = 4.48, GG2 = 2.43, Gp = 2.5 (MeV),
sig-pygmy/sig-GDR = 0.0245.

MT=51-66
Stored under Option-2 (transition probability array). Data were taken from /8/.

MF=14 Photon Angular Distributions
MT=16,17,51-66,91,102,103,107
Isotropic.

MF=15 Continuous Photon Energy Spectra
MT=16,17,91,102,103,107
Calculated with GNASH /7/.

References
1) Mughabghab S.F.: Neutron Cross Sections, vol.1, Part B (1984).
2) Raynal J.: IAEA SMR-9/8 (1970).
3) Igarasi S.: J. Nucl. Sci. Technol., 12, 67 (1975).
4) Haouat G. et al.: Nucl. Sci. Eng., 81, 491 (1982).
5) Raman S. et al.: At. Data Nucl. Data Tables, 36, 1 (1987).
6) Beer H. et al.: Phys. Rev., C30, 464 (1984).
7) Young P.G. and Arthur E.D.: LA-6947 (1977).
8) Lederer C.M. and Shirley V.S.: Table of Isotopes 7th Edition (1979).
9) Gilbert A. and Cameron A.G.W.: Can. J. Phys., 43, 1446 (1965).
10) Igarasi S.: JAERI-1224 (1972).
11) Berman B.L.: At. Data Nucl. Data Tables, 15, 319 (1975).
12) Igashira M. et al.: Int. Symp. Capture Gamma-ray Specroscopy and Related Topics - 1984, 523 (1985).

MAT number = 3724

72-Hf-178 NAIG+ Eval-Jul89 Hida, Yoshida and Shibata(JAERI)
Dist-Sep89

History
89-07 New evaluation for JENDL-3 was made by K.Hida, T.Yoshida (NAIG) and K.Shibata (JAERI).

MF=1 General Information
MT=451 Descriptive data and dictionary

MF=2 Resonance Parameters
MT=151 Resolved and unresolved resonance parameters
Resolved resonances for MLBW formula
Energy range : 0.5 eV to 1.5 keV
Res. energies and Gam-n : BNL-325 /1/.
Gam-gamma : 0.054 eV assumed if unknown.
Radius : 7.5 fm
Unresolved resonances
Energy range : 1.5 keV to 50 keV.
S0, S1, R and Gam-gamma : Adjusted so that the calculated total and capture cross section were reproduced well.
Results are D-obs = 89.9 eV, S0 = 2.20E-4, S1 = 0.51E-4, R = 8.5 m and Gam-gamma = 0.054 eV.

2200 m/sec cross sections and calculated res. integrals.

	2200 m/sec	res. integ.
total	88.49 b	-
elastic	4.46 b	-
capture	84.03 b	1915.8 b

MF=3 Neutron Cross Sections
Below 50 keV :
No background was given.
Above 50 keV :
MT=1,2,4,51-71,91,102 Total,elastic,inelastic and capture
Calculated with ECIS /2/ and CASTHY /3/. Deformed optical potential for ECIS calculation was determined so as to reproduce the experimental total cross section of natural hafnium, starting with the Haouat potential /4/.

```
V0 = 46.74-0.3*En, Ws = 3.77+0.4*En (En<10), Vso = 6.2 (MeV),
                        7.77         (En>10)
a0 = 0.63,          as = 0.52,                aso = 0.47 (fm),
r0 = 1.24,          rs = 1.24,                rso = 1.12 (fm),
     Beta-2 = 0.262,    Beta-4 = 0.0.
```

The deformation parameter Beta-2 was determined from the measured E2 transition probability data /5/. The lowest three levels belonging to the ground state rotational band were coupled in the calculation. The spherical optical potential for CASTHY calculation is the same as that of JENDL-2.

```
V0 = 38.0, Ws = 8.0+0.5*SQRT(En), Vso = 7.0 (MeV),
a0 = 0.47, as = 0.52            , aso = 0.47 (fm),
r0 = 1.32, rs = 1.32            , rso = 1.32 (fm).
```

Capture cross section was normalized to the measured data of Beer et al. /6/ at 30 keV.
Competing processes (n,2n), (n,3n), (n,p), and (n,alpha) were

calculated with GNASH /7/ and fed to ECIS-CASTHY calculation.
The level fluctuation and interference effects were considered.
Level scheme was taken from Table of Isotopes /8/.

No.	Energy(MeV)	Spin-Parity
g.s.	0.0	0 +
1	0.0932	2 +
2	0.3066	4 +
3	0.6322	6 +
4	1.0585	8 +
5	1.1474	8 -
6	1.1746	2 +
7	1.1993	0 +
8	1.2602	2 -
9	1.2766	2 +
10	1.3099	1 -
11	1.3224	3 -
12	1.3624	2 -
13	1.3641	9 -
14	1.4340	0 +
15	1.4438	0 +
16	1.4790	8 -
17	1.4961	2 +
18	1.5136	1 -
19	1.5613	2 +
20	1.5665	1 -
21	1.6015	10 -

Continuum levels assumed above 1.6400 MeV.
The level density parameters for Gilbert and Cameron's formula /9/ are the same as those of JENDL-2.

	a(1/MeV)	C(1/MeV)	T(MeV)	Ex(MeV)	sigma**2
Hf-178	22.36	2.22	0.451	4.08	12.94
Hf-179	22.57	6.88	0.465	3.98	9.31

MT=3 Nonelastic
Sum of MT=4,16,17,102,103,107.
MT=16,17,103,107 (n,2n), (n,3n), (n,p) and (n,alpha)
Calculated with GNASH /7/. The transmission coefficients for the incident channel were generated with ECIS /2/, while those for the exit channels with ELIESE-3 /10/. The preequilibrium parameter F2 was F2=5.0.

MT=251 Mu-bar
Calculated with ECIS /2/ and CASTHY /3/.

MF=4 Angular Distributions of Secondary Neutrons
MT=2,51-71,91
Calculated with ECIS /2/ and CASTHY /3/.
MT=16,17
Isotropic in the laboratory system.

MF=5 Energy Distributions of Secondary Neutrons
MT=16,17,91
Calculated with GNASH /7/.

MF=12 Photon Production Multiplicities
MT=16,17,91,102,103,107
Calculated with GNASH /7/ and stored under Option-1 (photon production multiplicities). The photon strength functions for

most nuclei were taken from /1/, while those for some hafnium isotopes were determined from capture cross section normalization to the experimental data. The photon profile function is a superposition of the Berman-type giant dipole resonance /11/ and the pygmy resonance whose parameter values were cited from the neighbouring nucleus Ta /12/.

EG1 = 15.23, EG2 = 12.3 , Ep = 5.2 (MeV),
GG1 = 4.48, GG2 = 2.43, Gp = 2.5 (MeV),
sig-pygmy/sig-GDR = 0.0245.

MT=51-71
Stored under Option-2 (transition probability array). Data were taken from /8/.

MF=14 Photon Angular Distributions
MT=16,17,51-71,91,102,103,107
Isotropic.

MF=15 Continuous Photon Energy Spectra
MT=16,17,91,102,103,107
Calculated with GNASH /7/.

References

1) Mughabghab S.F.: Neutron Cross Sections, vol.1, Part B (1984).
2) Raynal J.: IAEA SMR-9/8 (1970).
3) Igarasi S.: J. Nucl. Sci. Technol., 12, 67 (1975).
4) Haouat G. et al.: Nucl. Sci. Eng., 81, 491 (1982).
5) Raman S. et al.: At. Data Nucl. Data Tables, 36, 1 (1987).
6) Beer H. and Macklin R.L.: Phys. Rev., C26, 1404 (1982).
7) Young P.G. and Arthur E.D.: LA-6947 (1977).
8) Lederer C.M. and Shirley V.S.: Table of Isotopes 7th Edition (1979).
9) Gilbert A. and Cameron A.G.W.: Can. J. Phys., 43, 1446 (1965).
10) Igarasi S.: JAERI-1224 (1972).
11) Berman B.L.: At. Data Nucl. Data Tables, 15, 319 (1975).
12) Igashira M. et al.: Int. Symp. Capture Gamma-ray Specroscopy and Related Topics - 1984, 523 (1985).

MAT number = 3725

72-Hf-179 NAIG+ Eval-Jul89 Hida, Yoshida and Shibata(JAERI)
Dist-Sep89

History
89-07 New evaluation for JENDL-3 was made by K.Hida, T.Yoshida (NAIG) and K.Shibata (JAERI).

MF=1 General Information
MT=451 Descriptive data and dictionary

MF=2 Resonance Parameters
MT=151 Resolved and unresolved resonance parameters
Resolved resonances for MLBW formula
Energy range : 1.0E-5 eV to 250 eV
Res. energies and Gam-n : BNL-325 /1/. If unknown, Gam-n is calculated from D-obs and S0 given in /1/.
Gam-gamma : 0.066 eV assumed if unknown.
Radius : 7.8 fm
Unresolved resonances
Energy range : 250 eV to 50 keV.
S0, S1, R and Gam-gamma : Adjusted so that the calculated total and capture cross sections were reproduced well.
Results are D-obs = 5.71 eV, S0 = 2.20E-4, S1 = 0.83E-4, R = 7.7 fm and Gam-gamma = 0.066 eV.

2200 m/sec cross sections and calculated res. integrals.

	2200 m/sec	res. integ.
total	49.5 b	-
elastic	6.8 b	-
capture	42.8 b	523.0 b

MF=3 Neutron Cross Sections
Below 50 keV :
No background was given.
Above 50 keV :
MT=1,2,4,51-62,91,102 Total,elastic,inelastic and capture
Calculated with ECIS /2/ and CASTHY /3/. Deformed optical potential for ECIS calculation was determined so as to reproduce the experimental total cross section of natural hafnium, starting with the Haouat potential /4/.

```
   V0 = 46.66-0.3*En, Ws = 3.73+0.4*En (En<10), Vso = 6.2 (MeV),
                           7.73        (En>10)
   a0 = 0.63,         as = 0.52,                  aso = 0.47 (fm),
   r0 = 1.24,         rs = 1.24,                  rso = 1.12 (fm),
   Beta-2 = 0.261,    Beta-4 = 0.0.
```

The deformation parameter Beta-2 was determined from the measured E2 transition probability data /5/. The lowest three levels belonging to the ground state rotational band were coupled in the calculation. The spherical optical potential for CASTHY calculation is the same as that of JENDL-2.

```
   V0 = 38.0, Ws = 8.0+0.5*SQRT(En), Vso = 7.0 (MeV),
   a0 = 0.47, as = 0.52          , aso = 0.47 (fm),
   r0 = 1.32, rs = 1.32          , rso = 1.32 (fm).
```

Capture cross section was normalized to the measured data of

Beer et al. /6/ at 30 keV.
Competing processes (n,2n), (n,3n), (n,p), and (n,alpha) were calculated with GNASH /7/ and fed to ECIS-CASTHY calculation. The level fluctuation and interference effects were considered.
Level scheme was taken from Table of Isotopes /8/.

No.	Energy(MeV)	Spin-Parity
g.s.	0.0	9/2 +
1	0.1227	11/2 +
2	0.2143	7/2 -
3	0.2688	13/2 +
4	0.3377	9/2 -
5	0.3750	1/2 -
6	0.4386	15/2 +
7	0.5184	5/2 -
8	0.6169	7/2 -
9	0.6312	17/2 +
10	0.8483	19/2 +
11	0.8702	7/2 -
12	1.0034	5/2 +

Continuum levels assumed above 1.0700 MeV.
The level density parameters for Gilbert and Cameron's formula /9/ are the same as those of JENDL-2.

	a(1/MeV)	C(1/MeV)	T(MeV)	Ex(MeV)	sigma**2
Hf-179	22.57	6.88	0.465	3.98	9.31
Hf-180	21.37	2.35	0.519	5.42	7.64

MT=3 Nonelastic
Sum of MT=4,16,17,102,103,107.
MT=16,17,103,107 (n,2n), (n,3n), (n,p) and (n,alpha)
Calculated with GNASH /7/. The transmission coefficients for the the incident channel were generated with ECIS /2/, while those fo the exit channels with ELIESE-3 /10/. The preequilibrium parameter F2 was F2=5.0.

MT=251 Mu-bar
Calculated with ECIS /2/ and CASTHY /3/.

MF=4 Angular Distributions of Secondary Neutrons
MT=2,51-62,91
Calculated with ECIS /2/ and CASTHY /3/.
MT=16,17
Isotropic in the laboratory system.

MF=5 Energy Distributions of Secondary Neutrons
MT=16,17,91
Calculated with GNASH /7/.

MF=12 Photon Production Multiplicities
MT=16,17,91,102,103,107
Calculated with GNASH /7/ and stored under Option-1 (photon production.multiplicities). The photon strength functions for most nuclei were taken from /1/, while those for some hafnium isotopes were determined from capture cross section normalization to the experimental data. The photon profile function is a superposition of the Berman-type giant dipole resonance /11/ and the pygmy resonance whose parameter values were cited from the neighbouring nucleus Ta /12/.
EG1 = 15.23, EG2 = 12.3 , Ep = 5.2 (MeV),

GG1 = 4.48, GG2 = 2.43, Gp = 2.5 (MeV),
sig-pygmy/sig-GDR = 0.0245.

MT=51-62
Stored under Option-2 (transition probability array). Data were taken from /8/.

MF=14 Photon Angular Distributions
MT=16,17,51-62,91,102,103,107
Isotropic.

MF=15 Continuous Photon Energy Spectra
MT=16,17,91,102,103,107
Calculated with GNASH /7/.

References
1) Mughabghab S.F.: Neutron Cross Sections, vol.1, Part B (1984).
2) Raynal J.: IAEA SMR-9/8 (1970).
3) Igarasi S.: J. Nucl. Sci. Technol., 12, 67 (1975).
4) Haouat G. et al.: Nucl. Sci. Eng., 81, 491 (1982).
5) Raman S. et al.: At. Data Nucl. Data Tables, 36, 1 (1987).
6) Beer H. and Macklin R.L.: Phys. Rev., C26, 1404 (1982).
7) Young P.G. and Arthur E.D.: LA-6947 (1977).
8) Lederer C.M. and Shirley V.S.: Table of Isotopes 7th Edition (1979).
9) Gilbert A. and Cameron A.G.W.: Can. J. Phys., 43, 1446 (1965).
10) Igarasi S.: JAERI-1224 (1972).
11) Berman B.L.: At. Data Nucl. Data Tables, 15, 319 (1975).
12) Igashira M. et al.: Int. Symp. Capture Gamma-ray Specroscopy and Related Topics - 1984, 523 (1985).

MAT number = 3726

72-Hf-180 NAIG+ Eval-Jul89 Hida, Yoshida and Shibata(JAERI)
Dist-Sep89

History
89-07 New evaluation for JENDL-3 was made by K.Hida, T.Yoshida (NAIG) and K.Shibata (JAERI).

MF=1 General Information
MT=451 Descriptive data and dictionary

MF=2 Resonance Parameters
MT=151 Resolved and unresolved resonance parameters
Resolved resonances for MLBW formula
Energy range : 1.0E-5 eV to 2.5 keV
Res. energies and Gam-n : BNL-325 /1/. If unknown, Gam-n is calculated from D-obs and S0, and in this case, Gam-gamma from (Gam-n)*(Gam-gamma)/(Gam-total).
Gam-gamma : 0.050 eV assumed if unknown.
Radius : 8.0 fm
Unresolved resonances
Energy range : 2.5 keV to 50 keV.
S0, S1,R and Gam-gamma : Adjusted so that the calculated total and capture cross sections were reproduced well.
Results are D-obs = 158 eV, S0 = 1.90E-4, S1 = 0.44E-4, R = 8.5 fm and Gam-gamma = 0.05 eV.

2200 m/sec cross sections and calculated res. integrals.

	2200 m/sec	res. integ.
total	34.2 b	-
elastic	21.2 b	-
capture	13.0 b	34.1 b

MF=3 Neutron Cross Sections
Below 50 keV :
No background was given.
Above 50 keV :
MT=1,2,4,51-61,91,102 Total,elastic,inelastic and capture
Calculated with ECIS /2/ and CASTHY /3/. Deformed optical potential for ECIS calculation was determined so as to reproduce the experimental total cross section of natural hafnium, starting with the Haouat potential /4/.

V0 = 46.60-0.3*En, Ws = 3.70+0.4*En (En<10), Vso = 6.2 (MeV),
7.70 (En>10)
a0 = 0.63, as = 0.52, aso = 0.47 (fm),
r0 = 1.24, rs = 1.24, rso = 1.12 (fm),
Beta-2 = 0.256, Beta-4 = 0.0.

The deformation parameter Beta-2 was determined from the measured E2 transition probability data /5/. The lowest three levels belonging to the ground state rotational band were coupled in the calculation. The spherical optical potential for CASTHY calculation is the same as that of JENDL-2.

V0 = 38.0, Ws = 8.0+0.5*SQRT(En), Vso = 7.0 (MeV),
a0 = 0.47, as = 0.52 , aso = 0.47 (fm),
r0 = 1.32, rs = 1.32 , rso = 1.32 (fm).

Capture cross section was normalized to the measured data of Beer et al. /6/ at 30 keV.
Competing processes (n,2n), (n,3n), (n,p), and (n,alpha) were calculated with GNASH /7/ and fed to ECIS-CASTHY calculation.
The level fluctuation and interference effects were considered.
Level scheme was taken from Table of Isotopes /8/.

No.	Energy(MeV)	Spin-Parity
g.s.	0.0	0 +
1	0.09332	2 +
2	0.3086	4 +
3	0.6409	6 +
4	1.0839	8 +
5	1.1416	8 -
6	1.1832	4 +
7	1.1997	2 +
8	1.2910	4 +
9	1.3744	3 -
10	1.4092	4 +
11	1.5393	3 -

Continuum levels assumed above 1.6076 MeV.
The level density parameters for Gilbert and Cameron's formula /9/ are the same as those of JENDL-2.

	a(1/MeV)	C(1/MeV)	T(MeV)	Ex(MeV)	sigma**2
Hf-180	21.37	2.35	0.519	5.42	7.64
Hf-181	21.91	6.47	0.479	4.08	4.88

MT=3 Nonelastic
Sum of MT=4,16,17,102,103,107.
MT=16,17,103,107 (n,2n), (n,3n), (n,p) and (n,alpha)
Calculated with GNASH /7/. The transmission coefficients for the incident channel were generated with ECIS /2/, while those for the exit channels with ELIESE-3 /10/. The preequilibrium parameter F2 was F2=E.0.

MT=251 Mu-bar
Calculated with ECIS /2/ and CASTHY /3/.

MF=4 Angular Distributions of Secondary Neutrons
MT=2,51-61,91
Calculated with ECIS /2/ and CASTHY /3/.
MT=16,17
Isotropic in the laboratory system.

MF=5 Energy Distributions of Secondary Neutrons
MT=16,17,91
Calculated with GNASH /7/.

MF=12 Photon Production Multiplicities
MT=16,17,91,102,103,107
Calculated with GNASH /7/ and stored under Option-1 (photon production multiplicities). The photon strength functions for most nuclei were taken from /1/, while those for some hafnium isotopes were determined from capture cross section normalization to the experimental data. The photon profile function is a superposition of the Berman-type giant dipole resonance /11/ and the pygmy resonance whose parameter values were cited from the neighbouring nucleus Ta /12/.
EG1 = 15.23, EG2 = 12.3 , Ep = 5.2 (MeV),

GG1 = 4.48, GG2 = 2.43, Gp = 2.5 (MeV),
sig-pygmy/sig-GDR = 0.0245.

MT=51-61
Stored under Option-2 (transition probability array). Data were taken from /8/.

MF=14 Photon Angular Distributions
MT=16,17,51-61,91,102,103,107
Isotropic.

MF=15 Continuous Photon Energy Spectra
MT=16,17,91,102,103,107
Calculated with GNASH /7/.

References

1) Mughabghab S.F.: Neutron Cross Sections, vol.1, Part B (1984).
2) Raynal J.: IAEA SMR-9/8 (1970).
3) Igarasi S.: J. Nucl. Sci. Technol., 12, 67 (1975).
4) Haouat G. et al.: Nucl. Sci. Eng., 81, 491 (1982).
5) Raman S. et al.: At. Data Nucl. Data Tables, 36, 1 (1987).
6) Beer H. and Macklin R.L.: Phys. Rev., C26, 1404 (1982).
7) Young P.G. and Arthur E.D.: LA-6947 (1977).
8) Lederer C.M. and Shirley V.S.: Table of Isotopes 7th Edition (1979).
9) Gilbert A. and Cameron A.G.W.: Can. J. Phys., 43, 1446 (1965).
10) Igarasi S.: JAERI-1224 (1972).
11) Berman B.L.: At. Data Nucl. Data Tables, 15, 319 (1975).
12) Igashira M. et al.: Int. Symp. Capture Gamma-ray Specroscopy and Related Topics - 1984, 523 (1985).

MAT number = 3731

73-Ta-181 NAIG Eval-Mar87 N.Yamamuro
Dist-Sep89

HISTORY
76-03 The evaluation for JENDL-1 /1/ was made by H.Yamakoshi (Ship Research Institute) and JENDL-1 Compilation Group.
83-03 JENDL-1 data were adopted for JENDL-2 and extended to 20 MeV. MF=5 was revised, and unresolved resonance parameters were added by Y.Kikuchi (JAERI) /2/.
83-11 Comment data were added.
87-03 The evaluation for JENDL-3 was made by N.Yamamuro (NAIG). Resonance parameters were added by new experimental data. Neutron cross sections, except total and elastic scattering cross sections, and energy distributions of secondary neutrons and photons were calculated with GNASH /8/ and CASTHY /7/ codes.

MF=1 General Information
MT=451 Descriptive data and dictionary

MF=2 Resonance Parameters
MT=151 Resolved and unresolved resonance parameters
Resolved parameters for MLBW formula

The energy region from 1.0E-5eV to 1.0 keV. Parameters were taken from Ref./3,4,5/ for positive resonances, and from ENDF/B-IV for a negative resonance. The radiative width of 0.059eV was assumed for the resonance whose radiative width was unknown.

Unresolved parameters

In the energy range from 1 to 100keV, parameters were determined to reproduce the measured capture cross sections /4,6/. The parameters are as follows,

R= 7.8 fm , Dobs= 4.2 eV , radiative width= 0.065 eV,
So= 1.7E-04 S1= 2.0E-05 S2= 2.3E-04 NL= 3

Calculated 2200-m/sec cross sections and resonance integrals

	2200-m/sec	res. integ
elastic	5.65 b	-
capture	20.67 b	660.43 b
total	26.32 b	-

MF=3 Neutron Cross Sections
MT=1 Total
Evaluated from experimental data.
MT=2 Elastic scattering
(Total cross section) - (reaction cross section)
MT=4,51-64,91 Inelastic scattering
Below 3 MeV,calculated with optical and statistical model code CASTHY/7/, and above 3 MeV calculated with statistical and preequilibrium model code GNASH/8/.
Wilmore-Hodgson's optical-model potential parameters/9/ were used,which reproduced the experimental nonelastic cross

sections up to 15 MeV.

V=47.01-0.267E-0.00118E (MeV)
Ws=9.52-0.053E (MeV)
ro=1.268, as=0.66 (fm)
rs=1.241, as=0.48 (fm)

The level scheme was adopted from Ref./10/.

No.	Energy (MeV)	Spin-Parity
g.s.	0.0	7/2+
1	0.0062	9/2-
2	0.136	9/2+
3	0.159	11/2-
4	0.301	11/2+
5	0.338	13/2-
6	0.482	5/2+
7	0.495	13/2+
8	0.543	15/2-
9	0.615	1/2+
10	0.619	3/2+
11	0.717	15/2+
12	0.773	17/2-
13	0.965	17/2+
14	1.028	19/2-

Levels above 1.03MeV were assumed to overlapping.
Level density parameters used were as follows,

	1/MeV	Pair-E	T(MeV)	E (MeV)	Spin-cutoff
Ta-178	22.5	0.0	0.54	4.2	13.0
Ta-179	22.0	0.4	0.53	4.2	18.0
Ta-180	22.5	0.0	0.54	4.2	13.0
Ta-181	22.0	0.73	0.52	4.3	29.0
Ta-182	21.8	0.0	0.56	4.3	13.0

MT=16 (n,2n) cross section
Calculated with GNASH/8/.
MT=17 (n,3n) cross section
Calculated with GNASH/8/.
MT=28 (n,n p) cross section
Calculated with GNASH /8/.
MT=102 Radiative capture cross section
Calculated with CASTHY/7/.
MT=103 (n,p) cross section
Calculated with GNASH/8/.
MT=203 Total Hydrogen Production
Calculated with GNASH/8/.
MT=251 Mu-bar
Calculated with CASTHY/7/.

MF=4 Angular Distributions of Secondary Neutrons
MT=2 Calculated with CASTHY/7/.
MT=51-64,91,16,17,28
Isotropic in the center-of-mass system was assumed.

MF=5 Energy Distributions of Secondary Neutrons

MT=16,17,28,91
Calculated with GNASH/8/.

MF=12 Photon Production Multiplicities (option1)
MT=51-64.91,16,17,28,102,103
Calculated with GNASH/8/.

MF=14 Photon Angular Distributions
Isotropic in the center-of-mass system was assumed.

MF=15 Continuous Photon Energy Spectra
MT=91,16,17,28,102,103
Calculated with GNASH/8/.

References

1) Igarasi S. et al.: JAERI 1261 (1979)
2) Nakagawa T.: JAERI-M 84-103 (1984)
3) Mughabghab,S.F, and Garder,D.I.: BNL325,3rdEd. (1973).
4) Macklin,R,L,: Nucl,Sci,Eng., 86,362 (1984).
5) Tsubone,I., Nakajima,Y. and Kanda,Y.: private communication
6) Yamamuro,N., Saito,K., Emoto,T., Wada,T., Fujita,Y. and Kobayashi,K.: J.Nucl.Sci.Technol.,17,582 (1980).
7) Igarashi,S.: J.Nucl.Sci. Technol.,12,67 (1975).
8) Young,P.G. and Arthur,E.D.:"GNASH,Aprequilimu,statistical Nuclear-Model Code for Calculation of cross sections and Emission Spectia", LA-6974 (1977).
9) Wilmore,D.and Hodgson,P.E.: Nucl, Phys.,55,673 (1964).
10) Firestone,R.B. Nucl,Data sheets 43,289 (1984).

MAT number = 3740

74-W - 0 KHI,NEDAC Eval-Mar87 T.Watanabe(KHI), T.Asami(NEDAC)
Dist-Sep89

History
87-03 New evaluation was made for JENDL-3.
87-03 Compiled by T.Asami.
89-08 MF/MT=15/102 modified.

MF=1 General Information
MT=451 Descriptive data and dictionary
All the data were constructed with the evaluated ones of W-182, -183, -184 and -186, taking account of their abundances in the W element. The abundance data were taken from ref./1/ to be 0.263, 0.143, 0.3067 and 0.286 for W-182, -183, -184 and -186, respectively. All the data of W-180 were ignored because of its very low abundance.

MF=2 Resonance Parameters
MT=151 Resolved resonance parameters
Resolved parameters for MLBW formula were taken from the evaluated data on each stable isotope of tungsten.
The energy region was taken from 1.0E-5 eV to 12 keV.
Calculated 2200 m/sec cross sections and resonance integrals are as follows:

	2200 m/s cross section(b)	res. integral(b)
elastic	4.97	
capture	18.25	317.5
total	23.22	

MF=3 Neutron Cross Sections
Below 12 keV, background cross section was given to compensate the cross section of W-183 in the energies of 2.2 to 12 keV.
Above 12 keV, the total and partial cross sections were given pointwise.
MT=1 Total
The data were constructed from the evaluated ones for four W isotopes in taking account of their abundances.
MT=2 Elastic scattering
Obtained by subtracting the sum of the partial cross sections from the total cross section.
MT=4, 51-90, 91 Inelastic scattering
The data were constructed from the evaluated ones for each W isotope as follows:

MT	Level energy(MeV)	W-182	W-183	W-184	W-186
g.s.	0.0				
51	0.0465		51		
52	0.0991		52		
53	0.1001	51			
54	0.1112			51	
55	0.1226				51
56	0.2070		53		
57	0.2088		54		
58	0.2917		55		
59	0.3089		56		
60	0.3095		57		

61	0.3294	52			
62	0.3641			52	
63	0.3968				52
64	0.4121		58		
65	0.4870		59		
66	0.5510		60		
67	0.6805	53			
68	0.7377				53
69	0.7483			53	
70	0.8088				54
71	0.8618				55
72	0.8820				56
73	0.9033			54	
74	0.9526				57
75	1.0023			55	
76	1.0059			56	
77	1.0070				58
78	1.0316				59
79	1.0452				60
80	1.1214			57	
81	1.1357	54			
82	1.1445	55			
83	1.1500				61
84	1.2213			56	
85	1.2214	56			
86	1.2840				62
87	1.2941			62	
88	1.3311	57			
89	1.3221			63	
90	1.4428	58			

The threshold for the inelastic scattering to the continuum was set to be 0.68 MeV for convenience of the file making.

MT=16, 22, 28, 102, 103 and 107 (n,2n), (n,na), (n,np), (n,gamma), (n,p) and (n,a)
Constructed from the evaluated data for four stable isotopes of W, taking account of their abundances in the W element. The calculated capture cross section for each W isotope was normalized so as to reproduce the element W data of 72 mb at 500 keV/2/.

MT=251 Mu-bar
Calculated from MF/MT=4/2.

MF=4 Angular Distributions of Secondary Neutrons
MT=2
Constructed from the evaluated data for four stable isotopes of W, taking account of their abundances in the W element.
MT=51-90, 91
Constructed from the evaluated data for four stable isotopes of W, taking account of their abundances in the W element.
MT=16, 22, 28
Isotropic in the laboratory system.

MF=5 Energy Distributions of Secondary Neutrons
MT=16, 22, 28, 91
Constructed from the evaluated data for four stable isotopes

of W, taking account of their abundances in the W element.

MF=12 Photon Production Multiplicities
MT=102
Calculated with the GNASH code/3/.

MF=13 Photon Production Cross Sections
MT=3
Calculated with the GNASH code/3/.

MF=14 Photon Angular Distributions
MT=3, 102
Assumed to be isotropic in the laboratory system.

MF=15 Continuous Photon Energy Spectra
MT=3
Calculated with the GNASH code/3/.
MT=102
Calculated with the GNASH code/3/ and modified by using the data in ENSDF/4/ at thermal energy.

References
1) Holden, N.E., Martin, R.L. and Barnes, I.L. : Pure & Appl. Chem. 56, 675 (1984).
2) Grenier et al. : CEA-N-2195 (1981).
3) Young, P.G. and Arthur, E.D. : LA-6947 (1977).
4) ENSDF(Evaluated Nuclear Structure Data File)

MAT number = 3741

74-W -182 KHI,NEDAC Eval-Mar87 T.Watanabe(KHI), T.Asami(NEDAC)
Dist-Sep89

History
87-03 New evaluation was made for JENDL-3.
87-03 Compiled by T.Asami.

MF=1 General Information
MT=451 Descriptive data and dictionary

MF=2 Resonance Parameters
MT=151 Resolved resonance parameters
Resolved parameters for MLBW formula were given in the energy region from 1.0E-5 eV to 12 keV.
Parameters were evaluated in examining both the experimental data/1/ - /3/ and the recommended data of BNL./4/.
For unknown radiative width, an average value of 53 milli eV was assumed.
Parameters for negative resonance were selected so that the 2200 m/s cross section for capture reproduced gave a recommended value of 20.7 barns/4/ and gave a good fit to the experimental data for total cross sections around thermal energies.
The scattering radius was assumed to be 7.5 Fermi.
Calculated 2200 m/sec cross sections and resonance integrals are as follows:

	2200 m/s cross section(b)	res. integral(b)
elastic	8.84	
capture	20.7	628.6
total	29.5	

MF=3 Neutron Cross Sections
Below 12 keV, zero background cross section was given and all the cross-section data are reproduced from the evaluated resolved resonance parameters with MLBW formula.
Above 12 keV, the total and partial cross sections were given pointwise using the data taken mainly from the theoretical calculations. The total, elastic and inelastic scattering, and capture cross sections were calculated based on the coupled-channel model and the spherical optical-statistical model.
The calculations were performed with a combined program of the CASTHY code/5/ and the ECIS code/6/.
The optical potential parameters used are:

V = 48.83 - 0.0809*En, Vso = 5.6 (MeV)
Ws = 6.73 - 0.0536*En, Wv = 0 (MeV)
r = 1.168, rs = 1.268, rso = 1.592 (fm)
a = 0.617, aso = 0.664, b = 0.563 (fm)

The deformed potential parameters were taken from the work of Delaroche/7/.

MT=1 Total
As described above, calculated with the combined program of the ECIS and CASTHY codes.

MT=2 Elastic scattering
Obtained by subtracting the sum of the partial cross sections from the total cross section.

MT=4, 51-58, 91 Inelastic scattering
Calculated with the combined program of the ECIS/6/ and CASTHY

/5/, taking account of the contribution from the competing processes.
The level data used in the above calculations were taken from ref./8/ as follows:

MT	Level energy(MeV)	Spin-parity
g.s.	0.0	0+
1	0.1001	2+
2	0.3294	4+
3	0.6805	6+
4	1.1357	0+
5	1.1445	8+
6	1.2214	2+
7	1.2574	2+
8	1.2892	2-
9	1.3311	3+
10	1.3738	3-
11	1.4428	4+
12	1.4875	4-
13	1.5103	4+
14	1.5532	4-
15	1.6213	5-
16	1.6236	5+
17	1.6604	5-

Levels above 1.6863 MeV were assumed to be overlapping.

The calculated data for the inelastic scattering were finally lumped for the convenience on the construction of the element data, as follows:

MT no.	Level energy(MeV)	Lumping
51	0.1001	1
52	0.3294	2
53	0.6805	3
54	1.1357	4
55	1.1445	5
56	1.2214	6 - 8
57	1.3311	9 -10
58	1.4428	11 -17

MT=16, 22, 28, 103, 107 (n,2n), (n,na), (n,np), (n,p), (n,a)
Calculated with the GNASH code/9/ including the precompound effect. Transmission coefficients for neutrons, protons and alphas were calculated with the ELIESE-3 code/10/ using the above optical model parameters, the Menet's ones/11/ and the Huizenga-igo's/12/,.respectively.
Calculated data for the (n,p) cross sections were normalized to the Qaim's experimental data of 5.9 milli barns at 14.7 MeV /13/.

MT=102 Capture
Calculated with the CASTHY code/5/ and normalized to 72 mb at 500 keV of Grenier et al.'s data/14/.

MT=251 Mu-bar
Calculated with the optical model.

MF=4 Angular Distributions of Secondary Neutrons

MT=2
Calculated with the CASTHY code/5/.

MT=51-58, 91

Calculated with the combined program of the CASTHY/5/ and ECIS/6/ codes.

MT=16, 22, 28

Assumed to be isotropic in the laboratory system.

MF=5 Energy Distributions of Secondary Neutrons

MT=16, 22, 28, 91

Calculated with the GNASH code/9/.

References

1) Camarda H.S. et al. : Phys. Rev. C8, 1813 (1973).
2) Ohkubo M. : JAERI-M 5624 (1974).
3) Macklin R.L. et al. : LA-9200-MS (1982).
4) Mughaghab S.F. and Garber D.I. :"Neutron Cross Sections", Vol. 2, Part B (1984).
5) Igarasi s. : J. Nucl. Sci. Tech. 12, 67 (1975).
6) Raynal J. : IAEA-SMR-9/8 p.281 (1972).
7) Delaroche J.F. et al. : 1979 Knoxville Conf. 336 (1979).
8) ENSDF(Evaluated Nuclear Structure Data File)
9) Young P.G. and Arthur, E.D. : LA-6947 (1977).
10) Igarasi S. : JAERI 1224 (1972).
11) Menet J.J.H. et al.: Phys. Rev. C4, 1114 (1971).
12) Huizenga J.R. and Igo, G.J.: ANL-6373 (1961).
13) Qaim S.M. : Nucl. Phys. A243, 317 (1975).
14) Grenier et al. : CEA-N-2195 (1981).

MAT number = 3742

74-W -183 KHI,NEDAC Eval-Mar87 T.Watanabe(KHI), T.Asami(NEDAC)
Dist-Sep89

History
87-03 New evaluation was made for JENDL-3.

MF=1 General Information
MT=451 Descriptive data and dictionary

MF=2 Resonance parameters
MT=151 Resolved resonance parameters
Resolved parameters for MLBW formula were given in the energy region from 1.0E-5 eV to 2.2 keV.
Parameters were evaluated in examining both the experimental data/1/ - /3/ and the recommended data of BNL/4/.
For unknown radiative width, an average value of 55 milli eV was assumed.
Parameters for negative resonance were selected so that the 2200 m/s cross section for capture reproduced gave a recommended value of 10.2 barns/4/ and gave a good fit to the experimental data for total cross sections around thermal energies.
The scattering radius was assumed to be 7.3 Fermi.
Calculated 2200 m/sec cross sections and resonance integrals are as follows:

	2200 m/s cross section(b)	res. integral(b)
elastic	2.38	
capture	10.11	335.1
total	12.49	

MF=3 Neutron Cross Sections
Below 2.2 keV, zero background cross section was given and all the cross-section data are reproduced from the evaluated resonance parameters with MLBW formula.
Above 2.2 keV, the total and partial cross sections were given pointwise.
MT=1 total
Optical and statistical model calculation was made with CASTHY code/5/. The optical potential parameters used are:

$V = 48.83 - 0.0809 \cdot En$, $Vso = 5.6$ (MeV)
$Ws = 6.73 - 0.0536 \cdot En$, $Wv = 0$ (MeV)
$r = 1.168$, $rs = 1.268$, $rso = 1.592$ (fm)
$a = 0.617$, $aso = 0.664$, $b = 0.563$ (fm)

MT=2 Elastic scattering
Obtained by subtracting the sum of the partial cross sections from the total cross section.
MT=4, 51-60, 91 Inelastic scattering
Calculated with CASTHY/5/, taking account of the contribution from the competing processes. The direct component was calculated with the coupled-channel optical model code ECIS/6/.
The deformed potential parameters used were taken from the work of Delaroche/7/.
The level data used in the above two calculations were taken from ref./8/ as follows:

MT	Level energy(MeV)	Spin-parity
g.s.	0.0	0+
1	0.0465	3-

2	0.0991	5-
3	0.2070	7-
4	0.2088	3-
5	0.2917	5-
6	0.3089	9-
7	0.3095	11+
8	0.4121	7-
9	0.4530	7-
10	0.4870	13+
11	0.5510	9-
12	0.5953	9-
13	0.6228	9+

Levels above 0.680 MeV were assumed to be overlapping.

The calculated data for the inelastic scattering were finally lumped for the convenience on the construction of the element data, as follows:

MT no.	Level energy(MeV)	Lumping
51	0.0465	1
52	0.0991	2
53	0.2070	3
54	0.2088	4
55	0.2917	5
56	0.3089	6
57	0.3095	7
58	0.4121	8 - 9
59	0.4870	10
60	0.5510	11 -13

MT=16, 22, 28, 103, 107 (n,2n), (n,na), (n,np), (n,p), (n,a)
Calculated with the GNASH code/9/ including the precompound effect. Transmission coefficients for neutrons, protons and alphas were calculated with the ELIESE-3 code/10/ using the above optical model parameters, the Menet's ones/11/ and the Huizenga-Igo's/12/, respectively.
Calculated data for the (n,p) cross sections were normalized to the Qaim's experimental data of 4.1 milli barns at 14.7 MeV /13/.

MT=102 Capture
Calculated with the CASTHY code/5/ and normalized to 70 mb at 500 keV/14/.

MT=251 Mu-bar
Calculated with the optical model.

MF=4 Angular Distributions of Secondary Neutrons

MT=2
Calculated with the CASTHY code/5/.

MT=51-67, 91
Calculated with the combined program of the CASTHY/5/ and ECIS/6/ codes.

MT=16, 22, 28
Assumed to be isotropic in the laboratory system.

MF=5 Energy Distributions of Secondary Neutrons

MT=16, 22, 28, 91
Calculated with the GNASH code/9/.

References
1) Camarda H.S. et al. : Phys. Rev. C8, 1813 (1973).
2) Ohkubo M. : JAERI-M 5624 (1974).
3) Macklin R.L. et al. : LA-9200-MS (1982).
4) Mughaghab S.F. and Garber D.I. :"Neutron Cross Sections", Vol. 2, Part B (1984).
5) Igarasi S. : J. Nucl. Sci. Tech. 12, 67 (1975).
6) Raynal J. : IAEA-SMR-9/8 p.281 (1972).
7) Delaroche J.F. et al. : 1979 Knoxville Conf. 336 (1979).
8) ENSDF(Evaluated Nuclear Structure Data File)
9) Young P.G. and Arthur, E.D. : LA-6947 (1977).
10) Igarasi S. : JAERI 1224 (1972).
11) Menet J.J.H. et al.: Phys. Rev. C4, 1114 (1971).
12) Huizenga J.R. and Igo, G.J.: ANL-6373 (1961).
13) QAIM S.M. : Nucl. Phys. A243, 317 (1975).
14) Grenier et al. : CEA-N-2195 (1981).

MAT number = 3743

74-W -184 KHI,NEDAC Eval-Mar87 T.Watanabe(KHI), T.Asami(NEDAC)
Dist-Sep89

History
87-03 New evaluation was made for JENDL-3.
87-03 Compiled by T.Asami.

MF=1 General Information
MT=451 Descriptive data and dictionary

MF=2 Resonance Parameters
MT=151 Resolved resonance parameters
Resolved parameters for MLBW formula were given in the energy region from 1.0E-5 eV to 12 keV.
Parameters were evaluated in examining both the experimental data/1/ - /3/ and the recommended data of BNL/4/.
For unknown radiative width, an average value of 57 milli eV was assumed.
Parameters for negative resonance were selected so that the 2200 m/s cross section for capture reproduced gave a recommended value of 1.7 ba.ns/4/ and gave a good fit to the experimental data for total cross sections around thermal energies.
The scattering radius was assumed to be 7.5 Fermi.
Calculated 2200 m/sec cross sections and resonance integrals are as follows:

	2200 m/s cross section(b)	res. integral(bv)
elastic	7.35	
capture	1.70	16.2
total	9.05	

MF=3 Neutron Cross Sections
Below 12 keV, no background cross section was given and all the cross-section data are reproduced from the evaluated resolved resonance parameters with MLBW formula.
Above 12 keV, total and the partial cross sections were given pointwise.

MT=1 Total
Optical and statistical model calculation was made with CASTHY code/5/. The optical potential parameters used are:

$V = 48.83 - 0.0809 \cdot En$, $Vso = 5.6$ (MeV)
$Ws = 6.73 - 0.0536 \cdot En$, $Wv = 0$ (MeV)
$r = 1.168$, $rs = 1.268$, $rso = 1.592$ (fm)
$a = 0.617$, $aso = 0.664$, $b = 0.563$ (fm)

MT=2 Elastic scattering
Obtained by subtracting the sum of the partial cross sections from the total cross section.

MT=4, 51-61, 91 inelastic scattering
Calculated with CASTHY code/5/, taking account of the contribution from the competing processes. The direct component was calculated with the coupled-channel optical model code ECIS/6/. The deformed potential parameters used were taken from the work of Delaroche/7/.
The level data used in the above two calculations were taken from ref./8/ as follows:

MT	Level energy(MeV)	Spin-parity
g.s.	0.0	0+

1	0.1112	2+
2	0.3641	4+
3	0.7483	6+
4	0.9033	2+
5	1.0023	0+
6	1.0059	3+
7	1.1214	2+
8	1.1300	2-
9	1.1338	4+
10	1.2213	3-
11	1.2850	5-
12	1.2941	5+
13	1.3221	0+
14	1.3453	4-
15	1.3590	4+
16	1.3863	2+
17	1.4250	3+
18	1.4310	2+
19	1.4462	6-

Levels above 1.4739 MeV were assumed to be overlapping.

The calculated data for the inelastic scattering were finally lumped for the convenience on the construction of the element data, as follows:

MT no.	Level energy(MeV)	Lumping
51	0.1112	1
52	0.3641	2
53	0.7483	3
54	0.9033	4
55	1.0023	5
56	1.0059	6
57	1.1214	7 - 9
58	1.2213	10
59	1.2850	11
60	1.2941	12
61	1.3221	13 -19

MT=16, 22, 28, 103, 107 (n,2n), (n,na), (n,np), (n,p), (n,a)
Calculated with the GNASH code/9/ including the precompound effect. Transmission coefficients for neutrons, protons and alphas were calculated with the ELIESE-3 code/10/ using the above optical model parameters, the Menet's ones/11/ and the Huizenga-Igo's/12/, respectively.
Calculated data for the (n,p) cross sections were normalized to the Qaim's experimental data of 2.9 milli barns at 14.7 MeV /13/.
Calculated data for the (n,np) cross sections were normalized to the Qaim's experimental data of 0.65 milli barn at 14.7 MeV /13/.

MT=102 Capture
Calculated with the CASTHY code/5/ and normalized to 49 mb at 500 keV/14/.

MT=251 Mu-bar
Calculated with the optical model.

MF=4 Angular Distributions of Secondary Neutrons
MT=2

Calculated with the CASTHY code/5/.
MT=51-61, 91
Calculated with the combined program of the CASTHY/5/ and ECIS/6/ codes.
MT=16, 22, 28
Isotropic in the laboratory system.

MF=5 Energy Distributions of Secondary Neutrons
MT=16, 22, 28, 91
Calculated with the GNASH code/9/.

References

1) Camarda H.S. et al. : Phys. Rev. C8, 1813 (1973).
2) Ohkubo M. : JAERI-M 5624 (1974).
3) Macklin R.L. et al. : LA-9200-MS (1982).
4) Mughaghab S.F. and Garber D.I. :"Neutron Cross Sections", Vol. 2, part B (1984).
5) Igarasi S. : J. Nucl. Sci. Tech. 12, 67 (1975).
6) Ravnal J. : IAEA-SMR-9/8 p.281 (1972).
7) Delaroche J.F. et al. : 1979 Knoxville Conf. 336 (1979).
8) ENSDF(Evaluated Nuclear Structure Data File)
9) Young P.G. and Arthur E.D. : LA-6947 (1977).
10) Igarasi S. : JAEIi 1224 (1972).
11) Menet J.J.H. et al.: Phys. Rev. C4, 1114 (1971).
12) Huizenga J.R. and Igo, G.J.: ANL-6373 (1961).
13) Qaim S.M. : Nucl. Phys. A243, 317 (1975).
14) Grenier et al. : CEA-N-2195 (1981).

MAT number = 3744

74-W -186 KHI,NEDAC Eval-Mar87 T.Watanabe(KHI), T.Asami(NEDAC)
Dist-Sep89

History
87-03 New evaluation was made for JENDL-3.
87-03 Compiled by T.Asami.

MF=1 General Information
MT=451 Descriptive data and dictionary

MF=2 Resonance Parameters
MT=151 Resolved resonance parameters
Resolved parameters for MLBW formula were given in the energy region from 1.0E-5 eV to 12 keV.
Parameters were evaluated in examining both the experimental data/1/ - /3/ and the recommended data of BNL/4/.
For unknown radiative width, an average value of 60 milli eV was assumed.
Parameters for negative resonance were selected so that the 2200 m/s cross section for capture reproduced gave a recommended value of 37.8 barns/4/ and gave a good fit to the experimental data for total cross sections around thermal energies.
The scattering radius was assumed to be 7.64 Fermi/4/.
Calculated 2200 m/sec cross sections and resonance integrals are as follows:

	2200 m/s cross section(b)	res. integral(b)
elastic	0.14	
capture	37.89	347.1
total	38.03	

MF=3 Neutron Cross Sections
Below 12 keV, zero background cross section was given and all the cross-section data are reproduced from the evaluated resolved resonance parameters with MLBW formula.
Above 12 keV, the total and partial cross sections were given pointwise.
MT=1 total
Optical and statistical model calculation was made with CASTHY code/5/. The optical potential parameters used are:
V = 48.83 - 0.0809•En, Vso = 5.6 (MeV)
Ws = 6.73 - 0.0536•En, Wv = 0 (MeV)
r = 1.168, rs = 1.268, rso = 1.592 (fm)
a = 0.617, aso = 0.664, b = 0.563 (fm)
MT=2 Elastic scattering
Obtained by subtracting the sum of the partial cross sections from the total cross section.
MT=4, 51-62, 91 Inelastic scattering
Calculated with CASTHY/5/, taking account of the contribution from the competing processes. The direct component was calculated with the coupled-channel optical model code ECIS/6/.
The deformed potential parameters used were taken from the work of Delaroche/7/.
The level data used in the above two calculations were taken from ref./8/ as follows:

MT	Level energy(MeV)	Spin-parity
g.s.	0.0	0+

1	0.1226	2+
2	0.3968	4+
3	0.7377	2+
4	0.8088	6+
5	0.8618	3+
6	0.8820	0+
7	0.9526	2-
8	1.0070	2+
9	1.0316	4+
10	1.0452	3-
11	1.1500	0+
12	1.2840	2+
13	1.2980	2+
14	1.3220	2+

Levels above 1.3925 MeV were assumed to be overlapping.

The calculated data for the inelastic scattering were finally lumped for the convenience on the construction of the element data, as follows:

MT no.	Level energy(MeV)	Lumping
51	0.1226	1
52	0.3968	2
53	0.7377	3
54	0.8088	4
55	0.8618	5
56	0.8820	6
57	0.9526	7
58	1.0070	8
59	1.0316	9
60	1.0452	10
61	1.1500	11
62	1.2840	12 -14

MT=16, 22, 28, 103, 107 (n,2n), (n,na), (n,np), (n,p), (n,a)
Calculated with the GNASH code/9/ including the precompound effect. Transmission coefficients for neutrons, protons and alphas were calculated with the ELIESE-3 code/10/ using the above optical model parameters, the Menet's ones/11/ and the Huizenga-Igo's/12/, respectively.
Calculated data for the (n,p) cross sections were normalized to the Qaim's experimental data of 2.75 milli barns at 14.7 MeV /13/.
Calculated data for the (n,np) cross sections were normalized to the Qaim's experimental data of 0.25 milli barns at 14.5 MeV /13/.

MT=102 Capture
Calculated with the CASTHY code/5/ and normalized to 49 mb at 100 keV/14/.

MT=251 Mu-bar
Calculated with the optical model.

MF=4 Angular Distributions of Secondary Neutrons

MT=2
Calculated with the CASTHY code/5/.

MT=51-62, 91
Calculated with the combined program of the CASTHY/5/ and ECIS/6/ codes.

MT=16, 22, 28
Isotropic in the laboratory system.

MF=5 Energy Distributions of Secondary Neutrons
MT=16, 22, 28, 91
Calculated with the GNASH code/9/.

References

1) Camarda H.S. et al. : Phys. Rev. C8, 1813 (1973).
2) Ohkubo M. : JAERI-M 5624 (1974).
3) Macklin R.L. et al. : LA-9200-MS (1982).
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10) Igarasi S. : JAERI 1224 (1972).
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MAT number = 3820

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 82-Pb-  0 JAERI        Eval-Jul87 M.Mizumoto
                        Dist-Sep89
History
87-03  Newly evaluated for JENDL-3 by M.Mizumoto (JAERI)
87-11  Revision is recommended.
89-09  Revision is completed.
       Compilation was made by. T.Narita and T.Fukahori (JAERI)

MF=1  General Information
 MT=451  Descriptive data and dictionary

MF=2  Resonance Parameters
 MT=151  Resolved resonance parameters for MLBW formula
  Resonance ranges:
   Pb-204:1.0E-5 eV to 50 keV
   Pb-206,Pb-207,Pb-208: 1.0E-05 to 480 keV
  Parameters were evaluated from the following exp. data.
   Pb-204:Horen+84 /1/
   Pb-206:Horen+79 /2/, Mizumoto+79 /3/
   Pb-207:Allen+73 /4/, Raman+77 /5/, Horen+81 /6/
   Pb-208:Allen+73 /4/, Macklin+77 /7/, Horen+86 /8/
  The s-wave resonance energy of Pb-208 at 506 keV was changed
  to 525 keV in order to the interference mininum around 500 keV.

     Calculated 2200-m/s cross sections and res. integrals.
                      2200 m/s              res. integ.
      elastic          11.261 b                 -
      capture           0.172 b              0.137 b
      total            11.433 b                 -

MF=3  Neutron Cross Sections
 Below 480 keV
  Background cross sections are given for the elastic
  scattering cross section.

 Above 480 keV
 MT=1 Total
  Cross sections in the energy range from 480 keV to 15 MeV were
  obtained based on the experimental data of Schwartz+77 /9/.
  Above 15 MeV, cross sections were calculated with an optical and
  statistical model code CASTHY /10/.  The optical potential
  parameters were obtained by fitting average total cross section
  of natural lead as follows,
       V=47.0 - 0.250*E,  Ws = 2.30 + 0.41*E, Vso = 6.0 (MeV)
       r0 = 1.25         ,  rs = 1.30          , rso = 1.30 (fm)
       a0 = 0.65         ,  b  = 0.48          , as0 = 0.689 (fm)
  Level density parameters were determined using low-lying
  level data and observed neutron resonance spacing.
 MT=2  Elastic scattering
  (Total)-(All other partial cross sections)
 MT=4,51-90,91  Inelastic scattering
  Calculated with CASTHY /10/ and a DWBA calculation code DWUCK
  /11/for each isotope and constructed according to their isotopic
  abundances.
     Level scheme was taken from Ref /12/
```

NO.		Energy(MeV)	Spin-Parity		
g.s.		0.0	21		2.9396
1	•	0.5709	22		3.0165
2	•	0.8031	23	•	3.1977
3	•	0.8986	24	•	3.2230
4		1.1670	25	•	3.4130
5		1.3406	26		3.4750
6		1.4666	27	•	3.7085
7	•	1.6337	28		3.9199
8	•	1.6841	29		3.9464
9		1.9978	30	•	3.9609
10		2.2002	31		3.9957
11	•	2.3398	32	•	4.0855
12		2.3843	33		4.1252
13	•	2.6146	34		4.1803
14	•	2.6230	35		4.2962
15	•	2.6476	36	•	4.3237
16	•	2.6626	37		4.3584
17	•	2.7276	38		4.3929
18		2.7823	39		4.4237
19		2.8264	40	•	4.4805
20		2.8645			

Levels above 2.200 MeV were assumed to be continuum.
Levels without (•) marks are calculated with only CASTHY /10/.

MT=16,17 (n,2n) and (n,3n)
Calculated for each isotope with a multi-step Hauser Feshbach code GNASH /13/, in which the Ignatyuk level density formula /14/ was incorporated, and constructed according to the isotopic abundances.
The (n,2n) cross section was normalized to the averaged value 2.184 b at 14 MeV based on the experimental values by Frehaut+80 /15/, Iwasaki+85 /16/ Yanagi+82 /17/ and Takahashi+85 /18/.

MT=22 (n,n'alpha)
Calculated with GNASH /13/ for each isotope and constructed according to their abundances.

MT=28 (n,n'p)
Calculated with GNASH /13/ for each isotope and constructed according to their abundances.

MT=102 capture
Calculated with CASTHY /10/ for Pb-204, Pb-206 and Pb-207. For Pb-208, estimated from the experimental data. The capture cross section of natural lead was constructed from these isotopes.

MT=103 (n,p)
Calculated with GNASH /13/ for each isotope and constructed according to their abundances.

MT=107 (n,a)
Calculated with GNASH /13/ for each isotope and constructed according to their abundances.

MT=251 Mu-bar
Calculated with CASTHY /10/.

MF=4 *Angular Distributions of Secondary Neutrons*

MT=2,51-90 : calculated with CASTHY /10/ and DWUCK /11/ for each isotope and constructed according to their abundances.

MT=16,17,22,28,91 : assumed to be isotropic in the lab system.

MF=5 Energy Distributions of Secondary Neutrons
MT=16,17,22,28,91: calculated with GNASH /13/ for each isotope and constructed according to their abundances.

MF=12 Gamma-ray Multiplicity Produced by Neutron Reactions
MT=102 : calculated with GNASH /13/.

MF=13 Gamma-ray Production Cross Sections
MT=3 : calculated with GNASH /13/ for each isotope and constructed according to their abundances.

MF=14 Angular Distributions of Secondary Gamma-rays
MT=3,102 : assumed isotropic.

MF=15 Energy Distribution of Secondary Gamma-rays
MT=3,102 : calculated with GNASH /13/ for each isotope and constructed according to their abundances.

References

1) Horen D.J. et al. : Phys. Rev. C29, 2126 (1984).
2) Horen D.J. et al. : Phys. Rev. C20, 478 (1979).
3) Mizumoto M. et al. : Phys. Rev. C19 ,335 (1979).
4) Allen B.J. et al. : Phys. Rev., C8, 1504 (1973).
5) Raman S. et al. : Phys. rev. Lett., 39,598 (1977).
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7) Macklin R.L. et al. : Astrophys. J. 217, 222 (1977).
8) Horen D. J. et al. : Phys. Rev. C34, 420 (1986).
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11) Kunz P.D. : Univ. Colorado (1974).
12) Lederer C.M. and Shirley V.S.: Table of isotopes, 7th ed.
13) Young P.G. and Arthur E.D.: LA-6974 (1977).
14) Ignatyuk A.V. et al. : Sov. J. Nucl. Phys. 21, 255 (1975).
15) Frehaut et al. : BNL-NCS-51245 Vol 1 p399 (1980).
16) Iwasaki S. et al.: Proc. Santa Fe Conf. p191 (1985).
17) Yanagi et al. : OKTAVIAN reports A-84-02 (1982).
18) Takahashi et al. : Proc. Santa Fe Conf. p59 (1985).

MAT number = 3821

82-Pb-204 JAERI Eval-Jul87 M.Mizumoto
Dist-Sep89

History
87-03 Newly evaluated for JENDL-3 by M. Mizumoto (JAERI)
87-11 Revise is recommended.
89-09 Revision is completed.
Compilation was made by T Narita and T.Fukahori (JAERI)

MF=1 General Information
MT=451 Descriptive data and dictionary

MF=2 Resonance Parameters
MT=151 Resolved resonance parameters for MLBW formula
Resonance ranges: 1.0E-5 eV to 50 keV
Parameters were evaluated from the data of Horen+84 /1/.
Effective scattering radius of 8.5 fm was selected.

Calculated 2200-m/s cross sections and res. integrals.

	2200 m/s	res. integ.
elastic	11.197 b	-
capture	0.661 b	1.848 b
total	11.857 b	-

MF=3 Neutron Cross Sections
Below 50 keV
Background cross sections are given for the elastic scattering cross section.

Above 50 keV
Cross sections were obtained from optical and statistical model calculations. The optical potential parameters were obtained by fitting average total cross section of natural lead as follows,

V=47.0 - 0.250•E, Ws = 2.30 + 0.41•E, Vso = 6.0 (MeV)
r0 = 1.25 , rs = 1.30 , rso = 1.30 (fm)
a0 = 0.65 , b=0.48 , as0 = 0.689 (fm)

Level density parameters were determined using low-lying level data and observed neutron resonance spacing.

MT=1 Total
Calculated with optical and statistical mode code CASTHY /2/
MT=2 Elastic scattering
(Total)-(All other partial cross sections)
MT=4,51-56,91 Inelastic scattering
Calculated with CASTHY /2/
Level scheme taken from Ref. /3/

No.	Energy(MeV)	Spin-Parity
g.s.	0.0	0.0 +
1	0.8992	2.0 +
2	1.2739	4.0 +
3	1.5627	4.0 +
4	1.8174	4.0 +
5	2.0649	5.0 +
6	2.1855	9.0 -

Levels above 2.200 MeV were assumed to be continuum.

MT=16,17 (n,2n) and (n,3n)
Calculated with a multi-step Hauser Feshbach model code GNASH/4/ in which the Ignatyuk level density formula/5/ was incorporated. The (n,2n) cross section is normalized at 14 MeV to 2.12 barns by Ikeda+87 /6/.

MT=22 (n,n'alpha)
Calculated with GNASH /4/.

MT=28 (n,n'p)
Calculated with GNASH /4/.

MT=102 capture
Calculated with CASTHY /2/ and normalized to 0.661 barn at 0.025 eV.

MT=103 (n,p)
Calculated with GNASH /4/.

MT=107 (n,a)
Calculated with GNASH /4/.

MT=251 Mu-bar
Calculated with CASTHY /2.

MF=4 Angular Distributions of Secondary Neutrons
MT=2,51-56 : calculated with CASTHY /2/.
MT=16,17,22,28 : assumed to be isotropic in the lab system.
MT=91 : assumed the same distributions in the lab. system as those calculated with CASTHY /2/ in the center-of-mass system.

MF=5 Energy Distributions of Secondary Neutrons
MT=16,17,22,28,91: calculated with GNASH /4/.

MF=12 Gamma-ray Multiplicity Produced by Neutron Reactions
MT=16,17,51-56,22,91,102: calculated with GNASH /4/.

MF=14 Angular Distributions of Secondary Gamma-rays
MT=16,17,51-56,22,91,102: assumed to be isotropic.

MF=15 Energy distribution of secondary gamma-rays
MT=16,17,91,102: calculated with the GNASH /4/.

References

1) Horen D.J. et al. : Phys. Rev. C29, 2126 (1984).
2) Igarasi S.: J. Nucl. Sci. Technol., 12, 67 (1975).
3) Lederer C.M. and Shirley V.S.: Table of isotopes, 7th ed.
4) Young P.G. and Arthur E.D.: LA-6974 (1977).
5) Ignatyuk A.V. et al. : Sov. J. Nucl. Phys. 21, 255 (1975).
6) Ikeda Y. et al. : JAERI 1312 (1987).

MAT number = 3822

82-Pb-206 JAERI Eval-Jul87 M.Mizumoto
Dist-Sep89

History
87-03 Newly evaluated for JENDL-3 by M.Mizumoto (JAERI)
87-11 Revise is recommended.
89-09 Revision is completed.
Compilation is made by T.Narita and T.Fukahori (JAERI)

MF=1 General Information
MT=451 Descriptive data and dictionary

MF=2 Resonance Parameters
MT=151 Resolved resonance parameters for MLBW formula
Resonance ranges: 1.0E-5 eV to 500 keV
Parameters were evaluated from the data of Horen+79 /1/, and Mizumoto+79 /2/. Effective scattering radius of 8.5 fm was selected.

Calculated 2200-m/s cross sections and res. integrals.

	2200 m/s	res. integ.
elastic	10.463 b	-
capture	0.031 b	0.0980 b
total	10.494 b	-

MF=3 Neutron Cross Sections
Below 500 keV
Background cross sections are given for the elastic scattering cross section.

Above 500 keV
Cross sections were obtained from optical and statistical model calculations. The optical potential parameters were obtained by fitting average total cross section of natural lead as follows,

V=47.0 - 0.250•E, Ws = 2.30 + 0.41•E, Vso = 6.0 (MeV)
r0 = 1.25 , rs = 1.30 , rso = 1.30 (fm)
a0 = 0.65 , b=0.48 , aso = 0.689 (fm)

Level density parameters were determined using low-lying level data and observed neutron resonance spacing.

MT=1 Total
Calculated with optical and statistical mode code CASTHY /3/

MT=2 Elastic scattering
(Total)-(All other partial cross sections)

MT=4,51-64,91 Inelastic scattering
Calculated with CASTHY /3/ and DWBA calculation code DWUCK /4/.
Level Scheme taken from Ref /5/.

No.		Energy(MeV)	Spin-Parity
g.s.		0.0	0.0 +
1	*	0.8031	2.0 +
2		1.1670	0.0 +
3		1.3406	3.0 +
4		1.4666	2.0 +
5	*	1.6841	4.0 +
6		1.9978	4.0 +
7		2.2002	7.0 -

8		2.3843	6.0 -
9	•	2.6476	3.0 -
10		2.7823	5.0 -
11		2.8264	4.0 -
12		2.8645	7.0 -
13		2.9396	6.0 -
14		3.0165	5.0 -

Levels without (•) marks are calculated only with CASTHY /3/.
Levels above 3.100 MeV were assumed to be continuum.

MT=16 (n,2n)
Calculated with a multi-step Hauser Feshbach code GNASH /6/ in which the Ignatyuk level density formula/7/ was incorporated. and normalized to 2.17 barns at 14 MeV based on the results (x1.1) by Frehaut+80 /8/.

MT=17 (n,3n)
Calculated with GNASH /6/ and normalized to 0.245 barn at 20 MeV by Welch+81 /9/

MT=22 (n,n'alpha)
Calculated with GNASH /6/ and multiplied by 5.

MT=28 (n,n'p)
Calculated with GNASH /6/ and multiplied by 5.

MT=102 capture
Calculated with CASTHY /3/ and normalized to 0.0306 barn at 0.025 eV.

MT=103 (n,p)
Calculated with GNASH /6/ and normalized to 2.0 mb at 14.5 MeV by Belovickij+76 /10/.

MT=107 (n,a)
Calculated with GNASH /6/ and multiplied by 5.

MT=251 Mu-bar
Calculated with CASTHY /3/.

MF=4 Angular Distributions of Secondary Neutrons
MT=2,51-64,91 : calculated with CASTHY /3/ and DWUCK /4/.
MT=16,17,22,28 : assumed to be isotropic in the lab system.

MF=5 Energy Distributions of Secondary Neutrons
MT=16,17,22,28,91: calculated with GNASH /6/.

MF=12 Gamma-ray Multiplicity Produced by Neutron Reactions
MT=16,17,22,28,51-64,91,102,103,107 : calculated with GNASH /6/.

MF=14 Angular Distributions of Secondary Gamma-rays
MT=16,17,22,28,51-64,91,102,103,107 : assumed isotropic.

MF=15 Energy Distribution of Secondary Gamma-rays
MT=16,17,22,28,91,102,107 : calculated with the GNASH /6/.

References

1) Horen D.J. et al. : Phys. Rev. C20, 478 (1979).
2) Mizumoto M. et al. : Phys. Rev. C19 ,335 (1979)(1971).
3) Igarasi S.: J. Nucl. Sci. Technol., 12, 67 (1975).
4) Kunz P.D. : Univ. Colorado (1974).
5) Lederer C.M. and Shirley V.S.: Table of isotopes, 7th ed.
6) Young P.G. and Arthur E.D. : LA-6974 (1977).
7) Ignatyuk et al. : Sov. J. Nucl. Phys. 21, 255 (1975).
8) Frehaut et al. : BNL-NCS-51245 Vol 1 p399 (1980).

9) Welch P. et al. : BAP, 26, 708 (1981).
10) Belovickij et al. : 75 KIEV, 4, 209 (1976).

MAT number = 3823

82-Pb-207 JAERI Eval-Jul87 M.Mizumoto
Dist-Sep89

History
87-03 Newly evaluated for JENDL-3 by M.Mizumoto (JAERI)
87-11 Revise is recommended.
89-09 Revision is completed
Compilation is made by T.Narita and T.Fukahori (JAERI)

MF=1 General Information
MT=451 Descriptive data and dictionary

MF=2 Resonance Parameters
MT=151 Resolved resonance parameters for MLBW formula
Resonance ranges: 1.0E-5 eV to 500 keV
Parameters were evaluated from the data of Allen+73 /1/ Raman+77 /2/ and Horen+79 /3/.
Effective scattering radius of 8.04 fm was selected.

Calculated 2200-m/s cross sections and res. integrals.

	2200 m/s	res. integ.
elastic	11.448b	-
capture	0.7120 b	0.3725 b
total	12.160 b	-

MF=3 Neutron Cross Sections
Below 500 keV
Background cross sections are given for the elastic scattering cross section.

Above 500 keV
Cross sections were obtained with optical and statistical model code CASTHY /4/. The optical potential parameters were obtained by fitting average total cross section of natural lead as follows.

V=47.0 - 0.250*E, Ws = 2.30 + 0.41*E, Vso = 6.0 (MeV)
r0 = 1.25 , rs = 1.30 , rso = 1.30 (fm)
a0 = 0.65 , b=0.48 , aso = 0.689 (fm)

Level density parameters were determined using low-lying level data and observed neutron resonance spacing.

MT=1 Total
Calculated with CASTHY /4/.

MT=2 Elastic scattering
(Total)-(All other partial cross sections)

MT=4,51-59,91 Inelastic scattering
Calculated with CASTHY /4/ and the DWBA calculation code DWUCK /5/.
Level scheme taken from Ref /6/.

No.		Energy(MeV)	Spin-Parity
g.s.		0.0	1/2 -
1	*	0.5709	5/2 -
2	*	0.8986	3/2 -
3	*	1.6337	13/2 +
4	*	2.3398	7/2 -
5	*	2.6230	5/2 +
6	*	2.6626	7/2 +

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           7    *    2.7276              9/2 +
           8    *    3.2230             11/2 +
           9    *    3.4130              9/2 -
   All discrete inelastic levels with mark (*) are calculated with
   both CASTHY /4/ and DWUCK /5/.
   Levels above 3.500 MeV were assumed to be continuum.
  MT=16,17 (n,2n) and (n,3n)
   Calculated with a multi-step Hauser Feshbach code GNASH /7/
   in which the Ignatyuk level density formula /8/ was incorporated.
   The (n,2n) cross section was normalized to 2.08 barns
   at 14 MeV based on the results (x 1.1) by Frehaut+80 /9/.
  MT=22 (n,n'alpha)
   Calculated with GNASH /7/ and multiplied by 5.
  MT=28 (n,n'p)
   Calculated with GNASH /7/ and multiplied by as the same factor
   as for MT=103.
  MT=102 capture
   Calculated with CASTHY /4/ and normalized to 0.710 barn at
   0.025 eV.
  MT=103 (n,p)
   Calculated with GNASH /7/ and normalized to 1.6 mb at 14.5 MeV
   by Belovickij+76 /10/
  MT=107 (n,a)
   Calculated with GNASH /7/ and multiplied by 5.
  MT=251 Mu-bar
   Calculated with CASTHY /3/.

MF=4` Angular Distributions of Secondary Neutrons
  MT=2,51-59,91      : calculated with CASTHY /3/ and DWUCK /4/.
  MT=16,17,22,28     : assumed to be isotropic in the lab system.

MF=5  Energy Distributions of Secondary Neutrons
  MT=16,17,22,28,91: calculated with GNASH /7/.

MF=12 Gamma-ray Multiplicity Produced by Neutron Reactions
  MT=16,17,22,28,51-59,91,102,103,107 : calculated with GNASH /7/.

MF=14 Angular Distributions of Secondary Gamma-rays
  MT=16,17,22,28,51-59,91,102,103,107 : assumed isotropic.

MF=15 Energy Distribution of Secondary Gamma-rays
  MT=16,17,22,28,91,102,103,107 : calculated with the GNASH /7/
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References

1) Allen B.J. et al. : Phys. Rev., C8, 1504 (1973).
2) Raman S. et al. : Phys. Rev. Lett., 39,598 (1977)
3) Horen D.J. et al. : Phys. Rev. C20, 478 (1979)
4) Igarasi S.: J. Nucl. Sci. Technol., 12, 67 (1975).
5) Kunz P.D. : Univ. Colorado (1974)
6) Lederer C.M. and Shirley V.S.: Table of isotopes, 7th ed.
7) Young P.G. and Arthur E.D. : LA-1974 (1977)
8) Ignatyuk et al. : Sov. J. Nucl. Phys. 21, 255 (1975)
9) Frehaut et al. : BNL-NCS-51245 Vol 1 p399 (1980).
10) Belovickij et al. : 75 KIEV, 4, 209 (1976)

MAT number = 3824

82-Pb-208 JAERI Eval-Jul87 M.Mizumoto
Dist-Sep89

History
87-03 Newly evaluated for JENDL-3 by M.Mizumoto (JAERI)
87-11 Revision is recommended.
89-09 Revision is completed.
Compilation is made by T.Narita and T.Fukahori (JAERI)

MF=1 General Information
MT=451 Descriptive data and dictionary

MF=2 Resonance Parameters
MT=151 Resolved resonance parameters for MLBW formula
Resonance ranges: 1.0E-5 eV to 800 keV
Parameters were evaluated from the data of Allen+73 /1/ Macklin+77 /2/ and Horen+86 /3/.
Effective scattering radius of 6.5 fm was selected.
The s-wave resonance energy at 506 keV was changed to 525 keV to fit the interference around 500 keV region.

Calculated 2200-m/s cross sections and res. integrals.

	2200 m/s	res. integ.
elastic	11.246 b	-
capture	0.4258 mb	7.207 mb
total	11.246 b	

MF=3 Neutron Cross Sections
Below 800 keV
Background cross sections are given for the elastic scattering cross section.

Above 800 keV
Cross sections were obtained with an optical and statistical model calculation code CASTHY /4/. The optical potential parameters were obtained by fitting average total cross section of natural lead as follows.

V=47.0 - 0.250•E, Ws = 2.30 + 0.41•E, Vso = 6.0 (MeV)
r0 = 1.25 , rs = 1.30 , rso = 1.30 (fm)
a0 = 0.65 , b=0.48 , aso = 0.689 (fm)

Level density parameters were determined using low-lying level data and observed neutron resonance spacing.

MT=1 Total
Calculated with CASTHY /4/.

MT=2 Elastic scattering
(Total)-(All other partial cross sections)

MT=4,51-67,91 Inelastic scattering
Calculated with CASTHY /4/ and a DWBA calculation code DWUCK /5/.
Level schemes were taken from Ref /6/

No.		Energy(MeV)	Spin-Parity
g.s.		0.0	0 +
1	•	2.6146	3 -
2	•	3.1977	5 -
3		3.4750	4 -
4	•	3.7085	5 -

5		3.9199	6 -
6		3.9464	5 -
7	*	3.9609	4 -
8		3.9957	5 -
9	*	4.0855	2 +
10		4.1252	4 -
11		4.1803	5 -
12		4.2962	5 -
13	*	4.3237	4 +
14		4.3584	4 -
15		4.3829	6 -
16		4.4237	6 +
17	*	4.4805	6 -

Levels without (*) marks are calculated with only CASTHY /4/.
Levels above 4.500 MeV were assumed to be continuum.

MT=16,17 (n,2n) and (n,3n)
Calculated with a multi-step Hauser Feshbach model code GNASH/7/ in which the Ignatyuk level density formula/8/ was incorporated. The (n,2n) cross section was normalized to 2.13 barns at 14 MeV based on the results (x1.1) by Frehaut+80 /9/.

MT=22 (n,n'alpha)
Calculated with GNASH /7/ and multiplied by 5.

MT=28 (n,n'p)
Calculated with GNASH /7/ and normalized to 26 mb at 20 MeV by Welch+81 /10/.

MT=102 capture
Calculated with CASTHY /4/ and estimated from the experimental data by Csikai+67 /11/, Drake+71 /12/, Bergqvist+72 /13/ and Diven+60 /14/

MT=103 (n,p)
Calculated with GNASH /7/ and normalized to 4 mb at 18 MeV by Bass+68 /15/.

MT=107 (n,alpha)
Calculated with GNASH /7/ and normalized to 1.6 mb at 14.5 by Coleman+59 /16/.

MT=251 Mu-bar
Calculated with CASTHY /4/.

MF=4 Angular Distributions of Secondary Neutrons
MT=2,51-67,91 : calculated with CASTHY /4/ and DWUCK /5/.
MT=16,17,22,28 : assumed to be isotropic in the lab system.

MF=5 Energy Distributions of Secondary Neutrons
MT=16,17,22,28,51-67,91: calculated with GNASH /7/.

MF=12 Gamma-ray Multiplicity Produced by Neutron Reactions
MT=16,17,22,28,51-67,91,102,103,107 : calculated with GNASH /7/.

MF=14 Angular Distributions of Secondary Gamma-rays
MT=16,17,22,28,51-67,91,102,103,107 : assumed isotropic.

MF=15 Energy Distribution of Secondary Gamma-rays
MT=16,17,22,28,91,102,103,107 : calculated with the GNASH /7/.

References
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MAT number = 3831

83-Bi-209 JAERI Eval-May89 N.Yamamuro,A.Zukeran,JENDL-3 C.G.
Dist-Sep89

History
89-04 Evaluation was performed for JENDL-3.
89-05 Compiled by K.Shibata and T.Narita (JAERI).

MF=1 General Information
MT=451 Descriptive data and dictionary

MF=2 Resonance Parameters
MT=151 Resolved resonance parameters for MLBW formula
Parameters were mainly taken from the work of Mughabghab et al. /1/.
Resonance region : 1.0E-5 eV to 200 keV.
Scattering radius: 9.68 fm
Calculated 2200-m/s cross sections and res. integrals

	2200-m/s	res. integ.
elastic	9.298 b	-
capture	0.034 b	0.207 b
total	9.331 b	-

MF=3 Neutron Cross Sections
MT=1 Total
Below 200 keV : Background cross sections given between 30 keV and 200 keV.
200 keV to 20 MeV: Based on the experimental data /2,3,4/.
MT=2 Elastic scattering
(Total) - (Reaction cross section)
MT=3 Non elastic
Sum of MT=4, 16, 17, 22, 28, 102, 103, 104, 107
MT=4,51-62,91 Inelastic scattering
Statistical model calculations were made with the SINCROS system /5/ using the modified Walter-Guss potential parameters for neutrons. For MT=51,52,58,62, the experimental data of Smith et al./6/ were adopted below 5 MeV. The calculated cross section of MT=91 was modified so as to reproduce the measurements of the total inelastic cross section below 8 MeV.
The direct-process components were considered for the levels of MT=51,52,58,91 by the DWBA calculations.

The level scheme is given as follows:

No.	Energy(MeV)	Spin-Parity
g.s.	0.0	9/2 -
1.	0.8964	7/2 -
2.	1.6085	13/2 +
3.	2.4300	1/2 +
4.	2.4920	3/2 +
5.	2.5645	9/2 +
6.	2.5830	7/2 +
7.	2.5990	11/2 +
8.	2.6017	13/2 +
9.	2.6170	5/2 +
10.	2.7411	15/2 +

11.	2.7660	5/2 +
12.	2.8220	5/2 -

Levels above 2.85 MeV were assumed to be overlapping.

MT=16,17,22,28,103,104,107 (n,2n),(n,3n),(n,n'a),(n,n'p),(n,p) (n,d) and (n,a) cross sections
Calculated with SINCROS/5/.
Optical potential parameters for proton, alpha-particle and deuteron were taken from the works of Perey/7/, Lemos/8/ and Lohr and Haeverli/9/, respectively.
The calculated (n,p) cross section was multiplied by 0.3333 in order to fit to the experimental data /10-12/ around 14 MeV.

MT=102 Radiative capture cross section
1.0E-5 eV to 200 keV: Resonance parameters given between 30 keV and 200 keV.
200 keV to 3 MeV: Calculated with the CASTHY code/13/. The calculation was normalized to 4 mb at 100 keV.
3 MeV to 20 MeV: Based on the measurements./14-16/.

MT=251 Mu-bar
Calculated from File-4.

MF=4 Angular Distributions of Secondary Neutrons
MT=2,51-62
Calculated with CASTHY for equilibrium process.
The components of the direct process were added to the levels of MT=51,52,58 by using the DWUCK code /17/.
MT=16, 17, 22, 28
Assumed to be isotropic in the laboratory system.
MT=91
The Kalbach-Mann systematics/18/ adopted at 14 MeV.

MF=5 Energy Distributions of Secondary Neutrons
MT=16, 17, 22, 28, 91
Calculated with SINCROS.

MF=12 Photon Production Multiplicities
MT=3,102
Calculated with SINCROS.

MF=14 Photon Angular Distributions
MT=3,102
Assumed to be isotropic.

MF=15 Photon Energy Distributions
MT=3,102
Calculated with SINCROS.

References
1) Mughabghab S.F., Divadeenam M. and Holden N.E.: "Neutron Cross Sections, Vol. 1, Part A", Academic Press (1981).
2) Foster, Jr., D.G. and Glasgow, D.W.: Phys. Rev., C3, 576 (1971).

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16) Bergqvist, I., et al.: Nucl. Phys., A120, 161 (1968).
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MAT number = 3881

88-Ra-223 TIT Eval-Aug88 N.Takagi
Dist-Sep89

History
88-08 New evaluation was made by N. Takagi (Tokyo Institute of Technology, TIT)

MF=1 General Information
MT=451 Comment and dictionary
MT=452 Number of neutrons per fission
Evaluated with semi empirical formula of Howerton/1/.

MF=2 Resonance parameters
MT=151 Resonance parameters
No resonance parameters were given.

2200-m/s cross sections and resonance integrals

	2200 m/s value	Res. Int.
Total	143.10 b	-
Elastic	12.40 b	-
Fission	0.70 b	1.06 b
Capture	130.00 b	435 b

MF=3 Neutron Cross Sections
MT=1 Total cross section
Below 4 eV, calculated as sum of MT's = 2, 18 and 102.
Above 4 eV, optical model calculation was made with CASTHY/2/. The potential parameters/3/ used are as follows,

```
V = 41.0 - 0.05*En                          (MeV)
Ws= 6.4 + 0.15*SQRT(En)                     (MeV)
Wv= 0              , Vso = 7.0              (MeV)
r = rso = 1.31     , rs = 1.38              (fm)
a = aso = 0.47     , b  = 0.47              (fm)
```

MT=2 Elastic scattering cross section
Below 4 eV, the constant cross section of 12.4 barns was assumed, which was the shape elastic scattering cross section calculated with optical model. Above this energy, optical model calculation was adcn'ed.

MT=4,51-64,91 Inelastic scattering cross sections.
Optical and statistical model calculation was made with CASTHY/2/. The level scheme was taken from Ref. 4.

No	energy(keV)	spin-parity
g.s.	0.0	1/2 +
1	50.19	3/2 -
2	61.53	5/2 +
3	79.77	3/2 -
4	123.91	5/2 -
5	130.27	7/2 +
6	174.72	9/2 +
7	174.78	7/2 -
8	247.47	9/2 -
9	280.31	3/2 +
10	286.16	3/2 +

11	329.95	3/2 -
12	334.52	3/2 +
13	342.50	3/2 +
14	342.92	5/2 +

Levels above 369.43 keV were assumed to be overlapping.
The level density parameters were taken from Ref. 5.

MT=16,17,37 (n,2n), (n,3n) and (n,4n) reaction cross sections
Calculated with evaporation model.

MT=18 Fission cross section
Measured thermal cross section of 0.7 barn was taken from Ref. 6 , and 1/v form was assumed below 4 eV. Above this energy, the constant cross section was adopted.

MT=102 Capture cross section
Measured thermal cross section of 130 barns was taken from Ref. 6 , and 1/v form was assumed below 4 eV. Above 4 eV, calculated with CASTHY. The gamma-ray strength function was estimated from Gamma-gamma = 0.040 eV and level spacing = 8 eV.

MT=251 Mu-L
Calculated with CASTHY.

MF=4 Angular Distributions of Secondary Neutrons
MT=2,51-64,91 Calculated with optical model.
MT=16,17,18,37 Isotropic in the lab system.

MF=5 Energy Distributions of Secondary Neutrons
MT=16,17,37,91 Evaporation spectra
Obtained from level density parameters.

MT=18 Maxwellian fission spectrum.
Temperature was estimated from Z**2/A dependence/7/.

References

1) Howerton R.J.: Nucl. Sci. Eng., 62, 438 (1977).
2) Igarasi S.: J.Nucl.Sci.Technol.,12,67 (1975).
3) Ohsawa T., Ohta M.: J. Nucl. Sci. Technol., 18, 408 (1981).
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MAT number = 3882

88-Ra-224 TIT Eval-Aug88 N.Takagi
Dist-Sep89

History

88-08 New evaluation was made by N. Takagi (Tokyo Institute of Technology, TIT)

MF=1 General Information

MT=451 Comment and dictionary

MF=2 Resonance parameters

MT=151 Resonance parameters

No resonance parameters were given.

2200-m/s cross sections and resonance integrals

	2200 m/s value	Res. Int.
Total	24.50 b	-
Elastic	12.50 b	-
Capture	12.00 b	29.0 b

MF=3 Neutron Cross Sections

MT=1 Total cross section

Below 45 eV, calculated as sum of MT's = 2 and 102. Above 45 eV, optical model calculation was made with CASTHY/2/. The potential parameters/3/ used are as follows,

V = 41.0 - 0.05*En		(MeV)
Ws= 6.4 + 0.15*SQRT(En)		(MeV)
Wv= 0	, Vso = 7.0	(MeV)
r = rso = 1.31	, rs = 1.38	(fm)
a = aso = 0.47	, b = 0.47	(fm)

MT=2 Elastic scattering cross section

Below 45 eV, the constant cross section of 12.5 barns was assumed, which was the shape elastic scattering cross section calculated with optical model. Above this energy, optical model calculation was adopted.

MT=4,51-61,91 Inelastic scattering cross sections.

Optical and statistical model calculation was made with CASTHY/2/. The level scheme was taken from Ref. 4.

No	energy(keV)	spin-parity
g.s.	0.0	2 +
1	84.37	2 +
2	215.99	1 -
3	250.78	4 +
4	290.36	3 -
5	433.08	5 -
6	479.30	6 +
7	916.33	0 +
8	965.51	2 +
9	992.65	2 +
10	1052.95	1 -
11	1089.98	2 -

Levels above 1187 keV were assumed to be overlapping.
The level density parameters were taken from Ref. 5.

MT=16,17,37 (n,2n), (n,3n) and (n,4n) reaction cross sections
Calculated with evaporation model.

MT=102 Capture cross section
Measured thermal cross section of 12 barns was taken from Ref. 6 , and 1/v form was assumed below 45 eV. Above 45 eV, cross section was calculated with CASTHY. The gamma-ray strength function was estimated from Gamma-gamma = 0.040 eV and level spacing = 90 eV.

MT=251 Mu-L
Calculated with CASTHY.

MF=4 Angular Distributions of Secondary Neutrons
MT=2,51-61,91 Calculated with optical model.
MT=16,17,37 Isotropic in the lab system.

MF=5 Energy Distributions of Secondary Neutrons
MT=16,17,37,91 Evaporation spectra
Obtained from level density parameters.

References
1) Howerton R.J.: Nucl. Sci. Eng., 62, 438 (1977).
2) Igarasi S.: J.Nucl.Sci.Technol.,12,67 (1975).
3) Ohsawa T., Ohta M.: J. Nucl. Sci. Technol., 18, 408 (1981).
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MAT number = 3883

88-Ra-225 TIT Eval-Aug88 N.Takagi
Dist-Sep89

History
88-08 New evaluation was made by N. Takagi (Tokyo Institute of Technology, TIT)

MF=1 General Information
MT=451 Comment and dictionary

MF=2 Resonance parameters
No resonance parameters were given.

2200-m/s cross sections and resonance integrals

	2200 m/s value	Res. Int.
Total	112.40 b	-
Elastic	12.40 b	-
Capture	100.00 b	593 b

MF=3 Neutron Cross Sections
MT=1 Total cross section
Below 2.5 eV, calculated as sum of MT's = 2 and 102.
Above 2.5 eV, optical model calculation was made with CASTHY/2/. The potential parameters/3/ used are as follows,

V = 41.0 - 0.05•En		(MeV)
Ws= 6.4 + 0.15•SQRT(En)		(MeV)
Wv= 0	, Vso = 7.0	(MeV)
r = rso = 1.31	, rs = 1.38	(fm)
a = aso = 0.47	, b = 0.47	(fm)

MT=2 Elastic scattering cross section
Below 2.5 eV, the constant cross section of 12.4 barns was assumed, which was the shape elastic scattering cross section calculated with optical model. Above this energy, optical model calculation was adopted.

MT=4,51-56,91 Inelastic scattering cross sections.
Optical and statistical model calculation was made with CASTHY/2/. The level scheme was taken from Ref. 4.

No	energy(keV)	spin-parity
g.s.	0.0	3/2 +
1	25.39	5/2 +
2	42.75	3/2 +
3	100.60	9/2 +
4	111.60	7/2 +
5	149.90	3/2 +
6	179.80	3/2 +

Levels above 203 keV were assumed to be overlapping.
The level density parameters were taken from Ref. 5.

MT=16,17,37 (n,2n), (n,3n) and (n,4n) reaction cross sections
Calculated with evaporation model.

MT=102 Capture cross section
Assumed to be 100 barns at 0.0253 eV, and in 1/v form

below 2.5 eV. Above 2.5 eV, calculated with CASTHY. The gamma-ray strength function was estimated from Gamma-gamm = 0.040 eV and level spacing = 5 eV.

MT=251 Mu-L
Calculated with CASTHY.

MF=4 Angular Distributions of Secondary Neutrons
MT=2,51-56,91 Calculated with optical model.
MT=16,17,37 Isotropic in the lab system.

MF=5 Energy Distributions of Secondary Neutrons
MT=16,17,37,91 Evaporation spectra
Obtained from level density parameters.

References
1) Howerton R.J.: Nucl. Sci. Eng., 62, 438 (1977).
2) Igarasi S.: J.Nucl.Sci.Technol.,12,67 (1975).
3) Ohsawa T., Ohta M.: J. Nucl. Sci. Technol., 18, 408 (1981).
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5) Gilbert A., Cameron A.G.W.: Can. J. Phys., 43, 1446 (1965).

MAT number = 3884

88-Ra-226 TIT Eval-Aug88 N.Takagi
Dist-Sep89

History
88-08 New evaluation was made by N. Takagi (Tokyo Institute of Technology, TIT)

MF=1 General Information
MT=451 Comment and dictionary
MT=452 Number of neutrons per fission
Evaluated with semi empirical formula of Howerton/1/.

MF=2 Resonance parameters
MT=151 Resolved resonance parameters : 1.0E-5 eV to 1000 eV.
Multi-level Breit-Wigner formula was adopted.
Parameters were taken from those by Ivanov/2/.
No fission width was given for all the resonances.
Average gam-g = 0.0258 eV
Effective scattering radius = 9.60 fm

2200-m/s cross sections and resonance integrals

	2200 m/s value	Res. Int.
Total	22.58 b	-
Elastic	9.80 b	-
Fission	0.00006 b	0.0117 b
Capture	12.78 b	286 b

MF=3 Neutron Cross Sections
MT=1 Total cross section
Below 1 keV, cross section was represented with resonance parameters. Above 1 keV, optical model calculation was made with CASTHY/3/. The potential parameters/4/ used are as follows,

V = 41.0 - 0.05•En		(MeV)
Ws= 6.4 + 0.15•SQRT(En)		(MeV)
Wv= 0	, Vso = 7.0	(MeV)
r = rso = 1.31	, rs = 1.38	(fm)
a = aso = 0.47	, b = 0.47	(fm)

MT=2 Elastic scattering cross section
Below 1 keV, cross section was represented with resonance parameters. Above 1 keV, optical model calculation was adopted.

MT=4,51-66,91 Inelastic scattering cross sections.
Optical and statistical model calculation was made with CASTHY/3/. The level scheme was taken from Ref. 5.

No	energy(keV)	spin-parity
g.s.	0.0	0 +
1	67.67	2 +
2	211.54	4 +
3	253.73	1 -
4	321.54	3 -
5	416.60	6 +
6	446.20	5 -
7	626.90	7 -

8	650.00	0 +
9	669.40	8 +
10	824.60	0 +
11	857.90	9 -
12	873.70	2 +
13	960.00	10 +
14	1048.60	1 -
15	1070.50	2 -
16	1134.00	11 -

Levels above 1446 keV were assumed to be overlapping.
The level density parameters were taken from Ref. 6.

MT=16,17,37 (n,2n), (n,3n) and (n,4n) reaction cross sections
Calculated with evaporation model.

MT=18 Fission cross section
Measured thermal cross section of 0.05 mili-barn was taken from Ref. 6, and 1/v form was assumed below 15 eV. For energy region above fission threshold, the evaluation was based on experimental data /7-10/, and between 15 eV and fission threshold, cross section was assumed to be the same as the value at 15 eV.

MT=102 Capture cross section
Below 1 keV, cross section was represented with resonance parameters. Above 1 keV, it was calculated with CASTHY. The gamma-ray strength function was estimated from Gamma-gamma = 0.040 eV and level spacing = 30.3 eV.

MT=251 Mu-L
Calculated with CASTHY.

MF=4 Angular Distributions of Secondary Neutrons
MT=2,51-66,91 Calculated with optical model.
MT=16,17,18,37 Isotropic in the lab system.

MF=5 Energy Distributions of Secondary Neutrons
MT=16,17,37,91 Evaporation spectra
Obtained from level density parameters.

MT=18 Maxwellian fission spectrum.
Temperature was estimated from Z**2/A dependence/11/.

References
1) Howerton R.J.: Nucl. Sci. Eng., 62, 438 (1977).
2) Mughabghab S.F.: "Neutron Cross Sections, Vol.1, Neutron Resonance Parameters and Thermal Cross Sections , Part B, Z=61-100", Academic Press (1984).
3) Igarasi S.: J.Nucl.Sci.Technol.,12,67 (1975).
4) Ohsawa T., Ohta M.: J. Nucl. Sci. Technol., 18, 408 (1981).
5) Ellis-Akovali Y.A.: Nucl. Data Sheets, 50, 229 (1987).
6) Gilbert A., Cameron A.G.W.: Can. J. Phys., 43, 1446 (1965).
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10) Egorov S.A. et al.: Yad. Fiz., 37, 819 (1983).
11) Smith A.B. et al.: ANL/NDM-50 (1979).

MAT number = 3891

89-Ac-225 TIT Eval-Aug88 N.Takagi
Dist-Sep89

History
88-08 New evaluation was made by N. Takagi (Tokyo Institute of Technology, TIT)

MF=1 General Information
MT=451 Comment and dictionary

MF=2 Resonance parameters
MT=151 Resonance parameters
No resonance parameters were given.

2200-m/s cross sections and resonance integrals

	2200 m/s value	Res. Int.
Total	1012.40 b	-
Elastic	12.40 b	-
Capture	1000.00 b	1590 b

MF=3 Neutron Cross Sections
MT=1 Total cross section
Below 0.6 eV, calculated as sum of MT's = 2 and 102.
Above 0.6 eV, optical model calculation was made with CASTHY/2/. The potential parameters/3/ used are as follows.

V = 41.0 - 0.05*En		(MeV)
Ws= 6.4 + 0.15*SQRT(En)		(MeV)
Wv= 0	, Vso = 7.0	(MeV)
r = rso = 1.31	, rs = 1.38	(fm)
a = aso = 0.47	, b = 0.47	(fm)

MT=2 Elastic scattering cross section
Below 0.6 eV, the constant cross section of 12.4 barns was assumed, which was the shape elastic scattering cross section calculated with optical model. Above this energy, optical model calculation was adopted.

MT=4,51,91 Inelastic scattering cross sections.
Optical and statistical model calculation was made with CASTHY/2/. The level scheme was taken from Ref. 4.

No	energy(keV)	spin-parity
g.s.	0.0	3/2 +
1	40.0	3/2 +

Levels above 64 keV were assumed to be overlapping.
The level density parameters were taken from Ref. 5.

MT=16,17,37 (n,2n), (n,3n) and (n,4n) reaction cross sections
Calculated with evaporation model.

MT=102 Capture cross section
Assumed to be 1000 barns at 0.0253 eV by the correlation of thermal cross section with number of excess neutrons. Below 0.6 eV, the 1/v form was assumed. Above this energy, calculated with CASTHY. The gamma-ray strength function was estimated from Gamma-gamma = 0.040 eV and

level spacing = 1.2 eV.

MT=251 Mu-L
Calculated with CASTHY.

MF=4 Angular Distributions of Secondary Neutrons
MT=2,51,91 Calculated with optical model.
MT=16,17,37 Isotropic in the lab system.

MF=5 Energy Distributions of Secondary Neutrons
MT=16,17,37,91 Evaporation spectra
Obtained from level density parameters.

References

1) Howerton R.J.: Nucl. Sci. Eng., 62, 438 (1977).
2) Igarasi S.: J.Nucl.Sci.Technol.,12,67 (1975).
3) Ohsawa T., Ohta M.: J. Nucl. Sci. Technol., 18, 408 (1981).
4) Toth K.S.: Nucl. Data Sheets, 27, 701 (1979).
5) Gilbert A., Cameron A.G.W.: Can. J. Phys., 43, 1446 (1965).

MAT number = 3892

89-Ac-226 TIT Eval-Aug88 N.Takagi
Dist-Sep89

History
88-08 New evaluation was made by N. Takagi (Tokyo Institute of Technology, TIT)

MF=1 General Information
MT=451 Comment and dictionary

MF=2 Resonance parameters
MT=151 Resonance parameters
No resonance parameters were given.

2200-m/s cross sections and resonance integrals

	2200 m/s value	Res. Int.
Total	112.40 b	-
Elastic	12.40 b	-
Capture	100.00 b	1680 b

MF=3 Neutron Cross Sections
MT=1 Total cross section
Below 0.4 eV, calculated as sum of MT's = 2 and 102.
Above 0.4 eV, optical model calculation was made with CASTHY/2/. The potential parameters/3/ used are as follows,

V = 41.0 - 0.05•En		(MeV)
Ws= 6.4 + 0.15•SQRT(En)		(MeV)
Wv= 0	, Vso = 7.0	(MeV)
r = rso = 1.31	, rs = 1.38	(fm)
a = aso = 0.47	, b = 0.47	(fm)

MT=2 Elastic scattering cross section
Below 0.4 eV, the constant cross section of 12.4 barns was assumed, which was the shape elastic scattering cross section calculated with optical model. Above this energy, optical model calculation was adopted.

MT=4,91 Inelastic scattering cross sections.
Calculated with optical and statistical models by means of CASTHY/2/. No excited levels were taken into calculation, because spin of all levels were unknown/4/.

No	energy(keV)	spin-parity
g.s.	0.0	1 +

Levels above 290 keV were assumed to be overlapping.
The level density parameters were taken from Ref. 5.

MT=16,17,37 (n,2n), (n,3n) and (n,4n) reaction cross sections
Calculated with evaporation model.

MT=102 Capture cross section
Assumed to be 100 barns at 0.0253 eV, and in 1/v form below 0.4 eV. Above 0.4 eV, calculated with CASTHY.
The gamma-ray strength function was estimated from Gamma-gamma = 0.040 eV and level spacing = 0.8 eV.

MT=251 Mu-L
Calculated with CASTHY.

MF=4 Angular Distributions of Secondary Neutrons
MT=2,91 Calculated with optical model.
MT=16,17,37 Isotropic in the lab system.

MF=5 Energy Distributions of Secondary Neutrons
MT=16,17,37,91 Evaporation spectra
Obtained from level density parameters.

References

1) Howerton R.J.: Nucl. Sci. Eng., 62, 438 (1977).
2) Igarasi S.: J.Nucl.Sci.Technol.,12,67 (1975).
3) Ohsawa T., Ohta M.: J. Nucl. Sci. Technol., 18, 408 (1981).
4) Ellis-Akovali Y.A.: Nuc;. Data Sheets, 50, 229 (1987).
5) Gilbert A., Cameron A.G.W.: Can. J. Phys., 43, 1446 (1965).

MAT number = 3893

89-Ac-227 TIT Eval-Aug88 N.Takagi
Dist-Sep89

History
88-08 New evaluation was made by N. Takagi (Tokyo Institute of Technology, TIT)

MF=1 General Information
MT=451 Comment and dictionary
MT=452 Number of neutrons per fission
Evaluated with semi empirical formula of Howerton/1/.

MF=2 Resonance parameters
MT=151 Resonance parameters
No resonance parameters were given.

2200-m/s cross sections and resonance integrals

	2200 m/s value	Res. Int.
Total	902.40 b	-
Elastic	12.40 b	-
Fission	0.00029 b	0.138 b
Capture	890.00 b	1650 b

MF=3 Neutron Cross Sections
MT=1 Total cross section
Below 36 eV, calculated as sum of MT's = 2, 18 and 102.
Above 36 eV, optical model calculation was made with CASTHY/2/. The potential parameters/3/ used are as follows.

V = 41.0 - 0.05*En		(MeV)
Ws= 6.4 + 0.15*SQRT(En)		(MeV)
Wv= 0	, Vso = 7.0	(MeV)
r = rso = 1.31	, rs = 1.38	(fm)
a = aso = 0.47	, b = 0.47	(fm)

MT=2 Elastic scattering cross section
Below 36 eV, the constant cross section of 12.4 barns was assumed, which was the shape elastic scattering cross section calculated with optical model. Above this energy, optical model calculation was adopted.

MT=4,51-59,91 Inelastic scattering cross sections.
Optical and statistical model calculation was made with CASTHY/2/. The level scheme was taken from Ref. 4.

No	energy(keV)	spin-parity
g.s.	0.0	3/2 -
1	27.36	3/2 +
2	29.95	5/2 -
3	46.37	5/2 +
4	74.14	7/2 -
5	84.56	7/2 +
6	110.00	9/2 +
7	126.85	9/2 -
8	187.36	11/2 -
9	210.92	13/2 +

Levels above 273 keV were assumed to be overlapping.

The level density parameters were taken from Ref. 5.

MT=16,17,37 (n,2n), (n,3n) and (n,4n) reaction cross sections
Calculated with evaporation model.

MT=18 Fission cross section
Measured thermal cross section of 0.29 milli-barn was taken from Ref. 6 , and 1/v form was assumed below 36 eV. Above fission threshold energy, experimental data/7/ were adopted, and in the energy range between 36 eV and fission threshold, cross section was assumed to be constant with the value at 36 eV.

MT=102 Capture cross section
Measured thermal cross section of 890 barns was taken from Ref. 6 , and 1/v form was assumed below 36 eV. The cross section near 36 eV was adjusted so as to reproduce the measured resonance integral/6/. Above 0.45 eV, cross section was calculated with CASTHY. The gamma-ray strength function was estimated from Gamma-gamma = 0.040 eV and level spacing = 72 eV.

MT=251 Mu-L
Calculated with CASTHY.

MF=4 Angular Distributions of Secondary Neutrons
MT=2,51-59,91 Calculated with optical model.
MT=16,17,18,37 Isotropic in the lab system.

MF=5 Energy Distributions of Secondary Neutrons
MT=16,17,37,91 Evaporation spectra
Obtained from level density parameters.

MT=18 Maxwellian fission spectrum.
Temperature was estimated from Z**2/A dependence/8/.

References
1) Howerton R.J.: Nucl. Sci. Eng., 62, 438 (1977).
2) Igarasi S.: J.Nucl.Sci.Technol.,12,67 (1975).
3) Ohsawa T., Ohta M.: J. Nucl. Sci. Technol., 18, 408 (1981).
4) Maples C.: Nucl. Data Sheets, 22, 275 (1977).
5) Gilbert A., Cameron A.G.W.: Can. J. Phys., 43, 1446 (1965).
6) Mughabghab S.F.: "Neutron Cross Sections, Vol.1, Neutron Resonance Parameters and Thermal Cross Sections , Part B, Z=61-100", Academic Press (1984).
7) Kuks I.M. et al.: Yad. Fiz. Iss., 26, 46 (1978).
8) Smith A.B. et al.: ANL/NDM-50 (1979).

MAT number = 3901

90-Th-227 TIT Eval-Aug88 N.Takagi
Dist-Sep89

History
88-08 New evaluation was made by N. Takagi (Tokyo Institute of Technology, TIT)

MF=1 General Information
MT=451 Comment and dictionary
MT=452 Number of neutrons per fission
Evaluated with semi empirical formula of Howerton/1/.

MF=2 Resonance parameters
MT=151 Resonance parameters
No resonance parameters were given.

2200-m/s cross sections and resonance integrals

	2200 m/s value	Res. Int.
Total	1749.40 b	-
Elastic	12.40 b	-
Fission	202.00 b	210 b
Capture	1535.00 b	1420 b

MF=3 Neutron Cross Sections
MT=1 Total cross section
Below 0.45 eV, calculated as sum of MT's = 2, 18 and 102. Above 0.45 eV, optical model calculation was made with CASTHY/2/. The potential parameters/3/ used are as follows,

V = 41.0 - 0.05•En		(MeV)
Ws= 6.4 + 0.15•SQRT(En)		(MeV)
Wv= 0	, Vso = 7.0	(MeV)
r = rso = 1.31	, rs = 1.38	(fm)
a = aso = 0.47	, b = 0.47	(fm)

MT=2 Elastic scattering cross section
Below 0.45 eV, the constant cross section of 12.4 barns was assumed, which was the shape elastic scattering cross section calculated with optical model. Above this energy, optical model calculation was adopted.

MT=4, 91 Inelastic scattering cross sections.
Optical and statistical model calculation was made with CASTHY/2/. No excited levels were taken into the calculation.

No	energy(keV)	spin-parity
g.s.	0.0	3/2 +

Levels above 9.3 keV/4/ were assumed to be overlapping. The level density parameters were taken from Ref. 5.

MT=16,17,37 (n,2n), (n,3n) and (n,4n) reaction cross sections
Calculated with evaporation model.

MT=18 Fission cross section
Measured thermal cross section of 202 barns was taken from Ref. 6 , and 1/v form was assumed below 0.45 eV. In the

energy range above 0.45 eV, the shape was assumed to be the same as Th-233 fission cross section and it was normalized to the systematics of Behrens and Howerton/7/.

MT=102 Capture cross section
The thermal cross section of 1535 barns was estimated from the ratio of fission and capture cross sections at 1 eV and the measured fission cross section at 0.0253 eV/6/, and the 1/v form was assumed below 0.45 eV.
Above 0.45 eV, cross section was calculated with CASTHY.
The gamma-ray strength function was estimated from Gamma-gamma = 0.040 eV and level spacing = 0.9 eV.

MT=251 Mu-L
Calculated with CASTHY.

MF=4 Angular Distributions of Secondary Neutrons
MT=2,91 Calculated with optical model.
MT=16,17,18,37 Isotropic in the lab system.

MF=5 Energy Distributions of Secondary Neutrons
MT=16,17,37,91 Evaporation spectra
Obtained from level density parameters.

MT=18 Maxwellian fission spectrum.
Temperature was estimated from Z**2/A dependence/8/.

References
1) Howerton R.J.: Nucl. Sci. Eng., 62, 438 (1977).
2) Igarasi S.: J.Nucl.Sci.Technol.,12,67 (1975).
3) Ohsawa T., Ohta M.: J. Nucl. Sci. Technol., 18, 408 (1981).
4) Maples C.: Nucl. Data Sheets, 22, 275 (1977).
5) Gilbert A., Cameron A.G.W.: Can. J. Phys., 43, 1446 (1965).
6) Mughabghab S.F.: "Neutron Cross Sections, Vol.1, Neutron Resonance Parameters and Thermal Cross Sections , Part B, Z=61-100", Academic Press (1984).
7) Behrens J.W., Howerton R.J: Nucl. Sci. Eng., 65, 464, (1978).
8) Smith A.B. et al.: ANL/NDM-50 (1979).

MAT number = 3902

90-Th-228 Kinki U. Eval-Jun87 T.Ohsawa
Dist-Sep89

History
81-04 Evaluation for JENDL-2 was made by T. Ohsawa* and M. Ohta (Kyushu University). Details of the evaluation are described in Ref. /1/. (*present address: Kinki University)
83-11 Fission spectrum was added. Resonance formula was changed to MLBW formula. The total, (n,2n) and (n,3n) cross sections were modified.
87-06 Almost of JENDL-2 data were adopted for JENDL-3. (MF3,MT17), (MF3,MT91) and (MF3,MT102) were slightly modified in high energy region.
Compilation was made by T.Nakagawa (JAERI).

MF=1 General Information
MT=451 Comments and dictionary
MT=452 Total number of neutrons emitted per fission
Calculated with the semi-empirical formula of Howerton /2/.

MF=2 Resonance Parameters
MT=151 Resolved resonances
Resonance region is below 7.798 eV. Parameters were given for the MLBW formula. Only two resonances were observed by Simpson et al. /3/. An additional term with 1/v dependence was assumed to reproduce the thermal capture cross section. Fission cross section was also assumed to have 1/v behavior.

Calculated 2200-m/s cross sections and res. integ.(barns)

	2200-m/s	Res. Integ.
Elastic	12.81	-
Capture	119.9	1170
Fission	0.300	1.02
Total	133.0	-

MF=3 Neutron Cross Sections
Below 7.798 eV is the resonance region. Background data were given. The cross sections were evaluated in the energy region above 7.798 eV as follows.
MT=1 Total cross section
Optical model calculation with the following parameters:
V = 41.0 - 0.05*E (MeV),
Ws = 6.4 + 0.15*SQRT(E) (MeV), — der. Woods-Saxon —
Vso= 7.0 (MeV),
r0 = rso = 1.31 (fm),
rs = 1.38 (fm),
a = b = aso= 0.47 (fm).
These parameters were taken from those for Th-232 /4/.
MT=2 Elastic scattering cross section
Based on statistical and optical model calculations using the code CASTHY /5/.
MT=4,51-62,91 Inelastic scattering cross section
Statistical and optical model calculations.

Level scheme of Th-228 /6/.
No. Energy(MeV) Spin-Parity

g.s.	0.0	0 +
1	0.0576	2 +
2	0.1869	4 +
3	0.328	1 -
4	0.3961	3 -
5	0.5193	5 -
6	0.8317	0 -
7	0.8746	2 +
8	0.9441	2 +
9	0.952	1 -
10	0.9688	2 +
11	1.016	3 -
12	1.0224	3 +

Levels above 1.025 MeV were assumed to be overlapping.

MT=16,17 (n,2n) and (n,3n) cross sections
Calculated by means of the evaporation model of Segev and Caner /7/.

MT=18 Fission cross section
The data of Vorotnikov et al. /8/ were adopted up to 5 MeV. The fission cross section of the neighboring even-even isotope Th-230 normalized to join smoothly to the data of Vorotnikov et al. was adopted above 5 MeV.

MT=102 Capture cross section
Statistical and optical model calculations with gamma-ray strength function of 0.00791.

MT=251 Mu-bar
Calculated with optical model.

MF=4 Angular Distributions of Secondary Neutrons

MT=2,51-62,91
Statistical and optical model calculations.

MT=16,17,18
Assumed to be isotropic in the laboratory system.

MF=5 Energy Distributions of Secondary Neutrons

MT=16,17,91
Evaporation spectra

MT=18
Fission spectrum estimated from Z**2/A systematics by Smith et al. /9/.

References

1) Ohsawa T. and Ohta M.: Memoirs Faculty of Engineering, Kyushu Univ. 40, 149 (1980).
2) Howerton R.J.: Nucl. Sci. Eng. 62, 438 (1977).
3) Simpson O.D. et al.: ibid. 29, 423 (1967).
4) Ohsawa T. and Ohta M.: J. Nucl. Sci. Technol. 18, 408 (1981).
5) Igarasi S.: ibid. 12, 67 (1975).
6) Lederer C.M. and Shirly V.S. (Ed.): Table of Isotopes, 7th Edition (1978).
7) Segev M. and Caner M.: Ann. Nucl. Energy 5, 239 (1978).
8) Vorotnikov et al.: Sov. J. Nucl. Phys. 16, 505 (1973).
9) Smith A.B. et al.: ANL/NDM-50 (1979).

MAT number = 3903

90-Th-229 TIT Eval-Aug88 N.Takagi
Dist-Sep89

History
87-08 New evaluation was made by N. Takagi (Tokyo Institute of Technology, TIT)

MF=1 General Information
MT=451 Comment and dictionary
MT=452 Number of neutrons per fission
Evaluated with semi empirical formula of Howerton/1/.

MF=2 Resonance parameters
MT=151 Resolved resonance parameters : 1.0E-5 eV to 9.5 eV
Single-level Breit Wigner formula was adopted. Parameters were determined on the basis of recommendation of Mugabghab /2/. For the levels whose radiative width and/or fission width were unknown, average gamma-g of 0.043 eV was assumed, fission widths were calculated from (peak sig)•(gamma-f). Effective scattering radius was assumed to be 10 fm.

2200-m/s cross sections and resonance integrals

	2200 m/s value	Res. Int.
Total	104.09 b	-
Elastic	9.928 b	-
Fission	30.81 b	444 b
Capture	63.34 b	1236 b

MF=3 Neutron Cross Sections
MT=1 Total cross section
Above 9.5 eV, optical model calculation was made with CASTHY/3/. The potential parameters/4/ used are as follows,

V = 41.0 - 0.05•En		(MeV)
Ws= 6.4 + 0.15•SQRT(En)		(MeV)
Wv= 0	, Vso = 7.0	(MeV)
r = rso = 1.31	, rs = 1.38	(fm)
a = aso = 0.47	, b = 0.47	(fm)

MT=2 Elastic scattering cross section
Optical model calculation was adopted.

MT=4,51-54,91 Inelastic scattering cross sections.
Optical and statistical mode lcalculation was made with CASTHY/3/. The level scheme was taken from Ref. 5.

No	energy(keV)	spin-parity
g.s.	0.0	5/2 +
1	0.1	3/2 +
2	20.0	3/2 +
3	29.2	5/2 +
4	42.5	7/2 +

Levels above 67 keV were assumed to be overlapping.
The level density parameters were taken from Ref.6.

MT=16,17,37 (n,2n), (n,3n) and (n,4n) reaction cross sections
Calculated with evaporation model.

MT=18 Fission cross section
Above 9.5 eV, the cross-section shape was assumed to be the same as Th-233 fission cross section and it was normalized by the factor obtained from systematics of Behrens and Howerton/7/.

MT=102 Capture cross section
Calculated with CASTHY. The gamma-ray strength function was estimated from Gamma-g = 0.040 eV and level spacing = 0.53 eV.

MT=251 Mu-L
Calculated with CASTHY.

MF=4 Angular Distributions of Secondary Neutrons

MT=2,51-54,91	Calculated with optical model.
MT=16,17,18,37	Isotropic in the lab system.

MF=5 Energy Distributions of Secondary Neutrons

MT=16,17,37	Evaporation spectra were given
MT=18	Maxwellian fission spectrum. Temperature was estimated from Z**2/A values /8/.

References

1) Howerton R.J.: Nucl. Sci. Eng., 62, 438 (1977).
2) Mughabhab S.F.: "Neutron Cross Sections, Vol.1, Neutron Resonance Parameters and Thermal Cross Sections , Part B, Z=61-100", Academic Press (1984).
3) Igarasi S.: J. Nucl. Sci. Technol., 12, 67 (1975).
4) Ohsawa T. and Ohta M.: J. Nucl. Sci. Technol., 18, 408 (1981).
5) Toth K.S.: Nucl. Data Sheets, 24, 263 (1978).
6) Gilbert A., Cameron A.G.W.: Can. J. Phys., 43, 1446 (1965).
7) Behrens J.W. and Howerton R.J: Nucl. Sci. Eng., 65, 464, (1978).
8) Smith A.B. et al. : ANL/NDM-50 (1979).

MAT number = 3904

90-Th-230 Kinki U. Eval-Jul87 T.Ohsawa
Dist-Sep89

History

81-04 Evaluation for JENDL-2 was made by T. Ohsawa and M. Ohta (Kyushu University: present address of Ohsawa is Kinki University). Details of evaluation are described in Ref. /1/.

83-11 Fission spectrum was added. Resonance parameters, and total, (n,2n) and (n,3n) cross sections were modified.

87-07 Evaluation for JENDL-2 was adopted to JENDL-3. But re-calculation of cross sections and angular distributions was made with the same OMP and level density parameters.

Compilation was made by T.Nakagawa (JAERI).

MF=1 General Information

MT=451 Comments and Dictionary

MT=452 Total number of neutrons emitted per fission
Calculated with the semi-empirical formula of Howerton /2/.

MF=2 Resonance Parameters

MT=151 Resolved resonances
Resonance region is below 564.26 eV. The MLBW formula was selected to reproduce resonance cross sections. A total number of 28 resonances up to 583 eV measured by Kalebin et al. /3/ were adopted in the present evaluation.
A background term with 1/v dependence was added in order to reproduce the thermal capture cross section.

Calculated 2200-m/s cross sections and res. integ.(barns)

	2200-m/s	Res. Integ.
total	32.32	-
elastic	9.774	-
fission	0.0	1.08
capture	22.55	1040

MF=3 Neutron Cross Sections
Below 564.26 eV is the resonance region where the background cross sections are given. Above 564.26 eV, the cross sections were evaluated as follows.

MT=1 Total cross section
Optical model calculation with the following parameters:

```
V   = 41.0 - 0.05*E          (MeV),
Ws  = 6.4 + 0.15*SQRT(E)     (MeV),  -- der. Woods-Saxon --
Vso= 7.0                     (MeV),
r0 = rso = 1.31              (fm),
rs = 1.38                    (fm),
a  = b  = aso= 0.47          (fm).
```

These parameters were taken from those for Th-232 /4/.

MT=2 Elastic scattering cross section
Statistical and optical model calculations using the code CASTHY /5/.

MT=4,51-63,91 Inelastic scattering cross section
Statistical and optical model calculations.

Level scheme of Th-230 /6/.

No.	Energy(MeV)	Spin-Parity
g.s.	0.0	0 +
1	0.0534	2 +
2	0.173	4 +
3	0.357	6 +
4	0.506	1 -
5	0.571	3 -
6	0.635	0 +
7	0.678	2 +
8	0.682	5 -
9	0.781	2 +
10	0.881	4 +
11	0.951	1 -
12	1.009	2 +
13	1.012	3 -

Levels above 1.02 MeV were assumed to be overlapping.

MT=16,17 (n,2n) and (n,3n) cross sections
Calculated by means of the evaporation model of Segev and Caner /7/.

MT=18 Fission cross section
Evaluation was made on the basis of the data of Muir et al. /8/ up to 2 MeV. Above 2 MeV, the fission probability data of Back et al. /9/ were used to calculate the fission cross section.

MT=102 Capture cross section
Statistical and optical model calculations with gamma-ray strength function of 0.00791.

MT=251 Mu-bar
Calculated with CASTHY.

MF=4 Angular Distributions of Secondary Neutrons

MT=2,51-63,91
Statistical and optical model calculations.

MT=16,17,18
Assumed to be isotropic in the laboratory system.

MF=5 Energy Distributions of Secondary Neutrons

MT=16,17,91
Evaporation spectra.

MT=18
Fission spectrum estimated from Z**2/A systematics by Smith et al. /10/.

References

1) Ohsawa T. and Ohta M.: Memoirs Faculty of Engineering, Kyushu Univ. 40, 149 (1980).
2) Howerton R.J.: Nucl. Sci. Eng. 62, 438 (1977).
3) Kalebin S.M. et al.: Sov. J. Atom. Energy 26, 588 (1969).
4) Ohsawa T. and Ohta M.: J. Nucl. Sci. Technol. 18, 408 (1981).
5) Igarasi S.: ibid. 12, 67 (1975).
6) Lederer C.M. and Shirly V.S. (Ed.): Table of Isotopes, 7th Edition (1978).
7) Segev M. and Caner M.: Ann. Nucl. Energy 5, 239(1978).
8) Muir D.W. et al.: Proc. 3rd Conf. on Neutron Cross Sections and Technology, Knoxviile (1971), p.292.

9) Back B.B. et al.: Phys. Rev. C13, 2374 (1974).
10) Smith A.B. et al.: ANL/NDM-50 (1979).

MAT number = 3905

```
 90-Th-232 Kinki U.    Eval-Mar87 T.Ohsawa
                       Dist-Sep89
History
87-03 Re-valuation was made by T. Ohsawa (Kinki University).
      The following parts of previous evaluation /1/ were revised
      with new one.
           resonance parameters, elastic and inelastic scattering,
           Nu-p, Nu-d, energy distributions of neutrons.
88-09 Fission cross section was modified a little.
89-02 Fission product yields (MF=8) were replaced with JNDC FP
      Decay File version-2.
89-04 Fission spectrum was modified.
The compilation was made by T. Nakagawa(JAERI).

MF=1  General Information
  MT=451  Descriptive data and dictionary
  MT=452  Number of Neutrons per Fission
      Sum of prompt and delayed neutrons.
  MT=455  Delayed Neutrons per Fission
      Nu-d based on Tuttle's recommendation /2/.
  MT=456  Prompt Neutrons per Fission
      Taken from Davey's recommendation /3/.

MF=2  Resonance Parameters
  MT=151  Resolved and Unresolved Resonance Parameters
   Resolved resonances for MLBW formula : 1.0E-5 eV - 3.5 keV
      The parameters of JENDL-2 which were mainly based on Ref.4
      and BNL 325(3rd) were modified as follows:
      (1) For 22 resonances in the lower energy region which make
          major contribution to the resonance integral, the new
          parameters of Kobayashi /5/ were adopted;
      (2) The average radiative width of 24.7 meV were attributed
          to those resonances for which the radiative width was
          not known.
   Unresolved resonances : 3.5 keV - 50 keV
      Average resonance parameters were given.  The energy
      dependent S0 and S1 were calculated so as to reproduce the
      total and capture cross sections in this region.
      Fixed parameters :
        GG = 0.0212 eV, D-obs = 18.64 eV, R = 10.01 fm.
      Typical strength functions at 10 keV :
        S0 = 0.93E-4, S1 = 1.96E-4

   Calculated 2200-m/sec cross sections and resonance integrals
```

	2200 m/sec	Res. integ.
total	21.11 b	----
elastic	13.70 b	----
fission	0.0 b	0.636 b
capture	7.40 b	84.4 b

```
MF=3  Neutron Cross Sections
 Below 3.5 keV :
      Background cross section is given for the capture.
 Above 50 keV :
```

MT=1 Total
Based on the experimental data of Whalen/6/, Foster /7/ and Fasoli/8/ in the size resonance region, and Kobayashi/9/, Whalen/6/ and Uttley/10,11/ below 1.5 MeV, and optical model calculation above 14 MeV.
MT=2 Elastic Scattering
Obtained by subtracting the sum of capture, inelastic, fission, (n,2n), (n,3n) cross sections from the total cross section.
MT=4 Total Inelastic Scattering Cross Section
Sum of partial inelastic scattering cross sections.
MT=16 (n,2n)
Calculated with the model of Segev et al./12/.
MT=17 (n,3n)
Calculated with the model of Segev et al./12/.
MT=18 Fission
The ratio data Th-232/U-235 of Behrens/13/ were multiplied with the evaluated data/14/ of U-235(n,f).
MT=51-52 Inelastic scattering to the 1st and 2nd levels.
Calculated with consistent combination of coupled-channel (CC) and Hauser-Feshbach(HF) methods (CC/HF method)/15/. The code JUPITOR-1/16/ was used for CC-calculations, ELIESE-3/17/ for the HF-calculations.
MT=55,59,62,66 Inelastic scattering to the 5th, 9th, 12th and 16th levels.
Compound nuclear component was calculated with the code ELIESE-3 using the generalized transmission coefficients calculated with JUPITOR-1 for the entrance channel. Direct reaction component was calculated with the code DWUCK/18/.
MT=53,54,56-58,60,61,63-65,67-70,91 Inelastic scattering to the other discrete and continuum levels.
Calculated with ELIESE-3 using the generalized transmission coefficients for the entrance channel.
MT=102 Capture
Based on the measurement of Kobayashi/19/ and calculation with the code CASTHY/20/.

The parameters for the CC and spherical optical potentials were taken from Haouat et al./21/ and Ohsawa et al./22/, respectively:

CC	SOM	
V = 46.4-0.3•En	V = 41.0-0.05•En	(MeV)
Ws = 3.6+0.4•En	Ws = 6.4+0.15•SQRT(En)	(MeV)
Vso= 6.2	Vso= 7.0	(MeV)
r = 1.26	r = 1.31	(fm)
rs = 1.26	rs = 1.38	(fm)
rso= 1.12	rso= 1.31	(fm)
a = 0.63	a = 0.47	(fm)
as = 0.52	as = 0.47	(fm)
aso= 0.47	aso= 0.47	(fm)
beta2=0.190		
beta4=0.071		

The level scheme was taken from Ref./23/.

No.	Energy(MeV)	Spin-Parity
gs	0	0+
1	0.049	2+

2	0.162	4+
3	0.333	6+
4	0.557	8+
5	0.714	1−
6	0.730	0+
7	0.7741	2+
8	0.7743	3−
9	0.785	2+
10	0.830	3−
11	0.873	4+
12	0.883	5−
13	0.889	4+
14	0.960	5+
15	1.054	2−
16	1.073	2+
17	1.0777	1−
18	1.078	0+
19	1.094	3+
20	1.105	3−

Continuum levels were assumed above 1.110MeV.
The level density parameters of Gilbert and Cameron/24/ were used.

MT=251 Mu-bar
Calculated with the optical model.

MF=4 Angular Distributions of Secondary Neutrons
MT=2 Elastic scattering
Calculated with CC/HF method/15/.
MT=51-70 Inelastic
Calculated with CC/HF method/15/ and DWBA/18/.
MT=16,17,18,91 (n,2n), (n,3n), fission and continuum inelastic
Assumed to be isotropic in the LAB system.

MF=5 Energy Distributions of Secondary Neutrons
MT=16,17,91 (n,2n), (n,3n) and continuum inelastic
Calculated with PEGASUS/25/.
MT=18 Fission
Maxwell spectrum. The temperature parameters were estimate from the systematics of Howerton-Doyas/26/.
MT=455 Delayed Neutrons
The evaluation by Saphier et al./27/ was adopted.

MF=8 Fission Product Yield Data
MT=454 Independent Yields
Taken from JNDC FP Decay File version-2/28/.
MT=459 Cumulative Yields
Taken from JNDC FP Decay File version-2/28/.

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MAT number = 3906

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 90-Th-233 Kinki U.    Eval-Jul87 T.Ohsawa
                       Dist-Sep89
History
81-04 Evaluation for JENDL-2 was made by T. Ohsawa and M. Ohta
      (Kyushu University: present address of Ohsawa is Kinki
      Univ.). Details of the evaluation are described in Ref.
      /1/.
83-11 Fission spectrum was added.  The total, (n,2n) and (n,3n)
      cross sections were modified.
87-07 JENDL-2 data were adopted for JENDL-3.
Compilation was made by T.Nakagawa (JAERI).

MF=1  General Information
  MT=451  Comments and dictionary
  MT=452  Total number of neutrons emitted per fission
      Calculated with the semi-empirical formula of Howerton /2/.

MF=2  Resonance Parameters
  MT=151  Resolved resonances
      No resolved resonances were adopted, since there were no
      measurements made.  Capture and fission cross sections at
      0.0253 eV were extrapolated up to 200 eV by assuming the
      form of 1/v for the former, and up to 20 keV by assuming
      the form of 1/v plus the constant value of 0.3 barns for the
      latter.

      Calculated 2200-m/s cross sections and res. integ.(barns)
                           2200-m/s      Res. Integ.
              total        1478.0           -
              elastic        13.0           -
              fission        15.0          11.1
              capture      1450.0         643

MF=3  Neutron Cross Sections
  MT=1     Total cross section
      Optical model calculation with the following parameters:
         V  = 41.0 - 0.05*E        (MeV),
         Ws = 6.4 + 0.15*SQRT(E)  (MeV),  -- der. Woods-Saxon --
         Vso= 7.0                 (MeV),
         r0 = rso = 1.31          (fm),
         rs = 1.38                (fm),
         a  = b  = aso= 0.47      (fm).
      These parameters were taken from those for Th-232 /3/.
  MT=2     Elastic scattering cross section
      Statistical and optical model calculations using the code
      CASTHY /4/.
  MT=4,51-65,91  Inelastic scattering cross section
      Statistical and optical model calculations.

        Level scheme of Th-233 /5/.
          No.      Energy(MeV)  Spin-Parity
           g.s.     0.0           1/2 +
           1        0.01687       3/2 +
           2        0.05456       5/2 +
           3        0.09363       7/2 +
```

4	0.37121	5/2 +
5	0.53958	1/2 −
6	0.58393	1/2 +
7	0.6115	3/2 +
8	0.62902	5/2 +
9	0.6822	3/2 −
10	0.7135	1/2 +
11	0.7218	3/2 +
12	0.7695	5/2 +
13	0.8145	3/2 +
14	0.8914	3/2 +
15	0.9476	3/2 −

Levels above 0.95 MeV were assumed to be overlapping.

MT=16,17 (n,2n) and (n,3n) cross sections
Calculated by means of the evaporation model of Segev and Caner /6/.

MT=18 Fission cross section
Fission probability deduced from direct reaction /7, 8/ was used to calculate the fission cross section.

MT=102 Capture cross section
Statistical and optical model calculations with gamma-ray strength function of 0.00352.

MT=251 Mu-bar
Calculated with optical model.

MF=4 Angular Distributions of Secondary Neutrons

MT=2,51-65,91
Statistical and optical model calculations.

MT=16,17,18
Assumed to be isotropic in the laboratory system.

MF=5 Energy Distributions of Secondary Neutrons

MT=16,17,91
Evaporation spectra.

MT=18
Fission spectrum estimated from Z**2/A systematics of Smith et al. /9/

References

1) Ohsawa T. and Ohta M.: Memoirs Faculty of Engineering, Kyushu Univ. 40, 149 (1980).
2) Howerton R.J.: Nucl. Sci. Eng. 62, 438 (1977).
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MAT number = 3907

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 90-Th-234 Kinki U.    Eval-Jul87 T.Ohsawa
                       Dist-Sep89
History
81-04 Evaluation for JENDL-2 was made by T. Ohsawa and M. Ohta
      (Kyushu University: present address of Ohsawa is Kinki
      Univ.).  Details of the evaluation are described in Ref.
      /1/.
83-11 Fission spectrum was given.  The total, (n,2n) and (n,3n)
      cross sections were modified.
87-07 JENDL-2 data were adopted for JENDL-3.
Compilation was made by T.Nakagawa(JAERI).

MF=1  General Information
  MT=451  Comments and dictionary
  MT=452  Total number of neutrons emitted per fission
     Calculated with the semi-empirical formula of Howerton /2/.

MF=2  Resonance Parameters
  MT=151  Resolved resonances
     No resolved resonances were adopted, since there were no
     measurements made.  Capture and fission cross sections at
     0.0253 ev were extrapolated on an 1/v basis up to an energy
     of 15 eV.

     Calculated 2200-m/s cross sections and res. integ.(barns)
                        2200-m/s        Res. Integ.
           total         14.75             -
           elastic       13.0              -
           fission        0.0             0.26
           capture        1.75            93.7

MF=3  Neutron Cross Sections
  MT=1     Total cross section
     Optical model calculation with the following parameters:
        V  = 41.0 - 0.05*E       (MeV),
        Ws = 6.4 + 0.15*SQRT(E) (MeV),  -- der. Woods-Saxon --
        Vso= 7.0                 (MeV),
        r0 = rso = 1.31          (fm),
        rs = 1.38                (fm),
        a  = b  = aso= 0.47      (fm).
     These parameters were taken from those for Th-232 /3/.
  MT=2     Elastic scattering cross section
     Statistical and optical model calculations using the code
     CASTHY /4/.
  MT=4,51-67,91  Inelastic scattering cross section
     Statistical and optical model calculations.

        Level scheme of Th-234 (estimated from systematics)
           No.        Energy(MeV)  Spin-Parity
            g.s.       0.0            0 +
            1          0.048          2 +
            2          0.160          4 +
            3          0.336          6 +
            4          0.576          8 +
            5          0.730          0 +
```

6	0.767	2 +
7	0.785	2 +
8	0.853	4 +
9	0.882	1 -
10	0.889	4 +
11	0.942	3 -
12	0.987	6 +
13	1.050	5 -
14	1.053	6 +
15	1.073	8 +
16	1.206	7 +
17	1.277	8 +

Levels above 1.06 MeV were assumed to be overlapping.

MT=16,17 (n,2n) and (n,3n) cross sections
Calculated by means of the evaporation model of Segev and Caner /5/.

MT=18 Fission cross section
Fission probability deduced from direct reaction /6/ and systematics of Behrens /7/ were used to obtain fission cross section.

MT=102 Capture cross section
Statistical and optical model calculations with gamma-ray strength function of 0.00791.

MT=251 Mu-bar
Calculated with optical model.

MF=4 Angular Distributions of Secondary Neutrons

MT=2,51-67,91
Statistical and optical model calculations.

MT=16,17,18
Assumed to be isotropic in the laboratory system.

MF=5 Energy Distributions of Secondary Neutrons

MT=16,17,91
Evaporation spectra were given.

MT=18
Fission spectrum was estimated from Z**2/A systematics of Smith et al. /8/.

References

1) Ohsawa T. and Ohta M.: Memoirs Faculty of Engineering, Kyushu Univ. 40, 149 (1980).
2) Howerton R.J.: Nucl. Sci. Eng. 62, 438 (1977).
3) Ohsawa T. and Ohta M.: J. Nucl. Sci. Technol. 18, 408 (1981).
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MAT number = 3911

91-Pa-231 Kinki U.+ Eval-Mar87 T.Ohsawa, M.Inoue and T.Nakagawa
Dist-Sep89

History
87-03 New evaluation was performed for JENDL-3 by T. Ohsawa and M. Inoue.
87-07 Resonance parameters were evaluated by T.Nakagawa(JAERI).
88-07 Unresolved resonance region was modified.
Compilation was made by T.Nakagawa.

MF=1 General Information
MT=451 Descriptive data and dictionary
MT=452 Number of neutrons per fission
Sum of MT's = 455 and 456.
MT=455 Delayed neutrons
Decay consts were assumed to be same as Thorium.
Nu-d was evaluated on the basis of Tuttle's recommendation/1/.
MT=456 Number of prompt neutrons per fission
Based on the Bois-Frehaut's semi-empirical formula /2/.

MF=2, MT=151 Resonance Parameters
Resolved resonances for SLBW formula: 1.0-5 - 115 eV
Neutron and radiative widths were mainly adopted from Hussein et al./3/, and fission width estimated from the data of fission area measured by Platterd et al. /4/. For the resonances whose fission area was not measured, an average value of 40 micro-eV was assumed. A negative resonance was given on the basis of recommendation by Mughabghab /5/ to reproduce recommended thermal cross sections /5/.
Unresolved resonances : 115 eV - 40 keV
Parameters were based on the average values obtained from the resolved resonance parameters. S1 was determined from the optical model calculation. Scattering radius was adjusted so as to reproduce elastic scattering at 40 keV.
S0 = 0.90E-4, S1 = 1.2E-4, D-obs = 0.47eV,
Radiative width = 0.040 eV, R = 9.05 fm
Background cross section was given to the capture cross section to connect smoothly to that in high energy region.

Calculated 2200-m/s cross sections and resonance integrals

	2200 m/s	resonance integrals
total	210.69 b	-
elastic	9.954	-
fission	0.0196	4.61 b
capture	200.72	596 b

MF=3 Neutron Cross Sections
Cross sections were represented with resonance parameters below 40 keV. Above this energy, cross sections were evaluated as follows.

MT=1 Total cross section
Calculated with the coupled-channel(CC) model code JUPITOR-1/6/. The potential parameters used for the CC-

calculations are given below.

MT=2 Elastic scattering
Obtained by subtracting the sum of capture, inelastic, fission, (n,2n) and (n,3n) reaction cross sections from the total cross section.

MT=16 (n,2n)
Calculated with the model of Segev et al./7/.

MT=17 (n,3n)
Calculated with the model of Segev et al./7/.

MT=18 Fission
Based on the experimental data of Plattard/4/ below 12 MeV. Above 12 MeV, the evaluation of Mann/9/ was adopted after appropriate renormalization.

MT=53,63 Inelastic scattering to the 3rd and 13th excited levels(members of the ground state rotational band).
Calculated with the consistent combination of CC and Hauser-Feshbach(HF) methods (CC/HF method)/9/. The code JUPITOR-1 was used for the CC calculations, and ELIESE-3 /10/ for the HF calculations.

MT=51-52,54-62,64-70,91 Inelastic scattering to the other discrete and continuum levels.
Compound nuclear component was calculated with the code ELIESE-3 using the generalized transmission coefficients calculated with JUPITOR-1 for the entrance channel. The level density parameters were taken from Gilbert-Cameron /11/.

MT=102 Capture
Calculated with the code CASTHY/12/. The average radiative width and level spacing used to normalize the calculation are 40 meV and 0.47 eV, respectively/3/.

The parameters for the CC and spherical optical potentials were taken from Haouat et al./13/ and Ohsawa et al./14/ respectively.

CC	SOM	
V = 46.4-0.3•En	V = 41.0-0.05•En	(MeV)
Ws = 3.6+0.4•En	Ws = 6.4+0.15•SQRT(En)	(MeV)
Vso= 6.2	Vso= 7.0	(MeV)
r = 1.26	r = 1.31	(fm)
rs = 1.26	rs = 1.38	(fm)
rso= 1.12	rso= 1.31	(fm)
a = 0.63	a = 0.47	(fm)
as = 0.52	as = 0.52	(fm)
aso= 0.47	aso= 0.47	(fm)
beta2=0.190	—	
beta4=0.071	—	

The level scheme was taken from Nuclear Data Sheets/15/.

No.	Energy(MeV)	Spin-Parity
gs	0.0	3/2-

1	0.0093	1/2-
2	0.0585	7/2-
3	0.0778	5/2-
4	0.0842	5/2+
5	0.1013	7/2+
6	0.1029	3/2+
7	0.1116	9/2+
8	0.1340	11/2+
9	0.1693	11/2-
10	0.1741	5/2-
11	0.1835	5/2+
12	0.189	13/2+
13	0.2183	7/2-
14	0.2473	7/2+
15	0.2720	9/2-
16	0.287	1/2+
17	0.3179	3/2+
18	0.3202	3/2-
19	0.3400	11/2-
20	0.3518	5/2-

Continuum levels were assumed above 0.38 MeV. The level density parameters were taken from Gilbert-Cameron/11/.

MT=251 Mu-bar
Calculated with the optical model.

MF=4 Angular Distribution of Secondary Neutrons

MT=2 Elastic scattering
Calculated with the CC/HF method.

MT=51-70 Inelastic scattering
Calculated with the CC/HF method for the 3rd and 13th excited levels. For the other levels, calculations with ELIESE-3 using the generalized transmission coefficients for the entrance channel were adopted, and isotropic distributions were assumed above 5.0 MeV because of zero cross sections.

MT=91 Inelastic scattering to the continuum
Isotropic distributions in Lab. system was assumed.

MF=5 Energy Distributions of Secondary Neutrons

MT=16,17,91 (n,2n), (n,3n) and continuum inelastic
Evaporation spectra.

MT=18 Fission
Maxwell spectrum (taken from ENDF/B-V).

References
1) Tuttle, R.J.: INDC(NDS)-107/G (1979).
2) Bois, R. and Frehaut, J.: CEA-R-4791 (1976).
3) Hussein, A. et al.: Nucl. Sci. Eng., 78, 370 (1981).
4) Plattard, S. et al.: 79 Knoxville, p.491
5) Mughabghab, S.F.: "Neutron Cross Sections", vol. 1, part B, Academic Press (1984).

6) Tamura,T.: Rev. Mod. Phys. 37, 679 (1965).
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8) Mann, F.M.: HEDL-THE-78-100 (1979).
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11) Gilbert, M. and Cameron, A.G.W.: Can. J. Phys., 43, 1446 (1966).
12) Igarasi, S.: J. Nucl. Sci. Technol.,12, 67 (1975).
13) Haouat, G. et al.: ibid. 81, 419 (1982).
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15) Schmorak, M.R.: Nucl. Data Sheets 21, 91 (1977).

MAT number = 3912

```
 91-Pa-232 TIT          Eval-Aug88 N.Takagi
                        Dist-Sep89
History
88-08 New evaluation was made by N. Takagi (Tokyo Institute of
      Technology, TIT)

MF=1  General Information
  MT=451   Comment and dictionary
  MT=452   Number of neutrons per fission
            Evaluated with semi empirical formula of Howerton/1/.

MF=2  Resonance parameters
  MT=151   Resonance parameters
    No resonance parameters were given.

  2200-m/s cross sections and resonance integrals
                      2200 m/s value      Res. Int.
       Total            1176.23  b           -
       Elastic            12.23  b           -
       Fission           700.00  b          313 b
       Capture           464.00  b          309 b

MF=3  Neutron Cross Sections
  MT=1  Total cross section
        Below 1 eV, calculated as sum of MT's = 2, 18 and 102.
        Above 1 eV, optical model calculation was made with
        CASTHY/2/.  The potential parameters/3/ used are as
        follows,
           V = 41.0 - 0.05*En                          (MeV)
           Ws= 6.4 + 0.15*SQRT(En)                     (MeV)
           Wv= 0               , Vso = 7.0             (MeV)
           r = rso = 1.31      , rs = 1.38              (fm)
           a = aso = 0.47      , b  = 0.47              (fm)

  MT=2  Elastic scattering cross section
        Below 1 eV, assumed to be the same as shape elastic
        scattering cross section calculated with the optical
        model.  Above 1 eV, optical model calculation was
        adopted.

  MT=4, 91  Inelastic scattering cross sections.
        Optical and statistical model calculation was made with
        CASTHY/2/.  No excited levels were recommended in Ref. 4.
                  No          energy(keV)   spin-parity
                 g.s.             0.0          2 -
        Levels above 50 keV were assumed to be overlapping.
        The level density parameters were taken from Ref. 5.

  MT=16,17,37  (n,2n), (n,3n) and (n,4n) reaction cross sections
        Calculated with evaporation model.

  MT=18  Fission cross section
        Measured thermal cross section of 700 barns was taken from
        Ref. 6 , and 1/v form was assumed below 1 eV.  For
        energies above 1 eV, the shape was assumed to be the same
```

as U-233 fission cross section and normalized to the systematics by Behrens and Howerton/7/.

MT=102 Capture cross section

Measured thermal cross section of 464 barns was taken from Ref. 6 , and 1/v form was assumed below 1 eV. The cross section shape near 1 eV was adjusted so as to reproduce the resonance integral/6/. Above 1 eV, calculated with CASTHY. The gamma-ray strength function was estimated from Gamma-gamma = 0.040 eV and level spacing = 0.417 eV.

MT=251 Mu-L

Calculated with CASTHY.

MF=4 Angular Distributions of Secondary Neutrons

MT=2,91 Calculated with optical model.

MT=16,17,18,37 Isotropic in the lab system.

MF=5 Energy Distributions of Secondary Neutrons

MT=16,17,37,91 Evaporation spectra

Obtained from level density parameters.

MT=18 Maxwellian fission spectrum.

Temperature was estimated from Z**2/A dependence/8/.

References

1) Howerton R.J.: Nucl. Sci. Eng., 62, 438 (1977).
2) Igarasi S.: J.Nucl.Sci.Technol.,12,67 (1975).
3) Ohsawa T., Ohta M.: J. Nucl. Sci. Technol., 18, 408 (1981).
4) Schmorax M.R.: Nucl. Data Sheets, 36, 367 (1982).
5) Gilbert A., Cameron A.G.W.: Can. J. Phys., 43, 1446 (1965).
6) Mughabghab S.F.: "Neutron Cross Sections, Vol.1, Neutron Resonance Parameters and Thermal Cross Sections , Part B, Z=61-100", Academic Press (1984).
7) Behrens J.W., Howerton R.J: Nucl. Sci. Eng., 65, 464, (1978).
8) Smith A.B. et al.: ANL/NDM-50 (1979).

MAT number = 3913

91-Pa-233 Kinki U.+ Eval-Mar87 T.Ohsawa, M.Inoue and T.Nakagawa
Dist-Sep89

History
87-03 Re-evaluation was performed for JENDL-3 by T. Ohsawa, M. Inoue (Kyushu University) and T.Nakagawa(JAERI)
Compilation was made by T.Nakagawa.

MF=1 General Information
MT=451 Descriptive data and dictionary
MT=452 Number of neutrons per fission
Sum of Nu-p (MT=456) and Nu-d (MT=455)
MT=455 Number of delayed neutrons
Taken from Tuttle's semi-empirical formula /1/. Energy dependence was ignored.
MT=456 Number of prompt neutrons
Based on the semi-empirical formula by Bois and Frehaut /2/.

MF=2, MT=151 Resonance Parameters
Resolved resonances for SLBW formula: from 1.0E-5 to 16.5 eV
Parameters were taken from the recommendation by Mughabghab /3/ and modified to reproduce thermal cross sections and resonance integral of capture/3/.
Unresolved resonance parameters: from 16.5 eV to 40 keV
Average resonance parameters recommended by Mughabghab /3/ were adopted.
S0 = 0.75E-4, S1 = 1.5E-4, D-obs = 0.59 eV,
gamma width = 0.047 eV
(S1 was adjusted with ASREP/5/ so as to reproduce total and capture cross sections around 20 keV.)

Calculated 2200-m/s cross sections and resonance integrals

	2200-m/s	res. integ.
total	53.051 B	
elastic	13.021	
fission	0.0	2.1 b
capture	40.031	864

MF=3 Neutron Cross Sections
Below 40 keV, the resonance parameters were given. Above 40 keV, cross sections were evaluated as follows.

MT=1 Total cross section
Calculated with the coupled-channel(CC) model code JUPITOR-1/5/. The potential parameters used for the CC-calculations are given below.

MT=2 Elastic scattering
Obtained by subtracting the sum of capture, inelastic, fission, (n,2n) and (n,3n) reaction cross sections from the total cross section.

MT=16 (n,2n)
Calculated with the model of Segev et al./6/.

MT=17 (n,3n)
Calculated with the model of Segev et al./6/.

MT=18 Fission
Calculated using the experimental data on the fission probability/7/.

MT=53,66 Inelastic scattering to the 3rd and 16th excited levels(members of the ground state rotational band).
Calculated with the consistent combination of CC and Hauser-Feshbach(HF) methods (CC/HF method)/8/. The code JUPITOR-1 was used for the CC calculations, and ELIESE-3 /9/ for the HF calculations.

MT=51-52,54-65,67-70,91 Inelastic scattering to the other discrete and continuum levels.
Compound nuclear component was calculated with the code ELIESE-3 using the generalized transmission coefficients calculated with JUPITOR-1 for the entrance channel. The level density parameters were taken from Gilbert-Cameron /10/.

MT=102 Capture
Calculated with the code CASTHY/11/. The average radiative width and level spacing used to normalize the calculation are 40 meV and 0.79 eV, respectively/12/.

The parameters for the CC and spherical optical potentials were taken from Haouat et al./13/ and Ohsawa et al./14/ respectively.

CC	SOM	
V = 46.4-0.3•En	V = 41.0-0.05•En	(MeV)
Ws = 3.6+0.4•En	Ws = 6.4+0.15•SQRT(En)	(MeV)
Vso= 6.2	Vso= 7.0	(MeV)
r = 1.26	r = 1.31	(fm)
rs = 1.26	rs = 1.38	(fm)
rso= 1.12	rso= 1.31	(fm)
a = 0.63	a = 0.47	(fm)
as = 0.52	as = 0.52	(fm)
aso= 0.47	aso= 0.47	(fm)
beta2=0.190	---	
beta4=0.071	---	

The level scheme was taken from Nuclear Data Sheets/15/, except the 300.4 keV-level, for which 7/2- was adopted instead of 7/2+ according to the suggestion of Gonzalez/16/.

No.	Energy(MeV)	Spin-Parity
gs	0.0	3/2-
1	0.0067	1/2-
2	0.0572	7/2-
3	0.0706	5/2-
4	0.0865	5/2+
5	0.0947	3/2+
6	0.1036	7/2+
7	0.1090	9/2+
8	0.1634	11/2+
9	0.1691	1/2+

10	0.1792	9/2-
11	0.2017	3/2+
12	0.2123	5/2+
13	0.2379	9/2+
14	0.2573	5/2-
15	0.2796	7/2+
16	0.3004	7/2-
17	0.3061	7/2+
18	0.3661	9/2+
19	0.4477	3/2-
20	0.4546	3/2+

Continuum levels were assumed above 0.5 MeV. The level density parameters were taken from Gilbert-Cameron/7/.

MT=251 Mu-bar
Calculated from angular distributions.

MF=4 Angular Distribution of Secondary Neutrons

MT=2 Elastic scattering
Calculated with the CC/HF method.

MT=51-70 Inelastic scattering
Calculated with the CC/HF method for the 3rd and 13th excited levels. For the other levels, calculations with ELIESE-3 using the generalized transmission coefficients for the entrance channel were adopted.

MT=91 Inelastic scattering to the continuum
Isotropic distribution was assumed in the laboratory system.

MF=5 Energy Distributions of Secondary Neutrons

MT=16,17,91 (n,2n), (n,3n) and continuum inelastic
Evaporation spectra based on the level density parameters

MT=18 Fission
Maxwell spectrum (taken from ENDF/B-V).

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MAT number = 3921

92-U -232 Kinki U.+ Eval-Mar87 T.Ohsawa and T. Nakagawa
Dist-Sep89

History
87-03 Evaluation was carried out by T. Ohsawa (Kinki University)
and T. Nakagawa (JAERI).
T.Nakagawa: resonance parameters
T.Ohsawa : other quantities
Compilation was made by T.Nakagawa (JAERI).

MF=1 General Information
MT=451 Descriptive data and dictionary
MT=452 Total number of neutrons per fission
Sum of Nu-p and Nu-d
MT=455 Number of delayed neutrons
Determined from Tuttle's semi-empirical formula /1/.
MT=456 Number of prompt neutrons
Based on the semi-empirical formula by Bois and Frehaut /2/.

MF=2, MT=151 Resonance parameters
Resolved resonance parameters (from 1.0E-5 to 200 eV)
Recommendation by Mughabghab /3/ was adopted, and its formula was changed from Reich-Moore to Multilevel Breit- Wigner type. Background cross section was given to reproduce measured fission cross sections /4,5/ at valleys of levels.

Calculated 2200-m/s cross sections and resonance integrals

	2200-m/s	res. integ.
total	162.3 b	
elastic	10.79 b	
fission	76.66 b	364 b
capture	74.88 b	173 b

These values are almost the same as recommendation by Mughabghab/3/ except capture resonance integral which is recommended as 280+-15 barns.

MF=3 Neutron Cross Sections
Above 200 eV
MT=1 Total
Calculated with the spherical optical model.

The parameters for the spherical optical parameters were as follows:

V = 40.47 - 0.06*En (MeV), Vso = 8.8 (MeV)
Ws = 6.8 + 0.04*SQRT(En) (MeV), Wv = 0.0
r = 1.32 (fm), rs = 1.38 (fm), rso = 1.22 (fm)
a = as = aso = 0.47 (fm),

This set of parameters was found to give good agreement with the measurements of Simpson et al./6/ in the energy region from 1 keV to 10 keV.
MT=2 Elastic Scattering
Calculated with the code CASTHY/7/.
MT=16 (n,2n)
Calculated with the model of Segev-Fahima/8/.

MT=17 (n,3n)
Calculated with the model of Segev-Fahima/8/.

MT=18 Fission
Calculated by using the fission probability data of Gavron et al./9/ and compound formation cross sections calculated with the optical model. Below 1 keV, the cross section was determined on the basis of Farrell /5/.

MT=51-60,91 Inelastic scattering to the discrete and continuous levels
Calculated with the code CASTHY/7/. The level scheme was taken from Lederer et al./10/ and Schmorak/11/.

No.	Energy(MeV)	Spin-Parity
gs	0.0	0+
1	0.048	2+
2	0.157	4+
3	0.323	6+
4	0.541	8+
5	0.563	1-
6	0.629	3-
7	0.692	0+
8	0.736	2+
9	0.805	10+
10	0.867	2+

Continuum region was assumed above 1.0 MeV. The level density parameters of Gilbert-Cameron/12/ were used.

MT=102 Capture
Calculated with the code CASTHY/7/.

MT=251 Mu-bar
Calculated with the code CASTHY/7/.

MF=4 Angular Distributions of Secondary Neutrons

MT=2 Elastic scattering
Calculated with the code CASTHY/7/.

MT=51-60,91 Inelastic scattering
Calculated with the code CASTHY/7/.

MT=16,17 (n,2n), (n,3n)
Assumed to be isotropic in the Lab system.

MF=5 Energy Distributions of the Secondary Neutrons

MT=16,17 91 (n,2n), (n,3n) and continuum inelastic
Evaporation spectra.

MT=18 Fission
Maxwell spectrum. The temperature parameters were estimated from the systematics of Howerton-Doyas/13/.

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MAT number = 3922

92-U -233 SAEI+ Eval-Mar87 H.Matsunobu,Y.Kikuchi,T.Nakagawa
Dist-Sep89

History
82-06 Evaluation for JENDL-2 was made by N. Asano (SAEI), H. Matsunobu (SAEI) and Y.Kikuchi(JAERI).
87-03 Re-evaluation for JENDL-3 was made by H.Matsunobu (SAEI) Main part of revision was the cross sections above 10 keV and angular and energy distributions of neutrons.
Data were compiled by T. Nakagawa (JAERI).

MF=1 General Information
MT=451 Comments and dictionary
MT=452 Nu-total
Sum of Nu-d and Nu-p
MT=455 Nu-d
Below 4 MeV
Nu-d = 0.0075094 + 4.627E-5*ln(E(MeV))
Between 4 and 20 MeV
Based on the data of Masters et al. /1/ and Evans et al. /2/.
MT=456 Nu-p
Renormalization was made to 3.756 of Cf-252.
Below 1 MeV
Nu-p = 2.486 + 0.1121*(E-DE),
where DE is difference of average fragment kinetic energy between incident and thermal neutron energies. It was taken from data of Boldeman et al. /3/.
Between 1 and 2.73 MeV
Nu-p = 2.436 + 0.1279*E
Between 2.73 and 7.47 MeV
Nu-p = 2.327 + 0.1678*E
Above 7.47 MeV
Nu-p = 2.857 + 0.09689*E

MF=2 Resonance Parameters
MT=151
a) Resolved resonance region (1 eV to 100 eV)
Resolved resonance parameters for the single-level Breit-Wigner formula based on the data of Nizamuddin and Blons /4/.
b) Unresolved resonance region (0.1 keV to 30 keV)
Parameters were deduced with ASREP code /5/ so as to reproduce the evaluated cross sections in this energy region.

MF=3 Neutron Cross Sections
a) Thermal energy region (below 1.0 eV)
MT=1 Total
Sum of partial cross sections
MT=2 Elastic scattering
Calculated from resolved resonance parameters by using the effective scattering radius of 9.93 fm.
MT=18 Fission
Based on data of Weston et al. /6/, Cao et al. /7/, Deruytter and Wagemans /8/ and Pshenichny et al. /9/.

MT=102 Capture
Based on the data of Weston et al. /6/.

2200-m/s cross sections and calculated res. integrals

	2200 m/s	Res. Integ.
total	587.9 b	-
elastic	12.70 b	-
fission	529.9 b	772 b
capture	45.30 b	139 b

b) Resonance Region (from 1 eV to 30 keV)
Represented with resolved and unresolved resonance parameters and background cross sections. The unresolved resonance parameters were determined to reproduce cross cross sections evaluated as follows.

c) Smooth part (above 30 keV)

MT=1 Total
Based on the data of Poenitz /10,11/. Between 10 and 48 keV, cross-section curve calculated with the statistical-model code CASTHY /12/ and the coupled-channel theory code ECIS /13/ was normalized at 48 keV.

MT=2 Elastic
Obtained by subtracting non-elastic scattering cross section from the total cross section.

MT=4 and 51-64,91 Inelastic scattering
Calculated with CASTHY /12/ and ECIS /13/. Coupled levels were first three levels. Deformed OMP was adopted from the recommendation by Haouat et al. /14/, and spherical OMP the same as that used for JENDL-2.

Deformed OMP
V =46.4-0.3•E , Ws=3.3 +0.4•E , Vso=6.2 (MeV)
r0=1.26 , rs=1.26 , rso=1.12 (fm)
a0=0.63 , b =0.52 , aso=0.47 (fm)
Beta-2=0.22, Beta-4=0.08

Spherical OMP
V =41.8-0.20•E+0.008•E••2, Ws=6.50-0.15•E, Vso=6.0 (MeV)
r0=1.31 , rs=1.36 , rso=1.32 (fm)
a0=0.57 , b =0.44 , aso=0.50 (fm)
(dir. W.S.)

Level scheme was taken from Ref. /15/.

No.	Energy(MeV)	Spin-Parity	
g.s.	0.0	5/2 +	•
1	0.04035	7/2 +	•
2	0.0922	9/2 +	•
3	0.1551	11/2 +	•
4	0.29882	5/2 -	
5	0.31191	3/2 +	
6	0.3208	7/2 -	
7	0.34047	5/2 +	
8	0.3537	9/2 -	
9	0.397	11/2 -	
10	0.39849	1/2 +	
11	0.41576	3/2 +	
12	0.5039	7/2 -	

13	0.5467	5/2 +
14	0.5971	7/2 +

Above 0.6 MeV, assumed to be overlapped. Levels with asterisk were coupled in the ECIS calculation.

MT=16,17 (n,2n) and (n,3n)
Calculated by Pearlstein's method /16/. The (n,2n) cross section was normalized to fission-spectrum-averaged value of 0.00408 b measured by Kobayashi /17/.

MT=18 Fission
Based on the experimental data of Gwin et al. /18/, Carlson et al. /19/, Manabe et al. /20/, Kanda et al. /21/, Iwasaki et al. /22/, Meadows /23,24/ and Poenitz /25/, and the fission cross section of U-235 obtained by the simultaneous evaluation /26/.

MT=102 Capture
In the energy range from 30 keV to 1 MeV, the alpha values measured by Hopkins and Diven /27/ were multiplied by the fission cross section. In the high energy region, values calculated with CASTHY and ECIS were normalized to 0.0578 b at 1 MeV.

MT=251 Mu-bar
Calculated with CASTHY and ECIS.

MF=4 Angular Distributions of Secondary Neutrons

MT=2, 51-64 and 91
Calculated with CASTHY and ECIS.

MT=16,17 and 18
Assumed to be isotropic in the Lab system.

MF=5 Energy Distributions of Secondary Neutrons

MT=16,17,91
Calculated with PEGASUS /28/.

MT=18 Fission spectrum
Calculated with Madland-Nix formula /29/. The following parameters were taken from Ref./29/.

Average energy release	= 188.971 MeV
Total average FF kinetic energy	= 172.1 MeV
Average Masses of Light and heavy FF	= 95 and 139
Level density parameter	= A/11

MT=455 Delayed neutrons
Recommendation by Saphier et al. /30/ was adopted.

MF=8 Fission Product Yields

MT=454 Fission product yield data (independent)
MT=459 Fission product yield data (cumulative)
Both were taken from JNDC FP Decay Data file version 2 /31/.

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MAT number = 3923

92-U -234 Kawasaki Eval-Mar87 T.Watanabe
Dist-Sep89

History
87-03 New evaluation for JENDL-3 was made by T.Watanabe (Kwasaki Heavy Ind.)
87-06 Compilation was made by T.Nakagawa (JAERI)

MF=1 General Information
MT=451 Descriptive data and dictionary
MT=452 Number of neutrons per fission
Taken from ENDF/B-VI evaluation(=JENDL-2).

MF=2 Resonance Parameters
MT=251 Resonance Parameters ; 1.0E-5 eV - 50 keV
Resolved resonances for MLBW formula . 1.0E-5 eV - 1.5 keV
Parameters of Ref./1/ were adopted after modification of an average radiative width to 0.026 eV/2/. A negative level was added at -2.06 eV so as to reproduce the cross sections at 0.0253 eV/2/.
Total = 119.1 +- 1.3 b
Elastic = 19.6 +- 1.0 b
Capture = 99.8 +- 1.3 b

Unresolved resonances : 1.5 keV - 50 keV
The following parameters were given.
<WG> = 0.026 eV/2/, <WF> = 0.0 eV, D-obs = 10.6 eV/2/,
S-0 = 0.96E-4 (calculated with ECIS/3/),
S-1 = 1.197E-4 (adjusted to the total cross section calculated with ECIS/3/),
R = 9.70 fm (adjusted to the total cross section at 50 keV).

Calculated 2200m/s cross sections and resonance integrals.

	2200 m/s	Resonance integral
total	119.2 b	---
elastic	19.41 b	---
fission	6.22 mb	6.72 b
capture	99.75 b	632 b

MF=3 Neutron Cross Sections
Below 50 keV, resonance parameters were evaluated.
Background cross sections for the fission were given in the unresolved resonance region.

MT=1,2,4,51-62,91,102 Total, elastic and inelastic scattering, and capture
Calculated with coupled-channel code ECIS/3/ and spherical optical and statistical model code CASTHY/4/.

The Deformed optical potential parameters of Lagrange/5/ were adopted for the ECIS calculation.

V = 46.42 - 0.3 * En, ro = 1.26, ao = 0.63
Ws = 3.72 + 0.4 * En, rs = 1.26, b = 0.52
En up to 10 MeV

```
      = 7.72
          En above 10 MeV
   Vso   = 6.2                     rso= 1.12   aso= 0.47
   beta2 = 0.194
   beta4 = 0.071
```

The spherical optical potential parameters for the CASTHY calculation were determined so as to reproduce the total cross section calculated with ECIS by using the above OMP.

```
   V  = 41.49 - 0.1359 * En
   Ws = 9.284 - 0.2086 * En+ 0.03225 * En ** 2
   Vso= 4.248,
   r  = 1.316,  rs = 1.381, rso= 1.15
   ao = 0.528,  b  = 0.372, aso= 0.597
```

The level scheme was taken from Ref./6/.

No.	Energy(MeV)	Spin-Parity	Coupled lvl
g.s	0.0	0 +	*
1	0.04348	2 +	*
2	0.14334	4 +	*
3	0.29606	6 +	*
4	0.49702	8 +	*
5	0.7412	10 +	*
6	0.78628	1 -	
7	0.80989	0 +	
8	0.94785	4 +	
9	0.9626	5 -	
10	0.9691	3 +	
11	0.9895	2 -	
12	1.0236	4 +	

Continuum levels were assumed above 1.024MeV

Level density parameters were evaluated using D-obs and excited level data/2,6/.

	a(1/MeV)	T(MeV)	Ex(MeV)	Sig**2(0)
92-U-234	29.349	0.4058	4.769	16.872
92-U-235	31.415	0.3914	4.231	14.378

The gamma-ray strength function (=84.6E-4) was determined by normalizing the capture cross section to 0.46535 b at 50 keV which was calculated from above-mentioned unresolved resonance parameters.

MT=16,17 (n,2n) and (n,3n)
JENDL-2 data calculated with the evaporation model were renormalized so that they might be consistent with the fission and compound formation cross sections calculated with ECIS and CASTHY.

MT=18 Fission
Experimental data /7,8,9/ of fission cross section ratio to U-235 were evaluated. Fission cross section was obtained by multiplying the U-235 fission cross section/10/ to the ratio.

MT=251 Mu-L bar
Calculated with ECIS and CASTHY.

MF=4 Angular Distributions of Secondary Neutrons
MT=2,51-62,91 Calculated with ECIS and CASTHY
MT=16,17,18 Assumed to be isotropic in the lab. system.

MF=5 Energy Distributions of Secondary Neutrons
MT=16,17,91 Table type data were given.
Spectra were calculated with preequilibrium and multi-step evaporation model code PEGASUS /11/.
MT=18
Calculated with the formula of Madland and Nix /12/.
Constant compound nucleus formation cross section model was adopted.

Total average FF kinetic energy = 171.09 MeV
Average energy release = 187.976 MeV
Average mass number of light FF = 95
Average mass number of heavy FF = 140
Level density parameter = A/10.0

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MAT number = 3924

```
 92-U -235 SAEI+       Eval-Mar87 H.Matsunobu,K.Hida,T.Nakagawa+
                       Dist-Sep89
History
87-03 Newly evaluated for JENDL-3 by the following evaluators.
       K.Hida (NAIG)               gamma-ray production data
       Y.Nakajima (JAERI)          resolved resonances
       T.Nakagawa (JAERI)          unresolved resonances
       H.Matsunobu (SAEI)          other quantities
88-08 Data were partly modified to final JENDL-3 data.
       Nu-bar, Unresolved resonance parameters.
89-02 FP yields were replaced with JNDC FP Decay File version-2.
  Data were compiled in ENDF-5 format by T.Nakagawa (JAERI)

MF=1  General Information
  MT=451  Comments and dictionary
  MT=452  Total number of neutrons per fission
      Sum of nu-p (MT=456) and nu-d (MT=455).
  MT=455  Delayed neutron data
      Evaluated on the basis of the experimental data by Keepin et
      al. /1/, Keepin /2/, Masters et al. /3/, Conant and Palmedo
      /4/, Evans and Thorpe /5/, Cox /6/, Besant et al. /7/ and
      Synetos and Williams /8/.
  MT=456  Number of prompt neutrons
      Evaluated on the basis of the experimental data by Boldeman
      and Walsh /9/, Soleilhac et al. /10/, Frehaut et al.
      /11,12/, Meadows and Whalen /13/, Prokhorova et al. /14,15/,
      Savin et al. /16/, Kaeppeler and Bandl /17/, Boldeman et al.
      /18/, Frehaut and Boldeman /19/, Boldeman and Frehaut /20/,
      Gwin et al. /21/, Frehaut et al. /22/, Gwin et al. /23/,
      Howe /24/, and Boldeman and Hines /25/. The standard value
      of 3.756 of Cf-252 nu-p was used in the present evaluation.

MF=2  Resonance Parameters
  MT=151
  1) Resolved resonances : 1.0 - 100 eV
      2g*Gamma-n : Simple average of experimental data.
      Gamma-g    : Weighted average of experimental data.
      Gamma-f    : Calculated from the averaged fission area.
        Details of the evaluation given in Ref. /26/.
      Total spin J values were taken from Moore et al./27/.
  2) Unresolved resonance parameters : 100 eV - 30 keV
      The evaluated total, capture and fission cross sections were
      fitted by adjusting S0, S1 and Gamma-f.  The fission cross
      section was based on the experimental data of Weston and
      Todd /28/.  The capture cross section was determined as
      (Sig-f)*(alpha(JENDL-2)).

      2200-m/s cross sections and calculated res. integrals.
                      2200 m/s        res. integ.
         elastic       14.64 b           -
         fission      584.0 b          275 b
         capture       96.0 b          152 b
         total        694.6 b            -

MF=3  Neutron Cross Sections
```

Below 1.0 eV: Based on the experimental data.
Between 1.0 and 100 eV: Background data for resonance parameters are given to well reproduce the experimental data.
Above 100 eV: Data were evaluated as follows. Between 100 eV and 30 keV, the unresolved resonance parameters were given to reproduce these cross sections.

MT=1 Total
Evaluated on the basis of the experimental data by Uttley et al. /29/, Boeckoff et al. /30/, Schwartz et al. /31/, Green et al. /32/, Foster and Glasgow /33/, Poenitz et al. /34/, and Poenitz and Whalen /35/.

MT=2 Elastic scattering
Evaluated on the basis of the experimental data by Smith /36/, Smith and Whalen /37/ and Knitter et al. /38/ in the energy range from 0.3 to 2.3 MeV. In the remaining energy range it was derived by subtracting sum of partial cross sections from total cross section.

MT=4,51-79,91,251 Inelastic scattering cross section and mu-bar
Evaluated on the basis of experimental data and calculation with optical and statistical models, and coupled channel theory taking into account of deformation of nucleus.
The calculated inelastic scattering cross sections were decreased by factor of 0.9 below about 2 MeV so as to be in agreement with Smith et al. /39/.

Deformed optical potential parameters were adopted from the recommendation by Haouat et al. /40/.

```
   V  = 46.4  - 0.3*En,  Ws = 3.3 + 0.4*En, Vso= 6.2  (MeV)
   r0 = 1.26,            rs = 1.26,         rso= 1.12  (fm)
   a0 = 0.63,            b  = 0.52,         aso= 0.47  (fm)
   beta-2 = 0.22,    beta-4 = 0.08
```

The spherical optical potential parameters were obtained by fitting the experimental data of the total cross section.

```
   V  = 40.90 - 0.04*En, Ws = 6.5 + 0.25*En,Vso= 7.0  (MeV)
   r0 = 1.312,           rs = 1.375,        rso= 1.320 (fm)
   a  = 0.490,           b  = 0.454,        ao = 0.470 (fm)
```

Statistical model calculation with CASTHY code /41/.
Competing processes : fission (n,2n), (n,3n), (n,4n).
Level fluctuation was considered.

The level scheme taken from Refs./42,43/.

No.	Energy(keV)	Spin-Parity
g.s.	0.0	7/2 -
1	0.075	1/2 +
2	13.038	3/2 +
3	46.347	9/2 -
4	51.697	5/2 +
5	81.732	7/2 +
6	103.2	11/2 -
7	129.292	5/2 +
8	150.4	9/2 +
9	170.7	13/2 -
10	171.378	7/2 +
11	197.1	11/2 +
12	225.40	9/2 +

13	249.1	15/2 -
14	291.1	11/2 +
15	294.7	13/2 +
16	332.818	5/2 +
17	338.8	17/2 -
18	357.2	15/2 +
19	367.05	7/2 +
20	368.8	13/2 +
21	393.184	3/2 +
22	414.8	9/2 +
23	426.71	5/2 +
24	445.7	7/2 +
25	474.27	7/2 +
26	510.0	9/2 +
27	533.2	9/2 +
28	607.7	11/2 +
29	633.04	5/2 -

Continuum levels assumed above 650 keV.
The level density parameters : Gilbert and Cameron /44/.

MT=16,17,37 (n,2n), (n,3n), (n,4n)
Evaluated on the basis of the following experimental data and calculation with evaporation model.
(n,2n) : Frehaut et al. /45/
(n,3n) and (n,4n) : Veeser and Arthur /46/

MT=18 Fission
Derived with simultaneous evaluation/47/ on the basis of the capture cross sections of Au-197 and U-238, the fission cross sections of U-235, -238, Pu-239, -240 and -241 in the energy range from 50 keV to 20 MeV. Experimental data of U-235 considered in this evaluation are as follows:
Perez et al. /48/, Poenitz /49,50/, Czirr and Sidhu /51,52,53/, Szabo and Marquette /54/, Barton et al. /55/, Cance and Grenier /56,57/, Carlson and Patrick /58/, Kari /59/, Adamov et al. /60/, Arlt et al. /61, 62/, Wasson et al. /63,64/, Li et al. /65/, Mahdavi et al. /66/, Carlson and Behrens /67/, Corvi et al. /68/, Dushin et al. /69/ and Weston and Todd /28/.

MT=102 Capture
Derived from the evaluated alpha value and fission cross section below 1 MeV. Calculated with CASTHY above 1 MeV.

Alpha value was evaluated on the basis of the experimental data by Kononov et al. /70/, Dvukhsherstnov et al. /71/, Gwin et al. /72/, Bluhm and Yen /73/, Hopkins and Diven /74/, Beer and Koeppeler /75/ and Corvi et al. /68/

MF=4 Angular Distributions of Secondary Neutrons
MT=2, 51-79, 91 Calculated with CASTHY and ECIS codes.
MT=16,17,18,37 Isotropic in the lab system.

MF=5 Energy Distributions of Secondary Neutrons
MT=16,17,37,91
Calculated with PEGASUS/76/ on the basis of preequilibrium and multi-step evaporation model.
MT=18
Distributions calculated with the formula of Madland and Nix

/77/ were adopted. Constant compound nucleus formation cross section model was adopted.

Total average FF kinetic energy = 171.8 MeV
Average energy release = 186.980 MeV
Average mass number of light FF = 96
Average mass number of heavy FF = 140
Level density parameter = A/9.6

MT=455
Taken from Saphier et al. /78/

MF=8 Fission Product Yield Data
MT=454 and 459
Both were taken from JNDC FP Decay File version-2 /79/.

MF=12 Photon Production Multiplicities (option 1)
Given for the following sections below 369.579 keV
MT=18 Fission
The thermal neutron-induced fission gamma spectrum measured by Verbinski /81/ was adopted.
MT=51-69 Inelastic Scattering
The photon branching data taken from /43/ were converted to the photon multiplicities.
MT=102 Capture
Calculated with GNASH /80/, where the pygmy resonance was introduced /82/.

MF=13 Photon Production Cross Sections
MT=3 Non-elastic
Calculated with GNASH /80/ above 369.579 keV.
Verbinski's data /81/ were used up to 20 MeV.

MF=14 Photon Angular Distributions
MT=3,18,51-69,102
Isotropic distributions were assumed.

MF=15 Continuous Photon Energy Spectra
MT=3,102
Calculated with GNASH /80/
MT=18
Experimental data by Verbinski /81/ were adopted.

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MAT number = 3925

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 92-U -236 NAIG        Eval-Mar88 T.Yoshida
                       Dist-Sep89
History
79-03 New evaluation for JENDL-2 was made by T.Yoshida(NAIG).
86-12 JENDL-2 data were critically reviewed.
88-03 JENDL-2 data were revised to make JENDL-3 on the basis
      of the 86-12 review.  New Russian measurements (1982- 1986)
      were fully adopted, resultantly leading to a nearly 30
      per-cent reduction of capture cross-section above 1.5 keV.
      Sub-threshold fission curve was introduced between 1.5 keV
      and 700 keV.  Unknown gamma-f was assumed to be 0.354
      milli-eV.
  Data were compiled by T.Nakagawa (JAERI).

MF=1  General Information
  MT=451  Descriptive data and dictionary
  MT=452  Number of neutrons per fission
     Taken from Malinovskii's paper /1/

MF=2 MT=151  Resonance parameters
  Resolved resonances for MLBW formula : 1.0E-5 eV to 1.5 keV
     Res. energies and Gam-n(for Gam-n greater than 0.1*Gam-g)
                                                  : Carraro /2/
     Gam-n (for Gam-n smaller than 0.1*Gam-g) : Mewissen /3/
     Gam-g : Mewissen /3/, when not given, mean value was taken.
     Gam-f : Theobald /4/.
        Average Gam-g = 23.0 milli-eV
        Average Gam-f = 0.354 milli-eV
     A negative resonance was introduced to reproduce the 2200-
     m/s capture cross section of (5.11+-0.21) barns recommended
     in BNL-325 4th edition.
  Unresolved resonances : 1.5 keV to 40 keV
     Parameters were determined to reproduce total and capture
     cross sections calculated with CASTHY and evaluated fission
     cross section. Obtained parameters are:
        S0 = 0.906E-4, S1 = energy dependent (1.8E-4 - 2.7E-4)
        Gam-g = 0.023 eV, Gam-f = energy dependent
        R = 9.36 fm, D-obs = energy dependent (14.66 - 13.57 eV)

     Calculated 2200-m/s cross sections and res. integrals
                         2200-m/sec       Res. Integ.
         total           13.69   b          -
         elastic          8.337  b          -
         fission          0.0613 b          7.77 b
         capture          5.295  b        346.   b

MF=3  Neutron Cross Sections
  Below 1.5 keV, all background cross sections are zero.
  Above 1.5 keV, data were evaluated as follows. In the energy
  range from 1.5 to 40 keV, unresolved resonance parameters were
  evaluated and background cross section was given to elastic
  scattering.

  MT=1,2,4,51-79,91,102,251  Sig-t,Sig-el,Sig-in,Sig-c,Mu-bar
     Coupled channel and statistical model calculations were made
```

with ECIS /6/ and CASTHY codes /7/, respectively
The deformed optical potential parameters after Haouat and Lagrange /5/:

```
   Vr =49.8 - 16*sy - 0.3*En                       (MeV),
   Ws = 5.3 -  8*sy + 0.4*En   (En .LT. 10 MeV) (MeV),
      = 9.3 -  8*sy            (En .GE. 10 MeV) (MeV),
   Vso= 6.2                                        (MeV),
        where sy=(N-Z)/A
   r=1.26, rs=1.26, rso=1.12                       (fm),
   a=0.63, as=0.52, aso=0.47                       (fm).
```

The spherical optical potential parameters for the statistical model calculation with CASTHY:

```
   Vr =40.8 - 0.05*En,                        (MeV),
   Ws = 6.5 + 0.15*En                         (MeV),
   Vso= 7.0                                   (MeV),
   r=1.32, rs=1.38, rso=1.32                  (fm),
   a=0.47, as=0.47, aso=0.47                  (fm).
```

Competing processes : fission, (n,2n) and (n,3n)
Level fluctuation was considered. The gamma-ray strength function was determined so that the calculated capture cross section reproduced the measured value of 0.85 barn /8/ around 10 keV.
The level scheme taken from Ref. /9/.

No.	Energy(MeV)	J-Parity	No.	Energy(MeV)	J-Parity
gs	0.0	0 +	1	0.04524	2 +
2	0.14948	4 +	3	0.30979	6 +
4	0.52225	8 +	5	0.68757	1 -
6	0.7442	3 -	7	0.7828	10 +
8	0.8476	5 -	9	0.91916	0 +
10	0.9581	2 +	11	0.9604	2 +
12	0.9670	1 -	13	0.9880	2 -
14	1.0014	3 +	15	1.0020	7 -
16	1.0356	3 -	17	1.0512	4 +
18	1.0529	4 -	19	1.0587	4 +
20	1.0661	3 +	21	1.0700	4 -
22	1.0862	12 +	23	1.0938	2 +
24	1.1044	5 -	25	1.1110	2 -
26	1.1267	5 +	27	1.1470	3 +
28	1.1494	3 -	29	1.1640	6 -

Continuum levels assumed above 1.17 MeV.
The ground state, 1-st and 2-nd excited levels were coupled in the ECIS calculation.

MT=16,17 (n,2n) and (n,3n)
Calculated with the PEGASUS code /10/.

MT=18 Fission
Evaluated on the basis of measured data of U-236/U-235 /11,12/. To get absolute value Matsunobu's evaluation /13/ for U-235(n,f) was employed.

MF=4 Angular Distributions of Secondary Neutrons
MT=2,51,52 Calculated with ECIS and CASTHY
MT=53-79,91 Calculated with CASTHY.
MT=16,17,18 Isotropic distribution in the lab. system.

MF=5 Energy Distributions of Secondary Neutrons
MT=16,17,91 Calculated with PEGASUS.

MT=18 Maxwellian fission spectrum. Temperature was estimated from Z**2/A values /14/.

MF=8 Fission Product Yields Data
MT=454 Independent yields
MT=459 Cumulative yields
Both were taken from JNDC FP Decay Data File version-2/15/.

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MAT number = 3926

92-U -238 KYU,JAERI+ Eval-Apr87 Y.Kanda et al.
Dist-Sep89

History
87-01 Simultaneous evaluation for fission and capture cross sections was completed in the energy range above 50 keV.
87-04 Other quantities were evaluated by
Y. Kanda and Y. Uenohara (Kyushu Univ.): MF's = 3, 4 and 5 above resonance region.
T. Nakagawa (JAERI) : Resolved resonance parameters and background cross sections.
K. Hida (NAIG) : Data for gamma-ray production.
88-03 Data of total, elastic, inelastic (MT=59,60) and capture cross sections were partly modified.
89-03 Data of total, elastic, inelastic and capture cross sections were modified. Unresolved resonance parameters were also modified. FP yields were added.

MF=1 General Information
MT=451 Descriptive data and directory records
MT=452 Number of neutrons per fission
Sum of MT's= 455 and 456
MT=455 Delayed neutron data
Taken from Ref./1/.
MT=456 Number of prompt neutrons per fission
Taken from evaluation by Frehaut /2/.

MF=2 Resonance Parameters
MT=151 Resolved and unresolved resonance parameters
1) Resolved resonance parameters for MLBW formula
(resolved resonance region = 1.0E-5 eV to 9.5 keV)
After JENDL-2 evaluation /3/, Extensive analysis was made by Olsen /4/. In the JENDL-3 evaluation, the parameters were modified from JENDL-2 on the basis of of Olsen's data and resonance region was extended up to 9.5 keV. R' and parameters of the 6.67-eV level were adjusted to reproduce the thermal cross sections.
Resonance energy and neutron widths : weighted average of JENDL-2 and Olsen's data.
Capture and fission widths : Same as JENDL-2.
Effective scattering Radius : 9.7 fm
l-assignment : based on the method by Bollinger and Thomas /5/.
2) Unresolved resonance parameters
(unresolved resonance region = 9.5 keV to 50.0 keV)
Parameters were obtained with the parameter fitting code ASREP/6/ so as to reproduce the cross sections evaluated in this energy region.

2200-m/s cross sections and calculated resonance integrals.

	2200 m/s(b)	res. integ.(b)
total	11.820	
elastic	9.139	
fission	0.110E-6	2.02
capture	2.681	279.

MF=3 Neutron Cross Sections
Below 50 keV, background cross sections were given. In the resolved resonance region, they were estimated from picket-fence model and numbers of missing levels.
Above 50 keV, cross sections were evaluated as follows;

MT=1 Total
The same as JENDL-2 which were based on the following experimental data.
Below 500 keV: Uttley et al./7/, Whalen et al./8/, Poenitz et al./9/, Tsubone et al./10/
0.5 - 4.5 MeV: Poenitz et al./9/, Tsubone et al./10/, Kopsch et al./11/.
4.5 - 15 MeV : Foster and Glasgow /12/
15 - 20 MeV : Bratenahl et al./13/, Peterson et al./14/.

MT=2 Elastic Scattering
Calculated as (Total)-(Partial cross sections)

MT=4, 51-76, 91 Total and partial inelastic scattering
Cross sections were calculated by taking account of direct and compound processes. Cross sections for MT's = above 60 were increased by 5 % to final JENDL-3.
1) Direct process
Coupled-channel model code ECIS/15/ was used together with spherical optical and statistical model code CASTHY/16/ for calculation of inelastic cross sections to the 1-st and second levels. Cross sections were normalized to the experimental data/17,18,19/ around 3 MeV of incident energy. The optical potential parameters were taken from Ref./17/.

```
V0=46.2 - 0.3E, Ws = 3.6 + 0.4E, Vso = 6.2 (MEV)
r = 1.26, rs=1.26, rso=1.12                  (fm)
a = 0.63, as=0.52, aso=0.47                  (fm)
beta-2 =0.198, beta-4 =0.057
```

Direct cross sections to the other levels were calculated with DWUCK4/20/. Those of 3-rd, 6, 8, 9, 10, 11, 13 and 14-th levels were normalized to the experimental data /21/. Normalization factors to other levels were estimated from these results.

The optical potential parameters /22/ used in DWUCK-4:

```
V0 = 50.378-0.354E-27.073(N-Z)/A,            (MeV)
WS = 9.265-0.232E+0.03318E**2-12.666(N-Z)/A, (MeV)
Vso= 6.2,                                    (MeV)
r  = 1:264, a  = 0.612,                      (fm)
rs = 1.256, as = 0.553+0.0144E,              (fm)
rso= 1.1,   aso= 0.75                        (fm)
```

2) Compound process:
Calculated with CASTHY /16/. The same optical potential parameters as those for ECIS calculation were used.

Level Scheme /23/

NO.	ENERGY(MEV)	SPIN-PARITY
G.S.	0.0	0 +
1	0.044889	2 +

2	0.1484	4 +
3	0.3072	6 +
4	0.5178	8 +
5	0.6801	1 -
6	0.7319	3 -
7	0.7757	10 +
8	0.8271	5 -
9	0.927	0 +
10	0.95	2 -
11	0.9663	2 +
12	0.993	0 +
13	1.0373	2 +
14	1.0595	3 +
15	1.0765	12 +
16	1.107	1 -
17	1.1289	2 -
18	1.1503	9 -
19	1.169	3 -
20	1.2239	2 +
21	1.243	4 -
22	1.27	6 +
23	1.2785	2 -
24	1.290	5 -
25	1.3784	11 -
26	1.4153	14 +

Continuum levels were assumed above 1.5 MeV.

MT=16 (n,2n)
Smooth cross section was determined on the basis of Frehaut et al./24/ below 15 MeV, and Veeser et al./25/ and Karius et al./26/ above 15 MeV.

MT=17 (n,3n)
Based on Veeser et al./25/

MT=18 Fission
Below 100 keV : Taken from experimental data /27/.
100 - 600 keV : Evaluated on the basis of the data of Diffilippo et al. /28/, Behrens and Carlson /29/, Nordborg et al. /30/ and Meadows /31,32/.
Above 600 keV : Results of simultaneous evaluation /32/ made by considering the experimental data of Refs./29-32, 34-43/.

MT=102 Capture
Below 300 keV, evaluation was mainly based on the data measured by Kazakov et al./44/. Above 300 keV, data were taken from JENDL-2 which were determined mainly from the measurements by Poenitz /43/, Panitkin and Sherman /45/, Moxon /46/, Fricke et al. /47/ and Menlove and Poenitz /48/. At high energies, slight modification was made.

MT=251 Mu-L bar
Calculated from the angular distributions in MF=4, MT=2.

MF=4 Angular Distributions of Secondary Neutrons
MT=2,51,52 Calculated with ECIS/15/, CASTHY/16/ and

ELIESE-3/49/.
MT=53-76 Calculated with DWUCK4/20/ and ELIESE3
MT=16,17,18,91 Assumed to be isotropic in the lab. system.

MF=5 Energy Distributions of Secondary Neutrons
MT=16,17 Evaporation spectrum.
MT=91 Evaporation spectrum in a table form.
MT=18
Calculated with the formula of Madland and Nix /50/.
Constant compound nucleus formation cross section model was adopted.

```
Total average FF kinetic energy = 170.07 MeV
Average energy release          = 186.436 MeV
Average mass number of light FF =  98
Average mass number of heavy FF = 141
Level density parameter         = A/10.0
```

MT=455
Taken from Saphier et al. /51/

MF=8 Fission Product Yields Data
MT=454 Independent yields
MT=459 Cumulative yields
Both were taken from JNDC FP Decay Data File version-2/52/.

MF=12 Photon Production Multiplicities (option 1)
Given for the following sections below 933.941 keV.
MT=18 Fission
The thermal neutron-induced fission gamma spectrum of U-235 measured by Verbinski /54/ was adopted for the whole energy region. The intensity of photon below 0.14 MeV, where no data were given, was assumed to be the same as that between 0.14 and 0.3 MeV.
MT=51-59 Inelastic
Photon branching data were taken from Ref./55/, and converted to photon multiplicities.
MT=102 Capture
Calculated with GNASH/53/. In the case where the obtained multiplicities were too large, they were renormalized by using energy balance.

MF=13 Photon Production cross sections
MT=3 Non-elastic
Photon production cross section calculated with GNASH /53/ were grouped into the non-elastic in the energy range above 933.941 keV. Transmission coefficients for incident channel were generated with ECIS/15/, and those for exit channel with ELIESE-3/49/. The data for fission were based on the measured U-235 spectra /54/. Further details are given in Ref./56/

MF=14 Angular Distributions of Photons
Isotropic distributions were assumed for all sections.

MF=15 Continuous Photon Energy Spectra
MT=3 Non-elastic
Calculated with GNASH /53/.
MT=18 Fission

U-235 spectra measured by Verbinski/54/.
MT=102 capture
Calculated with GNASH/53/.

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MAT number = 3931

93-Np-237 Kyushu U.+ Eval-Nov87 Y.Uenohara, Y.Kanda
Dist-Jan88

History
79-03 New evaluation was made by N.Wachi and Y.Kanda (Kyushu University), and Y.Kikuchi (JAERI).
87-11 (n,2n), (n,3n) and fission cross sections were re-evaluated in the energy rage above 100 keV by Y.Uenohara and Y.Kanda (Kyushu University).
88-01 Compiled by T.Nakagawa (JAERI).
Modified quantities : (1,452), (1,456), (3,2), (3,16) (3,17) and (3,18)
89-02 FP yields were taken from JNDC FP Decay File version-2.
89-03 (n,2n) reaction cross section was modified.

MF=1 General Information
MT=451 Comments and dictionary
MT=452 Number of neutrons per fission
Sum of MT=455 and MT=456.
MT=455 Delayed neutron data
Experimental data of Benedetti + /1/ and systematics by Tuttle /2/.
MT=456 Number of neutrons per fission
Based on experimental data of Frehaut + /3/.

MF=2, MT=151 Resonance parameters
Resolved resonances for SLBW formula : 1.0E-5 - 130 eV
Res. energy, Gam-n, Gam-g: Weston and Todd /4/.
Gam-f : Plattard + /5/.
Average Gam-g = 40 milli-eV.
A negative resonance added.
Unresolved resonances : 130 eV - 30 keV
Parameters by Weston and Todd /4/ with slight modification
Adopted parameters :
S0=1.02E-4 , S1=1.888E-4 , D-obs=0.45 eV
Gam-g=40 milli-eV.
Gam-f values determined so that Sig-f = 0.009 b.

Calculated 2200 m/s cross sections and resonance integrals:

	2200 m/s value	Res.Int.
total :	208.5 b	-
elastic :	27.52 b	-
fission :	0.01921 b	6.36 b
capture :	181.0 b	663 b

MF=3 Neutron Cross Sections
MT=1,4,51-64,91,102,251 Total, inelastic, capture and Mu-bar
Calculated with optical and statistical model code CASTHY /6/.
The spherical optical potential parameters :
V = 43.55 , Ws = 11.0 , Vso = 7.0 (MeV)
r = rs = 1.32 , rso= 1.3 (fm)
a = b = 0.47 , aso= 0.4 (fm)
In the statistical model calculation with CASTHY code, competing processes, fission, (n,2n) and (n,3n), and level fluctuation were considered. The level scheme was taken

from compilation by Ellis /7/.

No	Energy(MeV)	Spin-Parity
g.s.	0.0	5/2+
1	0.03320	7/2+
2	0.05954	5/2-
3	0.07580	9/2+
4	0.10296	7/2-
5	0.13000	11/2+
6	0.15852	9/2-
7	0.2260	11/2-
8	0.26754	3/2-
9	0.281	1/2-
10	0.305	13/2-
11	0.327	7/2-
12	0.332	1/2+
13	0.357	5/2-
14	0.369	5/2+

Continuum levels assumed above 0.370 MeV.

The level density parameters were taken from Gilbert and Cameron /8/. The gamma-ray strength function for the capture cross section was determined so that Sig-c = 0.742 b at 200 keV.

MT=2 Elastic scattering

Calculated as (total - sum of partial cross sections).

MT=16 (n,2n)

For JENDL-2, data were calculated with the evaporation model of Segev+/9/. The data for JENDL-3 were evaluated by fitting to the following experimental data.

Perkin+ /10/, Landrum+ /11/, Lindke+ /12/, Fort+ /13/, Gromova+ /14/ and Kornilov+ /15/.

The data of JENDL-2 were used as prior values, and 50% fractional standard deviations were assigned to them.

MT=17 (n,3n)

For JENDL-2, calculated with the evaporation model of Segev + /9/. Above 16.5 MeV, the JENDL-2 data were modified by adding the values of (Sig-2n of JENDL-2)-(Sig-2n of JENDL-3). Below 16.5 MeV, the shape of (n,3n) cross section of JENDL-2 was normalized to the modified value at 16.5 MeV.

MT=18 Fission

Evaluated from measured data. Above 100 keV; simultaneous evaluation method was used by taking account of the following experimental data.

Klema /16/, Protopopov+ /17/, Schmitt+ /18/, Grundl /19/, Iyer+ /20/, Jiacoletti+ /21/, Kobayashi+ /22/, Arlt+ /23/, Cance+ /24/, Garlea+ /25/, Kuprijanov+ /26/, White+ /27,28/, Stein+ /29/, Behrens+ /30/ and Meadows /31/.

MF=4 Angular Distributions of Secondary Neutrons

MT=2,51-64,91 Calculated with the optical model.

MT=16,17,18 Isotropic in the laboratory system.

MF=5 Energy Distributions of Secondary Neutrons
MT=16,17,91 Evaporation spectrum.
MT=18 Estimated from Z**2/A systematics by Smith +/32/ by assuming E(Cf-252) = 2.13 MeV.

MF=8 Fission Product Yields
MT=454 and 459
Both were taken from JNDC FP Decay Data File version-2/33/.

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MAT number = 3932

93-Np-239 Kyushu U.+ Eval-Mar76 Y.Kanda, JENDL-CG
Dist-Sep89

History
76-03 The evaluation for JENDL-1 was performed by Kanda (Kyushu Univ.) and JENDL-1 Compilation Group. Details are given in Ref. /1/.
83-03 JENDL-1 data were adopted for JENDL-2 and extended to 20 MeV. MF=5 was revised.
87-07 Data format was converted into ENDF-5 format and adopted to JENDL-3.

MF=1 General Information
MT=451 Descriptive data and dictionary
MT=452 Number of neutrons per fission
Taken from the Np-237 data of ENDF/B-IV.

MF=2 Resonance Parameters
MT=151 No resonance parameters were given.

2200-m/sec cross sections and calculated resonance integrals.

	2200 m/sec	res. integ.
total	47.50 b	-
elastic	10.50 b	-
fission	0.0 b	7.06 b
capture	37.00 b	445. b

MF=3 Neutron Cross Sections
Below 4.0 eV.
MT=1 Total
Sum of partial cross sections.
MT=2 Elastic scattering
The constant cross section of 10.5 barns was assumed from
Sig=4*3.14*(0.147*A**(1/3))**2.
MT=18 Fission
Assumed to be zero barns.
MT=102 Capture
The form of 1/v was assumed. The 2200-m/sec cross section was adopted from the experimental data by Stoughton and Halperin /2/.
Above 4.0 eV.
MT=1 Total
Calculated with optical and statistical model code CASTHY /3/. Optical potential parameters were obtained by Ohta and Miyamoto /4/ by using the total cross section of Pu-239.
V = 45.87-0.2*en, Wi= 0.06, Ws= 14.1, Vso= 7.3 (MeV)
r = 1.27 , ri= 1.27, rs=1.302, rso= 1.27(fm)
a0= 0.652 , ai=0.315, as= 0.98, aso=0.652(fm)
MT=2 Elastic scattering
Calculated with CASTHY /3/.
MT=4,51-58,91 Inelastic scattering
Calculated with CASTHY /3/. The level scheme was adopted from Nucl. Data Sheets Vol.6.

No.	Energy(MeV)	Spin-Parity
g.s.	0.0	5/2 +
1	0.03114	7/2 +

2	0.07112	9/2 +
3	0.07467	5/2 -
4	0.11766	11/2 +
5	0.1230	7/2 -
6	0.17305	9/2 -
7	0.2414	11/2 -
8	0.320	13/2 -

Levels above 430 keV were assumed to overlapping. In the calculation the capture, fission, (n,2n) and (n,3n) cross sections were considered as competing processes.

MT=16,17 (n,2n) and (n,3n)
Calculated with Pearlstein's method /5/.

MT=18 Fission
Estimated from the Np-237 fission cross section by normalizing with neutron separation energies.

MT=102 Capture
Below 100 keV, the cross section was calculated from
Sig = 435 / SQRT(En) barns.
Above 100 keV, the shape of the experimental data for Np-237 by Nagle et al. /6/ was adopted and normalized to 1.4 barns at 100 keV.

MT=251 Mu-bar
Calculated with CASTHY /3/.

MF=4 Angular Distributions of Secondary Neutrons

MT=2	Calculated with CASTHY code /3/.
MT=51-58	Isotropic in the center-of-mass system.
MT=16,17,18,91	Isotropic in the laboratory system.

MF=5 Energy Distributions of Secondary Neutrons

MT=16,17,91	Evaporation spectrum.
MT=18	Maxwellian fission spectrum estimated from Z**2/A systematics /7/.

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MAT number = 3941

94-Pu-236 MAPI, JAERI Eval-Apr79 T.Hojuyama, Y.Kikuchi, T.Nakagawa
Dist-Sep89

History
79-04 New evaluation was made by T. Hojuyama (MAPI) /1/ in the energy range from 1.0E-5 eV to 20 MeV.
89-07 Cross sections below 9.15 eV were modified by Y.Kikuchi and T.Nakagawa (JAERI).

MF=1 General Information
MT=451 Comment and dictionary
MT=452 Number of neutrons per fission
Nu-p and Nu-d for thermal neutron based on Manero's semi-empirical formula /2/. Neutron-energy dependence of Nu based on Howerton's evaluation /3/.

MF=2 Resonance Parameters
MT=151 Resolved resonance parameters : 1.0E-5 to 9.15 eV
Average capture width, S0, <D> and R were estimated from systematics/4,5/. The first positive resonance was located at 6.3 eV, and its neutron width was estimated from S0. The fission width was determined so that the fission cross section calculated from unresolved resonance formula with the fission width might smoothly connect at 10 keV to the cross section in high energy region. A negative resonance was added at -0.8 eV and the parameters were adjusted so as to reproduce the fission cross section of 170 b at 0.0253 eV/4/ and reasonable capture cross section.

<WG>	:	0.030 eV
R	:	9.46 fm
<D>	:	6.3 eV
S0	:	1.25E-4 /4,5/

Calculated 2200-m/s cross sections and resonance integrals.

	2200 m/sec	Res. Integ.
total	331.1 b	-
elastic	16.34 b	-
fission	169.4 b	58.8 b
capture	145.4 b	401 b

MF=3 Neutron Cross Sections
MT= 1 Total cross section
Obtained by optical model calculation. Optical potential parameters were taken from Murata's evaluation /7/ except real potential.

---Optical Potential Parameters---
V = 39.5-0.05*En (MeV)
Ws = 6.5+0.15*En (MeV)
Vso= 7.0 (MeV)
r0 = rso= 1.32 ,rs = 1.38 (fm)
a = aso= 0.47 ,b = 0.47 (fm)

MT= 2 Elastic scattering cross section
Obtained by optical and statistical model calculations.
MT=4,51-54,91 Inelastic scattering cross sections
Obtained by optical and statistical model calculations.

Level scheme was taken from Ref./8/ except 4th level of which energy was based on Lynn /9/.

No.	En(keV)	Spin-Parity
g.s.	0.0	0 +
1	44.6	2 +
2	145	4 +
3	305	6 +
4	523	8 +

Continuum levels assumed above 661 keV.

MT=16,17 (n,2n) and (n,3n) cross sections
Calculated with statistical model based on Pearlstein /10/.

MT=18,19,20,21 Fission cross sections
Below 10 keV:
Calculated from the unresolved resonance formula with the following parameters.
S0 = 1.25E-4, S1 = 2.22E-4, <D> = 6.3 eV,
<WG>= 0.0415 eV. <WF> = 0.00355 eV.
Above 10 keV:
Calculated from fission plateau cross sections /7,12/ and Hill-Wheeler type barrier penetration factor /11/.
Fission barrier parameters were taken from Weigmann /13/.

MT=102 Capture cross section
Calculated by optical and statistical model with <WG> of 41.5 milli-eV and <D> of 6.3 eV.

MT=251 Mu-bar
Calculated with optical model.

MF=4 Angular Distribution of Secondary Neutrons

MT= 2	Based on optical and statistical model calculation.
MT=51-54	Isotropic in the center-of-mass system.
MT=16-21,91	Isotropic in the laboratory system.

MF=5 Energy Distribution of Secondary Neutrons

MT=16,17,91	Evaporation spectrum assumed
MT=18,19,20,21	Fission spectrum of Maxwellian form adopted. Theta taken from evaluation of Terrell/14/.

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MAT number = 3942

94-Pu-238 MAPI,JAERI Eval-Mar89 T.Kawakita, T.Nakagawa
Dist-Sep89

History
79-03 New evaluation was made by T.Kawakita (PNC).
89-03 Re-evaluation was made by T.Kawakita (MAPI) and T.Nakagawa(JAERI).

MF=1 General Information
MT=451 Descriptive data and dictionary
MT=452 Number of neutrons per fission
The thermal value of prompt neutrons was based on experimental data of Jaffey /1/ and Nu-d was taken from semi-empirical formula by Manero /2/. The energy dependent term was estimated from Howrton's formula /3/.
(Only total nu is given in the file.)

MF=2 Resonance Parameters
MT=151 Resolved resonance parameters for MLBW formula.
Energy range is from 1.0E-5 eV to 500 eV. Parameters were taken from the following experimental data.
49 resonances above 10 eV : Silbert /4/
4 resonances below 10 eV : Young /5/
The parameters of two negative and 2.9-eV resonances were adjusted to the thermal cross sections/6/.

Calculated 2200-m/s cross sections and resonance integrals

	2200-m/s	Res. Integ.
total	586.7 b	-
elastic	28.53 b	-
fission	17.89 b	32.7 b
capture	540.3 b	154 b

MF=3 Neutron Cross Sections

The energy region below 500 eV is the resonance region. Above 500 eV, the cross sections were evaluated as follows.

MT=1,2,4,51-78,91,102 Total, elastic and inelastic scattering, and capture cross sections
Calculated with optical and statistical models. CASTHY/7/ was used for the calculation.

Optical potential parameters:
The real potential was adjusted so as to obtained the reasonable compound nucleus formation cross section. The other parameters were taken from Murata's evaluation /8/.

V	= 38.8 - 0.05•En	(MeV)
Ws	= 6.5 + 0.15•En	(MeV)
Vso	= 7.0	(MeV)
a	= b =.aso= 0.47	(fm)
r	= rso= 1.32	(fm)
rs	= 1.52	(fm)

The level scheme:
Taken from Ref. /9/.

No.	Energy(keV)	Spin-Parity
g.s.	0.0	0 +
1	44.08	2 +
2	145.98	4 +
3	303.4	6 +
4	514.0	8 +
5	605.1	1 -
6	661.4	3 -
7	763.2	5 -
8	941.5	0 +
9	962.77	1 -
10	968.2	2 -
11	983.0	2 +
12	985.5	2 -
13	1028.55	2 +
14	1069.95	3 +
15	1082.57	4 -
16	1125.8	4 +
17	1174.5	2 +
18	1202.7	3 -
19	1228.6	0 +
20	1264.2	2 +
21	1310.3	2 +
22	1426.6	0 +
23	447.3	1 -
24	1458.5	2 +
25	1560.0	1 -
26	1596.5	2 +
27	1621.4	1 -
28	1636.6	1 -

Continuum levels assumed above 1.65 MeV.
The level density parameters of Gilbert and Cameron /10/.
The fission, (n,2n) and (n,3n) cross sections were taken into account as the competing processes.
For the capture cross section, the gamma-ray strength function was estimated from D-obs = 9.5eV and average radiative width = 0.04 eV.

MT=16,17 (n,2n) and (n,3n) reaction cross sections
Calculation based on the Pearlstein's method /11/.
MT=18 Fission cross section
Evaluated mainly on the basis of data measured by Budtz-Jorgensen/12/. Other experiments /4, 13-20/ were also taken into consideration.
MT=251 Mu-bar
Calculated with optical model.

MF=4 Angular Distributions of Secondary Neutrons
MT=2,51-78,91
Calculated with optical model.
MT=16,17,18
Isotropic in the laboratory system.

MF=5 Energy Distributions of Secondary Neutrons
MT=16,17,91
Evaporation spectrum was assumed.
MT=18

Maxwellian type fission spectrum. Temperature was estimated from Z**2/A systematics by Smith et al. /21/.

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MAT number = 3943

94-Pu-239 NAIG Eval-Mar87 M.Kawai, T.Yoshida, K.Hida
Dist-Sep89

History
87-03 Evaluation was made by
M.Kawai and K.Hida(NAIG) : cross sections above resonance region and other quantities,
T.Yoshida(NAIG) : resonance parameters and background cross sections,
88-08 Partly modified.
Nu-bar, Resolved resons., (n,2n).
89-02 FP yields were taken from JNDC FP Decay Data File version-2.
89-03 Unresolved resonance parameters were slightly modified.

Data were compiled by T.Nakagawa (JAERI).

MF=1 General Information
MT=451 Descriptive data and dictionary
MT=452 Number of neutrons per fission
Sum of Nu-p (MT=456) and Nu-d (MT=455).
MT=455 Delayed neutron data
Evaluated data by Tuttle /1/ were adopted.
MT=456 Number of prompt neutrons per fission
Standard Cf-252 SF Nu-p was taken to be 3.756. Thermal Nu-p was 2.8781 that was a mean value of experimental data. The energy dependent Nu-p was obtained from
below 10 eV : Ref./2/ multiplied by 1.001
10 eV <En< 500 eV: Ref./3/ multiplied by 1.0035
500eV <En< 100keV: Ref./2/ multiplied by 1.001
above 500 keV : Refs./4-8/
Factors are ratios of 2.8781 and the experiments at thermal energy.

MF=2 Resonance Parameters
MT=151 Resolved and unresolved resonance parameters
Resolved res. parameters for Reich-Moore formula: up to 1 keV
Parameters were taken from Refs./9/ and /10/, in which the fission cross section measured by Weston and Todd /11/ had been used as the basis of analysis. The parameters given in Ref. /10/ were revised in 1988 by the original authors and these final values /12/ were adopted here.
Unresolved resonances : from 1 to 30 keV.
The energy dependent S0, S1 and fission width were determined so as to reproduce the evaluated total, capture and fission cross sections.

2200-m/sec cross sections and calculated resonance integrals.

	2200 m/s	res. integ.
total	1025.5 b	-
elastic	8.831 b	-
fission	746.7 b	299 b
capture	270.0 b	185 b

MF=3 Neutron Cross Sections
Below 1 keV, background cross section was given to reproduce the fission cross section measured by Weston and Todd /11/.

Between 1 and 30 keV, cross sections were replaced with unresolved resonance parameters.

MT=1 Total
Below 7 MeV, JENDL-2 evaluation which were based on the experiments of Refs./13-17/ was adopted. Above 7 MeV, experimental data by Poenitz /18/ were adopted.

MT=2 Elastic scattering
Calculated as (Total) - (Partial cross sections).

MT=4, 51-68, 91 Inelastic scattering
The direct component was calculated with coupled channel code ECIS /19/. Eight states, marked with an asterisk in the level scheme given below, of the ground state rotational band were coupled in the calculation. Deformed optical potential parameters with a derivative Woods-Saxon absorption term were taken from Ref./20/:

```
V    =46.2 - 0.3*En           (MeV)
Wv   =-1.2 + 0.15*En          (MeV),   En > 8 MeV
Ws   = 3.6 + 0.4*En           (MeV),   En < 7 MeV
       6.4 + 0.1*(En-7)       (MeV),   En > 7 MeV
Vso  = 6.2                    (MeV)
r=rv = 1.26 ,  rs= 1.24    rso= 1.12 (fm)
a=av = 0.615,  as= 0.50 ,  aso= 0.47 (fm)
Beta-2= 0.21,  Beta-4= 0.065
```

The compound component was calculated with optical and statistical model code CASTHY /21/, taking into account level fluctuation and interference effects. The fission, (n,2n), (n,3n), and (n,4n) reactions were considered as competing processes.

The neutron transmission coefficients for the incident channel were generated with ECIS, whereas those for the exit channel were calculated with CASTHY using spherical optical potential parameters adopted for JENDL-2 evaluation:

```
V   = 40.72 - 0.05*En       (MeV)
Ws  = 6.78 - 0.29*En        (MeV)
Vso= 7.0                    (MeV)
r   = rso= 1.32, rs =1.357  (fm)
a   = aso= b = 0.47         (fm)
```

The surface absorption is of derivative Woods-Saxon type.
The level scheme was taken from Ref./22/:

No.	Energy(keV)	Spin-Parity	Coupled level
g.s.	0.0	1/2 +	*
1	7.86	3/2 +	*
2	57.28	5/2 +	*
3	75.71	7/2 +	*
4	163.76	9/2 +	*
5	194.	11/2 +	*
6	285.46	5/2 +	
7	317.	13/2 +	*
8	330.13	7/2 +	
9	360.	15/2 +	*
10	387.41	9/2 +	
11	391.6	7/2 -	
12	435.	9/2 -	

13	462.	11/2 +
14	469.8	1/2 -
15	488.	11/2 -
16	492.1	3/2 -
17	505.5	5/2 -
18	511.84	7/2 +

Continuum levels were assumed above 538 keV.

MT= 16, 17, 37 (n,2n), (n,3n), and (n,4n)

Calculated with a modified version of GNASH /23/. The neutron transmission coefficients were generated with ECIS /19/ and optical model code ELIESE-3 /24/, respectively, using the above-mentioned deformed and spherical potentials. The level schemes for Pu-236, -237, -238, -239 and -240 were taken from Refs. /22/ and /25-28/. The Gilbert-Cameron's composite formula /29/ was used to represent the level density. Level density parameters were determined from the observed s-wave resonance spacing /30/ and the level schemes. The spin cut-off factors in the constant temperature model were represented by Gruppelaar's prescription /31/.

	Pu-236	Pu-237	Pu-238	Pu-239	Pu-240
a (1/MeV)	25.50	28.00	26.23	29.44	26.96
T (MeV)	0.442	0.416	0.422	0.398	0.412
C (1/MeV)	3.06	14.5	2.88	15.0	3.30
E-joint(MeV)	4.71	4.09	4.38	3.97	4.26
sigma**2	8.63	8.18	6.47	11.6	9.69
no. levels	4.0	19.0	22.0	19.0	28.0
E-max (MeV)	0.307	0.4735	1.3103	0.5118	1.2621
D-obs (eV)	0.395	10.7	0.383	9.0	2.3
Gamma-g(eV)	0.043	0.027	0.043	0.034	0.043

D-obs of Pu-236, -237 and -238 were not available from Ref. /30/, and hence the parameters "a" for these nuclei were determined assuming its linear dependence on the mass A:

a = 0.365*A - 60.64 for even-even Pu isotopes

a = 0.659*A - 128.18 for odd-mass Pu isotopes

which were derived by analyzing the data of Pu-241, -242, -243, and -244 as well as Pu-239 and -240. Low-lying levels were hardly observed for Pu-236 and it was assumed to be identical to that of Pu-238 to determine the constant temperature parameters.

Evaluated fission cross section described below was fed to GNASH as a competing process. The preequilibrium process was taken into account. Though the parameter F2 was adjusted, the calculated (n,2n) cross section failed to well reproduce the measured data. Therefore, the measured (n,2n) cross section of Frehaut et al./33/ was adopted in place of the calculated one.

MT=18 Fission

Below 50 keV

Based on measurements of Ref./34/ and Ref./35/.

Above 50 keV

Simultaneous evaluation was performed by Kanda et al./36/

MT=102 Capture
The cross section in the energy range below 1 MeV was derived as a product of the evaluated fission cross section and alpha value. The alpha values are identical to those of JENDL-2. Above 1 MeV the results of the statistical model calculation with CASTHY /21/ linked with ECIS /19/ were adopted. The photon strength function was normalized in the CASTHY calculation so as to reproduce the capture cross section of 280 mb at 100 keV.

MT=251 Mu-bar
Calculated with optical model.

MF=4 Angular Distributions of Secondary Neutrons
MT=2,51-68,91 Calculated with ECIS /19/ and CASTHY /21/.
MT=16,17,18,37 Isotropic in the laboratory system.

MF=5 Energy Distributions Secondary Neutrons
MT=16,17,37,91
Calculated with threshold cross section calculation code PEGASUS /37/ on the basis of preequilibrium and multi-step evaporation model.
MT=18
Distributions calculated with the formula of Madland and Nix /38/ were adopted. Constant compound nucleus formation cross section model was adopted.

Total average FF kinetic energy = 177.1 MeV
Average energy release = 198.154 MeV
Average mass number of light FF = 100
Average mass number of heavy FF = 140
Level density parameter = A/9.0

MT=455
Taken from Saphier et al. /39/

MF=8 Fission product yields
MT=454 Independent yields
MT=459 Cumulative yields
Both were taken from JNDC FP Decay Data File version-2/40/.

MF=12 Photon Production Multiplicities and Transition Probability arrays
MT=16,17,37,91,102 (n,2n),(n,3n),(n,4n),Inelastic Scattering to the continuum, and Capture
Data calculated with GNASH /23/ were stored under Option-1 (multiplicities). The photon branching data were taken from Refs. /22/ and /25-28/. Some assumptions were made for levels of Pu-237 and -239 which had no information on branching: If E1 transitions were allowed to lower levels, the transition probabilities were equally shared among them. If not, equally shared collective E2 transitions were assumed. The photon strength functions were represented by the Brink-Axel type giant dipole resonance with conventional resonance positions and widths. They were normalized to input values at the thermal energy. The pygmy resonance was introduced only for Pu-240. The parameters were assumed to be the same as those of U-238 /41/.

MT=18 Fission
Stored under Option-1 (multiplicities). The thermal neutron *induced fission gamma spectrum measured by* Verbinski /42/ was adopted and used up to 20 MeV neutron. Since no data were given for the photons below 0.14 MeV, it was assumed to be the same as that of the photons between 0.14 and 0.3 MeV.

MT=51-68 Inelastic Scattering
Stored under Option-2 (transition probability arrays). Data were taken from Ref./22/, and the same assumptions as described above were applied to the levels to which no data were given.

MF=14 Photon Angular Distributions
MT=16,17,18,37,51-68,91,102 Isotropic.

MF=15 Continuous Photon Energy Spectra
MT=16,17,37,91,102 Calculated with GNASH /23/
MT=18 Experimental data by Verbinski /42/ were adopted.

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MAT number = 3944

94-Pu-240 NAIG+ Eval-May87 T.Murata, A.Zukeran
Dist-Sep89

History
87-05 Evaluation was made by
T.Murata (NAIG) : Cross sections above resonance region and other quantities,
A.Zukeran(Hitachi): Resonance parameters.
88-06 MT's=16, 17, 37 and 102 were modified.
89-02 FP yields were taken from JNDC FP Decay File version-2.
Compilation was made by T. Nakagawa (JAERI).

MF=1 General Information
MT=451 Comments and dictionary
MT=452 Number of neutrons per fission
Sum of MT=455(delayed neutrons) and MT=456(prompt neutrons).
MT=455 Delayed neutron data
Assumed to be the same as those of Pu-239.
MT=456 Number of prompt neutrons
Linear least-squares fitting to the experimental data of Frehaut et al. /1/ renormalized to Cf-252 Nu-p=3.756.

MF=2 Resonance Parameters
MT=151 Resolved and unresolved resonance parameters
1) Resolved resonances for MLBW formula (1.0E-5 to 4 keV)
Parameters of a negative and the 1.057-eV resonances were revised on the basis of recommendation by Mughabghab /2/. Neutron and capture widths of other levels were based on the experimental data by Hockenbury et al. /3/ in the energy range from 20 to 500 eV, and Kolar and Boeckhoff /4/ from 500 eV to 4 keV. The average capture width of 29.5 milli-eV was assumed for the resonances whose capture widths were unknown. Below 610 eV, the sub-threshold fission widths were calculated from the area data by Weston and Todd /5/. Above 610 eV, they were taken from the data by Auchampaugh and Weston /6/.
2) Unresolved resonances (4 to 40 keV)
Energy dependent parameters were determined to reproduce the evaluated cross sections in this energy region. Fission widths were adjusted to average cross sections measured by Weston and Todd /5/.

Calculated 2200-m/sec cross sections and res. integerals.

	2200-m/sec	res. integ.
total	291.13 b	
elastic	1.644 b	-
fission	0.0588 b	8.94 b
capture	289.4 b	8110. b

MF=3 Neutron Cross Sections
Below 4 keV: Background cross sections are given to the capture cross section.
Above 4 keV: Evaluated as follows. In the energy range from 4 to 40 keV, the cross sections are represented with the unresolved resonance parameters, and the background cross sections are given in MF=3.

MT=1 Total
Evaluated with spline fitting to the experimental data of Smith et al./7/, Kaeppeler et al./8/ and Poenitz et al./9/

MT=2 Elastic scattering
Obtained by subtracting the other cross sections from total cross section.

MT=4 Total inelastic scattering
Sum of partial inelastic scattering cross sections (MT=51 to MT=91).

MT=51-78, 91 Partial inelastic scattering
Below 3 MeV, the results of statistical and coupled- channel calculation made by Lagrange et al. /10/ were adopted. For some levels, for which Smith's experimental data /11/ were available, the calculated results were normalized (for 1st, 2nd, 3rd, 5th and 9 to 11th levels).

Level scheme

No.	Energy(MeV)	Spin-Parity
g.s.	0.0	0 +
1	0.04285	2 +
2	0.14169	4 +
3	0.29431	6 +
4	0.4976	8 +
5	0.59736	1 -
6	0.64889	3 -
7	0.74232	5 -
8	0.8607	0 +
9	0.90032	2 +
10	0.93807	1 -
11	0.95887	2 -
12	0.9924	4 +
13	1.0018	3 -
14	1.0306	3 +
15	1.0375	4 -
16	1.0764	4 +
17	1.0895	0 +
18	1.1155	5 -
19	1.1370	2 +
20	1.1615	6 -
21	1.1778	3 +
22	1.2230	2 +
23	1.2325	4 +
24	1.2408	2 -
25	1.2621	3 +
26	1.2820	3 -
27	1.30873	5 -
28	1.41079	0 +

Levels above 1.4108 MeV were assumed to be continuum.

MT=16,17,37 (n,2n),(n,3n) and (n,4n)
Calculated from neutron emission cross section and branching ratio to each reaction channel. Neutron emission cross section was obtained by subtracting the fission and capture cross sections from compound nucleus formation cross section

calculated with spherical optical model. Branching ratio was obtained from formalism given by Segev et al. /12/

MT=18 Fission
Below 100 keV: Average values of fission cross section measured by Weston and Todd /5/ were normalized to the value at 100 keV of the simultaneous evaluation.
Above 100 keV: Simultaneous evaluation was made by taking account of experimental data of fission ratio and absolute cross sections of U-235, U-238, Pu-239, Pu-240 and Pu-241, and capture cross section of Au-197 /13/.

MT=102 Capture
Below 350 keV: Based on the experimental data of Hockenbury et al. /3/, Weston and Todd /14/ and the ratio data of Wisshak and Kaeppeler /15/ with the capture cross section of Au-197 /13/. As a guide line, statistical model calculation was made with CASTHY code /16/.
Above 350 keV: The statistical model calculation was normalized to the value at 350 keV. Direct and collective capture was included in high energy region adopting the value for U-238 given by Kitazawa et al. /17/.

The spherical optical potential parameters

```
   V  = 40.6 - 0.05*En,  Ws = 6.5 + 0.15*En (MeV)
   Vso= 7.0                                 (MeV)
   r  = rso =1.32     ,  rs = 1.38          (fm)
   a  = as  = aso =0.47                     (fm)
```

Level density parameters were determined to reproduce the resonance level spacings and staircases of discrete levels.

MT=251 Mu-bar
The same as JENDL-1 /18/ except for 20 MeV.

MF=4 Angular Distributions of Secondary Neutrons
MT=2
Taken from JENDL-2 /18/.
MT=16,17,18,37,91
Assumed to be isotropic in the laboratory system.
MT=51-78
For the 1st and 2nd levels, results of Lagrange et al. /10/ were adopted. For others, statistical and DWBA calculations were made.

MF=5 Energy Distributions of Secondary Neutrons
MT=16,17,91
Calculated with pre-compound and multi-step evaporation theory code PEGASUS /19/.
MT=37
Evaporation spectrum was given.
MT=18 Fission spectra
Calculated from Madland-Nix formula /20/.

Average energy release	= 199.179 MeV
Total average FF kinetic energy	= 177.53 MeV
Average mass number of light FF	= 101
Average mass number of heavy FF	= 140
Level density parameter	= A/10.0

MT=455 Delayed neutron spectra
Assumed to be the same as Pu-239 which were taken from the evaluation by Saphier et al. /21/.

MF=8 Fission Product Yields
MT=454 Independent yields
MT=459 Cumulative yields
Both were taken from JNDC FP Decay File version-2/22/.

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MAT number = 3945

94-Pu-241 JAERI Eval-Oct87 Y.Kikuchi,N.Sekine,T.Nakagawa
Dist-Sep89

History
79-10 New evaluation was made by Y.Kikuchi (JAERI) and N.Sekine (HEC). Data of JENDL-1 /1/ were superseded.
79-12 Files 2, 3 and 4 were released as JENDL-2B /2/.
87-03 Data were revised by adopting the simultaneous evaluation for the fisstion cross section.
89-02 FP Yields were added.

MF=1 General Information
MT=451 Comment and dictionary
MT=452 Number of neutrons per fission
Sum of Nu-p (MT=456) and Nu-d (MT=455).
MT=455 Delayed neutron data
Data of Benedetti + /3/
MT=456 Number of prompt neutrons per fission
Data of Boldeman and Frehaut /4/ for thermal fission were adopted at low energy by assuming Nu-p(Cf-252 spontaneous fission) = 3.753 for JENDL-2. For JENDL-3, data were increased by a factor of 3.756/3.753. An energy dependent term was based on Frehaut + /5/

MF=2,MT=151 Resonance Parameters (the same as JENDL-2)
Resolved resonances : 1 - 100 eV
JENDL-1 data /1/ modified for better fit to experiments. A negative resonance added. Background cross section applied for fission and capture.

Unresolved resonances : 100 eV - 30 keV
Obtained by fitting evaluated fission and capture cross sections.
Energy dependent parameters : So, S1 and Gam-f.
Fixed parameters : R=9.8 fm , Gam-g = 0.040 ev,
D-obs = 0.85 eV

2200-m/sec cross sections and calculated resonance integrals.

	2200 m/sec	Res. Integ.
total	1388.2 b	-
elastic	10.23 b	-
fission	1015. b	590 b
capture	363.0 b	187 b

MF=3 Neutron Cross Sections
Point-wise data below 1 eV down to 1.0E-5 eV
Total : on the basis of the data of Smith + /6/
Fission : on the basis of the data of Wagemans + /7/
Elastic : calculated from resonace parameters
Capture : total - (fission + elastic)

Background cross sections for resolved resonances are given, and no background cross sections for unresolved resonances.

Above 30 keV, smooth cross sections given as follows.

MT=1, 2, 4, 51-61, 91, 251 : Total, elastic, inelastic scattering cross sections and mu-bar
Calculated with optical and statistical models. Optical potential parameters used were obtained from systematics /8/
V = 40.25 - 0.05*En , Ws = 6.5 , Vso = 7.0 (MeV)
r = rso = 1.32 , rs = 1.38 (fm)
a = b = aso = 0.47 (fm)
Statistical model calculation was performed with CASTHY code /9/. Taken into the calculation were competing processes (fission, (n,2n), (n,3n), (n,4n)) and level fluctuation.
The level scheme taken from Ref. /10/.

No	Energy(keV)	Spin-Parity
g.s.	0	5/2 +
1	41.8	7/2 +
2	94.0	9/2 +
3	161.5	1/2 +
4	170.8	3/2 +
5	223.1	5/2 +
6	230.0	9/2 +
7	242.7	7/2 +
8	300	11/2 +
9	335	9/2 +
10	368	13/2 +
11	445	11/2 -

Continuum levels assumed above 490 keV.
The leval density parameters : Gilbert and Cameron /11/.

MT=16, 17, 37 (n,2n), (n,3n), (n,4n)
Calculated with evaporation model.

MT=18 Fission
Above 70 keV, simultaneous evaluation with U-235, U-238, Pu-240, Pu-241 /12/ were adopted. The experimental data taken into account are those by Szabo+ /13,14/, Carlson+ /15,16/, Fursov+ /17/and Keappeler+ /18/. Below 45 keV, JENDL-2 was adopted. These two sets of data were connected smoothly between 45 and 70 keV.

MT=102 Capture
Based on the data of Alpha by Weston+ /19/ up to 250 keV. Calculated with CASTHY above 250 keV. The gamma-ray strength function was determined so that Sig-c =269 mb at 250 keV.

MF=4 Angular Distributions of Secondary Neutrons
MT=2, 51-61 : Calculated with CASTHY.
MT=16,17,18,37,91 : Isotropic in the laboratory system.

MF=5 Energy Distributions of Secondary Neutrons
MT=16,17,18,37,91
Calculated with pre-equilibrium and multi-step evaporation code PEGASUS/20/.
MT=18 Prompt fission neutron spectrum.
Determined from Z**2/A systematics by Smith et al. /21/.
MT=455 Delayed neutron spectrum.
Evaluation by Sahier et al. /22/ was adopted.

MF=8 Fission Product Yields
MT=454 Independent yields
MT=459 Cumulative yields
Both were taken from JNDC FP Decay File version-2/23/.

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MAT number = 3946

94-Pu-242 NAIG Eval-Mar87 T.Murata, M.Kawai
Dist-Sep89

History
87-05 Evaluation was made by
T.Murata (NAIG): Cross sections above resonance region and other quantities,
M.Kawai (NAIG): Resonance parameters.
89-02 FP Yields were added.
Compilation was made by T. Nakagawa (JAERI).

MF=1 General Information
MT=451 Descriptive data and dictionary
MT=452 Total number of neutrons per fission
Taken from ENDF/B-IV /1/.

MF=2 Resonance Parameters
MT=151 Resonance parameters
Resolved resonance parameters for MLBW (1.0E-5 eV to 1.15 keV)
Evaluation for JENDL-2 was modified on the basis of fission cross section measurements by Weigmann et al. /2/
Res. Energies = BNL 325 (3rd) /3/
Neutron and capture widths = Poortmans et al. /4/, Auchampaugh et al./5/
Fission widths = Weigmann et al. /2/
R = 9.9 fm
Average capture width = 0.0242 eV
Two negative resonances were added to reproduce 2200-m/s cross sections recommended by Mughabghab /6/
Unresolved resonance parameters (1.15 to 40 keV)
Parameters were determined to reproduce cross sections evaluated as described below.

Calculated 2200-m/s cross sections and resonance integrals

	2200-m/s(b)	res. integ.(b)
total	27.11	----
elastic	8.32	----
fission	0.00256	5.58
capture	18.79	1130

MF=3 Neutron Cross Sections
Below 40 keV, represented with resonance parameters.

MT=1 SIG-TOT
Below 6 keV : Experimental data of Young and Reeder /7/ were averaged over some keV energy interval.
Above 6 keV : Spline fitting to experimental data of Kaeppeler et al. /8/ and Moore et al. /9/

MT=2 SIG-EL
Obtained by subtracting other cross sections from total.

MT=4 SIG-INEL
Sum of partial inelastic cross sections

MT=51-91 Partial SIG-INEL

Below 3 MeV : The results of statistical and coupled channel calculation of Lagrange et al./10/ were adopted.
Above 3 MeV : Extrapolation of the values was made based on DWBA calculation.

Level Scheme

No.	Energy(MeV)	Spin-Parity
G.S.	0.0	0 +
1	0.04285	2 +
2	0.141685	4 +
3	0.294314	6 +
4	0.4976	8 +
5	0.59736	1 -
6	0.64889	3 -
7	0.74232	5 -
8	0.8607	0 +
9	0.90032	2 +
10	0.93807	1 -
11	0.95887	2 -
12	0.9924	4 +
13	1.0018	3 -
14	1.0306	3 +
15	1.0375	4 -
16	1.0764	4 +
17	1.0895	0 +
18	1.1155	5 -
19	1.1370	2 +
20	1.1615	6 -
21	1.1778	3 +
22	1.223	2 +
23	1.2325	4 +
24	1.2408	1 -
25	1.2621	3 +
26	1.2820	3 -
27	1.30873	5 -
28	1.41079	0 +

Levels above 1.41079 MeV were assumed to be continuum.

MT=16,17,37 Sigmas of (n,2n), (n,3n) and (n,4n)
Given by multiplication of neutron emission cross section and branching ratio to each reaction. The neutron emission cross section was obtained by subtracting fission and capture cross sections from reaction cross section calculated with spherical optical model. The branching ratio was calculated with the formalism given by Segev et al./11/

MT=18 SIG-FISS
Below 100 keV : Shape of SIG-FISS determined on the fission area data of Auchampaugh et al./12/ Then normalized to the value of higher energy region.
Above 100 keV : Fisson ratio to U-235 was determined on the experimental data of Behrens et al./13/ and multiplied by U-235 fission cross section /14/.

MT=102 SIG-CAP
Energy region of 6 keV to 210 keV : Determined on the basis of

experimental data of Hochenbury et al./15/ and Wisshak and Kaeppeler /16/.

Other energy region : Statistical calculation result with CASTHY code /17/ was normalized to SIG-CAP in the region of 6 to 210 keV. Direct and collective capture processes were included in high energy region using the value of U-238 given by Kitazawa et al./18/

** Parameters for the CASTHY code calculation

Spherical optical potential parameters

V=40. 1-0.05En ,	Ws=6.5+0.15En ,	Vso=7.0	(MeV)
r=1.32 ,	rs=1.38 ,	rso=1.32	(fm)
a=as=aso=0.47			(fm)

Level density parameters were determined to reproduce the resonance level spacings and level scheme sum staircases.

MT=251 Mu-L

Assumed to be the same as that of Pu-240.

MF=4 Angular Distributions

The same distributions as Pu-240 were assumed, which were determined as follows.

MT=2 DSIG-El

Spherical optical model calculation

MT=51 to 91 DSIG-Inel

For the 1st and 2nd levels the results of calculation of Lagrange et al./10/ are available and their results were adopted. For other levels, statistical plus DWBA calculations were made.

MF=5 Energy Distributions of Secondary Neutrons

MT=16,17 and 91

Distributions were calculated with PEGASUS/19/

MT=37

Evaporation spectrum was taken from JENDL-2

MT=18

Taken from JENDL-2. Temperature was estimated from Z**2/A systematics by Smith et al. /20/

MF=8 Fission Product yields

MT=454 Independent Yields

MT=459 Cumulative Yields

Both were taken from JNDC FP Decay Data File version-2/21/.

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MAT number = 3951

95-Am-241 JAERI Eval-Mar88 T.Nakagawa
JAERI-M 89-008 Dist-Sep89
History
82-03 Evaluation for JENDL-2 was made by Y.Kikuchi (JAERI) /1/.
88-03 Re-evaluation for JENDL-3 was made by T.Nakagawa (JAERI) /2/.

MF=1 General Information
MT=451 Comment and dictionary
MT=452 Number of neutrons per fission
Sum of Nu-p (MT=456) and Nu-d (MT=455).
MT=455 Delayed neutron data
Estimated with semi-empirical formula by Tuttle /3/.
MT=456 Number of prompt neutrons
Experimental data of Jaffey and Lerner /4/.

MF=2,MT=151 Resonance parameters
Resolved resonances for MLBW formula : 1.0E-5 - 150 eV
Data of Derrien and Lucas /5/ were adopted and 5 negative resonances were added. Values of total spin J were replaced with arbitrarily assumed values.

Unresolved resonances : 150 eV - 30 keV
Parameters were determined by using ASREP/6/ so as to reproduce the capture cross section measured by Vanpraet et al. /7/ and the fission cross section by Dabbs et al. /8/.
Energy independent parameters:
R=9.37 fm, Gam-g=0.044 eV, Dobs=0.4 eV
Energy dependent parameters:
At 150 eV: S0= 1.08E-4, S1=2.72E-4, WF=0.24 milli-eV
At 30 keV: S0= 0.79E-4, S1=1.99E-4, WF=0.30 milli-eV

Calculated 2200-m/s cross sections and resonance integrals

	2200 m/s value	Res. Int.
total	614.6 b	-
elastic	11.13 b	-
fission	3.018 b	13.9 b
capture	600.4 b	1300 b

MF=3 Neutron Cross Sections

MT=1,2 Total and elastic scattering cross sections
Calculated with optical and statistical models by using CASTHY/9/. Optical potential parameters/10/ were obtained by fitting the data of Phillips and Howe /11/ :

```
V = 43.4 - 0.107*En                        (MeV)
Ws= 6.95 - 0.339*En + 0.0531*En**2         (MeV)
Wv= 0                  , Vso = 7.0         (MeV)
r = rso = 1.282        , rs = 1.29         (fm)
a = aso = 0.60         , b  = 0.5          (fm)
```

MT=4,51-66,91 Inelastic scattering cross sections
Optical and statistical model calculation with CASTHY code /9/. The level scheme was taken from Ref. /12/

No	energy(keV)	spin-parity
g.s.	0	5/2 -
1	41.176	7/2 -
2	93.65	9/2 -
3	158.0	11/2 -
4	205.883	5/2 +
5	235.0	7/2 +
6	272.0	9/2 +
7	320.0	11/2 +
8	471.81	3/2 -
9	504.448	5/2 -
10	549.0	7/2 -
11	623.1	1/2 +
12	636.861	3/2 -
13	652.089	1/2 -
14	653.23	3/2 +
15	670.24	3/2 +
16	682.0	11/2 -

Continuum levels assumed above 732 keV.

The level density parameters were determined on the basis of number of excited levels/13/ and resonance level spacing/14/.

	Am-242	Am-241
a(1/MeV)	29.6	29.0
T(MeV)	0.342	0.367
C(1/MeV)	22.98	9.95
E-x(MeV)	2.323	3.122
spin-cutoff(1/MeV**0.5)	30.85	30.45
pairing E(MeV)	0.0	0.43

MT=16,17 (n,2n) and (n,3n) reaction cross sections
JENDL-2 data calculated with evaporation model were adopted.

MT=18 Fission cross section
Evaluated on the basis of the data by Dabbs et al./8/

MT=102 Capture cross section
Evaluated on the basis of the measured data of Vanpraet et al./7/ in the unresolved resonance region. Above 30 keV, Calculation with CASTHY was adopted. The gamma-ray strength function was determined so that the cross section was 1.7 barns at 60 keV.

MT=251 Mu-bar
Calculated with optical model.

MF=4 Angular Distributions of Secondary Neutrons
MT=2,51-66,91 Calculated with CASTHY.
MT=16,17,18 Isotropic in the lab system.

MF=5 Energy Distributions of Secondary Neutrons
MT=16,17,91 Evaporation spectrum.
MT=18 Maxwellian fission spectrum. Temperature was estimated from Z**2/A values /15/.

MF=8 Fission product yield data

MT=454 Fission product yield data
Taken from ENDF/B-IV, and renormalized to 2.0.

References

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12) Ellis-Akovali Y.A.: Nucl. Data Sheets, 44, 407 (1985).
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15) Smith A.B. et al.: ANL/NDM-50 (1979).

MAT number = 3952

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 95-Am-242 JAERI        Eval-Mar80 T.Nakagawa, S.Igarasi
JAERI-M 8903 (1980)    Dist-Sep89
History
80-03 New evaluation was made by T.Nakagawa and S.Igarasi(JAERI).
      Details are given in Ref. /1/.
87-04 Format was translated to ENDF-5 format.
88-03 Since no recent experimental data were available, the data
      of JENDL-2 were adopted for JENDL-3.

MF=1  General Information
  MT=451  Comment and dictionary
  MT=452  Number of neutrons per fission
           Sum of prompt and delayed neutrons.
  MT=455  Delayed neutron data
           Estimated from Tuttle's semi-empirical formula /2/.
  MT=456  Number of prompt neutrons per fission
           Semi-empirical formula by Howerton /3/
             Nu-p= 3.268 + 0.172*E(MeV).

MF=2  Resonance Parameters
  MT=151  No resonance parameters

     2200m/s cross sections and calculated resonance integrals.
                        2200 m/sec    Res. Integ.
           total        7611.44 b         -
           elastic        11.44 b         -
           fission      2100.0  b       1260 b
           capture      5500.0  b        391 b

MF=3  Neutron Cross Sections
  MT=1,2,4,51-72,91,102,251        Sig-t,Sig-el,Sig-in,Sig-c,Mu-bar
     Below 0.225 eV:
           1/v form was assumed for fission and capture cross
           sections.  Effective scattering radius of 9.54 fm was
           used for elastic scattering cross-section calculation.
     Above 0.225 eV:
           Optical and statistical models were used.
           The spherical optical potential parameters (MeV, fm) :
            V= 42.0 - 0.107*E , r= 1.282 , a= 0.6
            Ws= 9.0 - 0.339*E + 0.0531*E**2 , r= 1.29 , a= 0.5
            Vso= 7.0 , r= 1.282 , a= 0.6
            Statistical model calculation with CASTHY code /4/.
            Competing processes : fission,(n,2n) and (n,3n).
            Level fluctuation considered.  Gam-g = 0.05 eV and
            D = 0.45 eV used for capture cross section calculation.
            The level scheme taken from the compilation by Ellis
            and Haese /5/.
              No.      Energy(MeV)         Spin-Parity
             g.s.        0.0                 1   -
               1         0.044               0   -
               2         0.049               3   -
               3         0.049               5   -
               4         0.074               2   -
               5         0.113               6   -
               6         0.148               4   -
```

7	0.148	5	-
8	0.190	7	-
9	0.242	3	-
10	0.263	6	-
11	0.263	7	-
12	0.288	4	-
13	0.288	2	-
14	0.325	3	-
15	0.341	5	-
16	0.377	4	-
17	0.410	6	-
18	0.430	5	-
19	0.488	7	-
20	0.500	6	-
21	0.581	7	-
22	0.679	8	-

Overlapping levels are assumed above 0.681 MeV.
The level density parameters of Gilbert and Cameron /6/.

MT=16,17 (n,2n) and (n,3n) cross sections
Calculated with the evaporation model by Pearlstein /7/.

MT=18 Fission cross section
The empirical formula used for the Am-242m data was applied by shifting the energy origin to -49 keV.

MF=4 Angular Distributions of Secondary Neutrons
MT=2 Legendre coefficients are given by the optical and statistical model calculations.
MT=16,17,18,91 Isotropic distributions in the center-of-mass system.
MT=51-72 Isotropic distributions in the laboratory system.

MF=5 Energy Distributions of Secondary Neutrons
MT=16,17,91 Evaporation spectrum
MT=18 Fission spectrum estimated from Z**2/A systematics by Smith et al. /8/ by assuming E(Cf-252) = 2.13 MeV.

References

1) T. Nakagawa and S. Igarasi : JAERI-M 8903 (1980), in Japanese.
2) R.J. Tuttle : INDC(NDS)-107/G+Special, 29 (1979).
3) R.J. Howerton : Nucl. Sci. Eng., 62, 438 (1977).
4) S. Igarasi : J. Nucl. Sci. Technol., 12, 67(1975).
5) Y.A. Ellis and R.L. Haese : Nucl. Data Sheets 21, 615 (1977).
6) A. Gilbert and A.G.W. Cameron : Can. J. Phys., 43, 1446 (1965).
7) S. Pearlstein : Nucl. Sci. Eng., 23, 238 (1965).
8) A.B. Smith et al. : ANL/NDM-50 (1979).

MAT number = 3953

95-Am-242mJAERI Eval-Mar88 T.Nakagawa
JAERI-M 89-008 Dist-Sep89
History
80-03 New evaluation was made by T.Nakagawa and S.Igarasi (JAERI).
Details are given in Ref. /1/.
88-03 Re-evaluation was made for JENDL-3 by T.Nakagawa (JAERI)/2/.

MF=1 General Information
MT=451 Comment and dictionary
MT=452 Number of neutrons per fission
Sum of prompt and delayed neutrons.
MT=455 Delayed neutron data
Estimated from Tuttle's semi-empirical formula /3/.
MT=456 Number of prompt neutrons per fission
Based on the relative measurements /4,5/ to the U-235 data, and on the empirical formula by Howerton /6/.

MF=2 Resonance Parameters
MT=151 Resonance parameters
Resolved resonance parameters : below 20 eV
Parameters for 48 levels deduced by Browne et al./7/ and the single level Breit-Wigner formula were adopted.

Unresolved resonance parameters : 20 eV - 30 keV
Parameters were determined so as to reproduce the fission cross section of Browne et al./7/. Background sig was given to the fission at low energies.
Average WG = 0.05 eV, Average WF = 1.28 eV,
D-obs = 0.4 eV, S0 = 1.07E-4, S1 = e-dependent,
R = 9.59 fm

Calculated 2200m/s cross sections and resonance integrals.

	2200 m/sec	Res. Integ.
total	7969. b	-
elastic	5.667 b	-
fission	6409. b	1560 b
capture	1254. b	246 b

MF=3 Neutron Cross Sections
Below 30 keV: Cross sections were represented with the resonance parameters.
Above 30 keV:

MT=1,2 Total and elastic scattering cross sections
Calculated with optical and statistical model code CASTHY/8/.
The spherical optical potential parameters (MeV, fm) :
V= 42.0 - 0.107*E , r= 1.282 , a= 0.6
Ws= 9.0 - 0.339*E + 0.0531*E**2 , r= 1.29 , a= 0.5
Vso= 7.0 , r= 1.282 , a= 0.6

MT=4,51-72,91 Inelastic scattering cross sections
Calculated with CASTHY/8/. The level scheme was taken from the compilation by Ellis and Haese /9/, with shifted energy origin at -49 keV.

No.	Energy(MeV)	Spin-Parity
g.s.	-0.049	1 -
1	-0.005	0 -
2	0.0	3 -
3	0.0 (meta stable)	5 -
4	0.025	2 -
5	0.064	6 -
6	0.099	4 -
7	0.099	5 -
8	0.141	7 -
9	0.193	3 -
10	0.214	6 -
11	0.214	7 -
12	0.239	4 -
13	0.239	2 -
14	0.276	3 -
15	0.292	5 -
16	0.323	4 -
17	0.361	6 -
18	0.381	5 -
19	0.439	7 -
20	0.451	6 -
21	0.532	7 -
22	0.630	8 -

Overlapping levels were assumed above 0.632 MeV.
The level density parameters were determined on the basis of number of excited levels/10/ and resonance level spacing/11/.

	Am-243	Am-242
a(1/MeV)	31.3	29.6
T(MeV)	0.355	0.342
C(1/MeV)	11.71	22.98
E-x(MeV)	3.278	2.323
spin-cutoff(1/MeV**0.5)	31.81	30.85
pairing E(MeV)	0.5	0.0

MT=16,17 (n,2n) and (n,3n) cross sections
Taken from JENDL-2 calculated with the evaporation model by Pearlstein /12/.

MT=18 Fission cross section
Determined by cubic spline-fitting to the data measured by Browne et al./7/

MT=102 Capture cross section
Calculated with CASTHY/8/. The gamma-ray strength function was estimated from WG=0.05 eV and D-obs=0.4 eV.

MT=251 Mu-L bar
Calculated with CASTHY/8/.

MF=4 Angular Distributions of Secondary Neutrons
MT=2,51-72,91
Legendre coefficients were given by the optical and statistical model calculations.
MT=16,17,18
Isotropic distributions in the laboratory system.

MF=5 *Energy Distributions of Secondary Neutrons*
MT=16,17,91 Evaporation spectrum with nuclear temperature calculated from level densities.
MT=18 Fission spectrum estimated from Z**2/A systematics by Smith et al. /13/ by assuming E(Cf-252) = 2.13 MeV.

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1) Nakagawa T. and Igarasi S.: JAERI-M 8903 (1980), in Japanese.
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MAT number = 3954

95-Am-243 JAERI Eval-Mar88 T.Nakagawa
JAERI-M 89-008 Dist-Sep89
History
77-03 New evaluation was made by S.Igarasi and T.Nakagawa (JAERI).
Details are given in Ref. /1/.
82-03 Complete reevaluation for JENDL-2 was made by Y.Kikuchi (JAERI). Details are given in Ref. /2/.
88-03 Reevaluated for JENDL-3 was made by T.Nakagawa (JAERI)/3/.

MF=1 General Information
MT=451 Comment and dictionary
MT=452 Number of neutrons per fission
Sum of Nu-p (MT=456) and Nu-d (MT=455).
MT=455 Delayed neutron data
Estimated with semi-empirical formula by Tuttle /4/.
MT=456 Number of prompt neutrons
Estimated from systematics. Same as previous evaluation /1/.

MF=2,MT=151 Resonance parameters
Resolved resonances for MLBW formula : 1.0E-5 - 215 eV.
JENDL-2 evaluation/2/ was based on the data of Simpson et al./5/. The fission widths were modified for JENDL-3 on the basis of Knitter and Budtz-Jorgensen/6/. Values of total spin were assumed arbitrarily.

Unresolved resonances : 215 eV - 30 keV
Parameters of JENDL-2 were adopted.
Obtained from optical model calculation:
S0=0.93E-4, S1=2.44E-4, R=9.34 fm
Estimated from resolved resonances:
Dobs=0.67 eV, WG=0.039 eV, WF=0.00012 eV

Calculated 2200-m/s cross sections and resonance integrals

	2200 m/s value	Res. Int.
total	86.10 b	-
elastic	7.483 b	-
fission	0.1161 b	7.59 b
capture	78.50 b	1830 b

MF=3 Neutron Cross Sections
Below 30 keV: Cross sections were represented with the resonance parameters.
Above 30 keV:

MT=1,2 Total and elastic scattering cross sections
Calculated with optical and statistical model code CASTHY/7/. Optical potential parameters were obtained /8/ by fitting the data of Phillips and Howe /9/ for Am-241:

```
V = 43.4 - 0.107*En                    (MeV)
Ws= 6.95 - 0.339*En + 0.0531*En**2     (MeV)
Vso = 7.0                              (MeV)
r = rso = 1.282   , rs = 1.29          (fm)
a = aso = 0.60    , b  = 0.5           (fm)
```

MT=4,51-59,91 Inelastic scattering cross sections
Calculated with CASTHY/8/. The level scheme was taken from Ref. /10/

No	Energy(keV)	Spin-Parity
g.s.	0	5/2 -
1	42.2	7/2 -
2	84.0	5/2 +
3	96.4	9/2 -
4	109.3	7/2 +
5	143.5	9/2 +
6	189.3	11/2 +
7	266.0	3/2 -
8	300.0	5/2 -
9	345.0	7/2 -

Continuum levels assumed above 383 keV.

The level density parameters were determined on the basis of number of excited levels/11/ and resonance level spacing/12/.

	Am-244	Am-243
a(1/MeV)	30.3	31.3
T(MeV)	0.340	0.355
C(1/MeV)	26.47	11.71
E-x(MeV)	2.373	3.278
spin-cutoff(1/MeV**0.5)	31.39	31.81
pairing E(MeV)	0.0	0.5

MT=16,17,37 (n,2n), (n,3n) and (n,4n) reaction cross sections
Taken from JENDL-2 calculated with the evaporation model.

MT=18 Fission cross section
30 keV - 100 keV : smooth corve connecting the data in the unresolved resonance region and above 100 keV
100 keV - 10 MeV : Spline-fitting to Kanda et al./13/, Fursov et al./14/ and Knitter and Budtz-Jorgensen/6/.
10 MeV - 20 MeV : Shape was estimated on the basis of Behrens and Browne/15/

MT=102 Capture cross section
Calculated with CASTHY/8/. The gamma-ray strength function was determined to reproduce the cross section of 2.2 b at 30 keV/16/.

MT=251 Mu-L bar
Calculated with CASTHY/8/.

MF=4 Angular Distributions of Secondary Neutrons
MT=2,51-59,91
Legendre coefficients were given by the optical and statistical model calculation.
MT=16,17,18,37
Isotropic distributions in the laboratory system.

MF=5 Energy Distributions of Secondary Neutrons
MT=16,17,37,91
Evaporation spectrum with nuclear temperature calculated from level densities.

MT=18

Maxwellian fission spectrum estimated from Z**2/A systematics by Smith et al./17/.

MF=8 Fission product yield data

MT=454 Fission product yield data

Taken from ENDF/B-IV and renormalized to 2.0.

References

1) Igarasi S. and Nakagawa T.: JAERI-M 7174 (1977).
2) Kikuchi Y.: JAERI-M 82-096 (1982).
3) Nakagawa T.: JAERI-M 89-008 (1989).
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11) ENSDF, Evaluated Nuclear Structure Data File (1988).
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14) Fursov B. et al.: 85 Santa Fe, 1, 641 (1986).
15) Behrens J.W. and Browne J.C.: Nucl. Sci. Eng., 77, 444 (1981).
16) Weston L.W. and Todd J.H.: Nucl. Sci. Eng., 91, 444 (1985).
17) Smith A.B.: ANL/NDM-50 (1979).

MAT number = 3955

95-Am-244 JAERI Eval-Mar88 T.Nakagawa
JAERI-M 89-008 Dist-Sep89
History
88-03 Evaluated for JENDL-3 was made by T.Nakagawa (JAERI)/1/.

MF=1 General Information
MT=451 Comment and dictionary
MT=452 Number of neutrons per fission
Sum of Nu-p (MT=456) and Nu-d (MT=455).
MT=455 Delayed neutron data
Estimated from semi-empirical formula by Tuttle /2/.
MT=456 Number of prompt neutrons
Estimated from semi-empirical formula by Howerton/3/.

MF=2,MT=151 Resonance parameters
No resonance parameters were given.

2200-m/s cross sections and resonance integrals

	2200 m/s value	Res. Int.
total	2912. b	-
elastic	11.62 b	-
fission	2300. b	1260 b
capture	600. b	316 b

MF=3 Neutron Cross Sections
MT=1 Total cross section
Below 0.07 eV, sum of partial cross sections. Above 0.07 eV, calculated with optical and statistical model code CASTHY/4/. The same optical potential parameters as those for Am-242 which were obtained /5/ by fitting the data of Phillips and Howe /6/ for Am-241, and modified a little.

$V = 42.0 - 0.107 \cdot En$ (MeV)
$Ws = 9.0 - 0.339 \cdot En + 0.0531 \cdot En^{2}$ (MeV)
$Vso = 7.0$ (MeV)
$r = rso = 1.282$, $rs = 1.29$ (fm)
$a = aso = 0.60$, $b = 0.5$ (fm)

MT=2 Elastic scattering cross section
Calculated with CASTHY/4/.

MT=4,51-75,91 Inelastic scattering cross sections
Calculated with CASTHY/4/. The level scheme was taken from Ref. /7/

No	Energy(keV)	Spin-Parity
g.s.	0	6 -
1	88.0	1 +
2	100.309	2 +
3	123.281	3 +
4	148.283	4 +
5	175.657	1 -
6	183.511	5 -
7	197.295	2 -
8	228.299	3 -
9	261.696	2 -
10	272.202	4 -

11	289.212	1 -
12	296.658	3 -
13	322.761	5 -
14	355.575	0 -
15	342.650	3 -
16	343.658	4 -
17	348.405	3 +
18	361.838	2 -
19	377.057	0 +
20	390.028	4 +
21	398.743	5 -
22	414.689	2 +
23	418.957	2 +
24	420.131	2 +
25	421.204	3 -

Levels above 435 keV were assumed to be overlapping. The level density parameters were determined on the basis of number of excited levels/8/ and resonance level spacing/9/.

	Am-245	Am-244
a(1/MeV)	31.3	30.3
T(MeV)	0.360	0.340
C(1/MeV)	18.06	26.47
E-x(MeV)	3.265	2.373
spin-cutoff(1/MeV**0.5)	31.98	31.39
pairing E(MeV)	0.39	0.0

MT=16,17,37 (n,2n), (n,3n) and (n,4n) reaction cross sections
Calculated with evaporation model.

MT=18 Fission cross section
Below 0.07 eV, 1/v shaped cross section was normalized to 2300 +- 300 b at 0.0253 eV/9/. Above 0.07 eV, the cross section was assumed to be the same as that of Am-242g (MAT=3952 of JENDL-3).

MT=102 Capture cross section
Below 0.07 eV, 1/v cross section was normalized to 600 b at 0.0253 eV that was estimated by assuming the same cross section ratio as higher energy region. Above 0.07 eV, calculated with CASTHY/4/. The gamma-ray strength function was determined from D-obs=0.13 eV calculated from level density parameters and WG=0.05 eV.

MT=251 Mu-L bar
Calculated with CASTHY/4/.

MF=4 Angular Distributions of Secondary Neutrons
MT=2,51-75,91
Legendre coefficients were given by the optical and statistical model calculation.
MT=16,17,18,37
Isotropic distributions in the laboratory system.

MF=5 Energy Distributions of Secondary Neutrons
MT=16,17,37,91
Evaporation spectrum with nuclear temperature calculated

from level densities.

MT=18

Maxwellian fission spectrum estimated from Z**2/A systematics by Smith et al./10/.

References

1) Nakagawa T.: JAERI-M 89-008 (1989).
2) Tuttle R.J.: INDC(NDS)-107/G+Special, p.29 (1979).
3) Howerton R.J.: Nucl. Sci. Eng., 62, 438 (1977).
4) Igarasi S.: J. Nucl. Sci. Technol., 12, 67 (1975).
5) Igarasi S. and Nakagawa T.: JAERI-M 8342 (1979).
6) Phillips T.W. and Howe R.E.: Nucl. Sci. Eng., 69, 375 (1979).
7) Shurshikov E.N.: Nucl. Data Sheets, 49, 785 (1986).
8) ENSDF, Evaluated Nuclear Structure Data File (1988).
9) Mughabghab S.F.: "Neutron Cross Sections, Vol. 1, Part B", Academic Press, Inc. (1984).
10) Smith A.B.: ANL/NDM-50 (1979).

MAT number = 3956

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 95-Am-244mJAERI        Eval-Mar88 T.Nakagawa
JAERI-M 89-008          Dist-Sep89
History
88-03 Evaluated for JENDL-3 was made by T.Nakagawa (JAERI)/1/.

MF=1  General Information
  MT=451   Comment and dictionary
  MT=452   Number of neutrons per fission
       Sum of Nu-p (MT=456) and Nu-d (MT=455).
  MT=455   Delayed neutron data
       Estimated from semi-empirical formula by Tuttle /2/.
  MT=456   Number of prompt neutrons
       Estimated from semi-empirical formula by Howerton/3/.

MF=2,MT=151    Resonance parameters
  No resonance parameters were given.

  2200-m/s cross sections and resonance integrals
                        2200 m/s value      Res. Int.
       total             2012.  b              -
       elastic             11.62 b             -
       fission           1600.  b            1260  b
       capture            400.  b             316  b

MF=3  Neutron Cross Sections
  MT=1  Total cross section
       Below 0.07 eV, sum of partial cross sections.  Above 0.07
       eV, calculated with optical and statistical model code
       CASTHY/4/. The same optical potential parameters as those
       for Am-242 which were obtained /5/ by fitting the data of
       Phillips and Howe /6/ for Am-241, and modified a little.
          V = 42.0 - 0.107*En                         (MeV)
          Ws= 9.0  - 0.339*En + 0.0531*En**2          (MeV)
          Vso = 7.0                                   (MeV)
          r = rso = 1.282    , rs = 1.29              (fm)
          a = aso = 0.60     , b  = 0.5               (fm)

  MT=2  Elastic scattering cross section
       Calculated with CASTHY/4/.

  MT=4,51-75,91  Inelastic scattering cross sections
       Calculated with CASTHY/4/.  The level scheme was taken
       from Ref. /7/ and shifted by 88 keV.
                  No          Energy(keV)   Spin-Parity
                   1            -88.0          6 -
                  target s.       0.0          1 +
                   2             12.309        2 +
                   3             35.281        3 +
                   4             60.283        4 +
                   5             87.657        1 -
                   6             95.511        5 -
                   7            109.295        2 -
                   8            140.299        3 -
                   9            173.696        2 -
                  10            184.202        4 -
```

11	201.212	1 -
12	208.658	3 -
13	234.751	5 -
14	247.575	0 -
15	254.650	3 -
16	255.658	4 -
17	260.405	3 +
18	273.838	2 -
19	289.057	0 +
20	302.028	4 +
21	310.743	5 -
22	326.689	2 +
23	330.957	2 +
24	332.131	2 +
25	333.204	3 -

Levels above 447 keV were assumed to be overlapping. The level density parameters were determined on the basis of number of excited levels/8/ and resonance level spacing/9/.

	Am-245	Am-244
a(1/MeV)	31.3	30.3
T(MeV)	0.360	0.340
C(1/MeV)	18.06	26.47
E-x(MeV)	3.265	2.373
spin-cutoff(1/MeV**0.5)	31.98	31.39
pairing E(MeV)	0.39	0.0

MT=16,17,37 (n,2n), (n,3n) and (n,4n) reaction cross sections
Calculated with evaporation model.

MT=18 Fission cross section
Below 0.07 eV, 1/v shaped cross section was normalized to 1600 +- 300 b at 0.0253 eV/9/. Above 0.07 eV, the cross section was assumed to be the same as that of Am-242g (MAT=3952 of JENDL-3).

MT=102 Capture cross section
Below 0.07 eV, 1/v cross section was normalized to 400 b at 0.0253 eV that was estimated by assuming the same cross section ratio as higher energy region. Above 0.07 eV, calculated with CASTHY/4/. The gamma-ray strength function was determined from D-obs=0.13 eV calculated from level density parameters and WG=0.05 eV.

MT=251 Mu-L bar
Calculated with CASTHY/4/.

MF=4 Angular Distributions of Secondary Neutrons
MT=2,51-75,91
Legendre coefficients were given by the optical and statistical model calculation.
MT=16,17,18,37
Isotropic distributions in the laboratory system.

MF=5 Energy Distributions of Secondary Neutrons
MT=16,17,37,91
Evaporation spectrum with nuclear temperature calculated

from level densities.

MT=18

Maxwellian fission spectrum estimated from Z**2/A systematics by Smith et al./10/.

References

1) Nakagawa T.: JAERI-M 89-008 (1989).
2) Tuttle R.J.: INDC(NDS)-107/G+Special , p.29 (1979).
3) Howerton R.J.: Nucl. Sci. Eng., 62, 438 (1977).
4) Igarasi S.: J. Nucl. Sci. Technol., 12, 67 (1975).
5) Igarasi S. and Nakagawa T.: JAERI-M 8342 (1979).
6) Phillips T.W. and Howe R.E.: Nucl. Sci. Eng., 69, 375 (1979).
7) Shurshikov E.N.: Nucl. Data Sheets, 49, 785 (1986).
8) ENSDF, Evaluated Nuclear Structure Data File (1988).
9) Mughabghab S.F.: "Neutron Cross Sections, Vol. 1, Part B", Academic Press, Inc. (1984).
10) Smith A.B.: ANL/NDM-50 (1979).

MAT number = 3961

96-Cm-241 JAERI Eval-Mar89 T.Nakagawa
Dist-Sep89

History
89-03 Evaluation for JENDL-3 was made by T. Nakagawa(JAERI)/1/.

MF=1 General Information
  MT=451 Descriptive data
  MT=452 Number of neutrons per fission
    Sum of MT=455 and MT=456
  MT=455 Delayed neutron data
    Estimated from the systematics by Tuttle /2/.
  MT=456 Number of prompt neutrons per fission
    Based on the empirical formula by Howerton /3/.

MF=2 Resonance Parameters
  MT=151 No esonance parameters were given.

Calculated 2200m/s cross sections and resonance integrals.

	2200 m/sec	Res. Integ.
total	851.9 b	---
elastic	11.9 b	---
fission	700.0 b	969 b
capture	140.0 b	160 b

MF=3 Neutron Cross Sections

Below 1 eV:
This energy range was assumed to be the thermal region, and fission and capture cross sections with 1/v shape were given and elastic scattering with a constant value. The total cross section is a sum of them.

Above 1 eV:

MT=1,2,4,51-54,91,102,251 Total, Elastic and Inelastic scattering, Capture cross sections and Mu-L
Calculated with optical and statistical model code CASTHY/4/.
The spherical optical potential parameters (MeV,fm):
  V =42.0-0.107*En, r =1.282, a =0.60
  Ws =6.95-0.339*En+0.0531*En**2, rs =1.29, b =0.50
    (derivative Woods-Saxon form)
  Vso=7.0, rso=1.282, aso=0.60
This set of potential parameters was determined /5/ to reproduce well the total cross section of Am-241 by Phillips and Howe /6/, and a real part was modified a little to give a slightly high reaction cross sections in a low energy region.

In the statistical model calculation, competing processes of fission, (n,2n) and (n,3n), and level fluctuation were considered. The level scheme of Cm-241 was taken from the compilation by Ellis-Akovali /7/:

No.	Energy(MeV)	Spin-Parity
g.s.	0.0	1/2 +

1	0.0530	3/2 +
2	0.103	5/2 +
3	0.157	7/2 +
4	0.255	9/2 +

Overlapping levels were assumed above 0.35 MeV. The level density parameters were determined on the basis of numbers of excited levels.

	Cm-242	Cm-241
a(1/MeV)	28.0	28.57
T(MeV)	0.40	0.378
C(1/MeV)	2.5771	5.287
E-x(MeV)	4.3163	3.560
spin-cutoff(1/MeV**0.5)	30.00	30.22
pairing E(MeV)	0.15	0.72

Average radiative width = 0.040 eV and D = 6.6 eV obtained from the level density parameters were used for the capture cross section calculation.

MT=16, 17 (n,2n) and (n,3n) cross sections
Calculated with the evaporation model by Pearlstein /8/. Neutron emission cross section was assumed to be (compound nucleus formation cross section calculated with optical model - fission).

MT=18 Fission cross section
The same cross section as Cm-243 /1/ was assumed. Below 1 keV, structure was replaced with a smooth curve.

MF=4 Angular Distributions of Secondary Neutrons
MT=2,51-54,91
Legendre coefficients calculated with the optical and statistical models were given.
MT=16,17,18
Isotropic distributions in the laboratory system.

MF=5 Energy Distributions of Secondary Neutrons
MT=16,17,91 Evaporation spectrum.
MT=18 Estimated from Z**2/A systematics by Smith et al. /9/, assuming E(Cf-252) = 2.13 MeV.

References

1) Nakagawa T.: to be published as JAERI-M report.
2) Tuttle R.J.: INDC(NDS)-107/G+Special, 29 (1979).
3) Howerton R.J.: Nucl. Sci. Eng. 62, 438 (1977).
4) Igarasi S.: J.Nucl.Sci.Technol. 12, 67 (1975).
5) Igarasi S. and Nakagawa T.: JAERI-M 8342 (19879).
6) Phillips T.W. and Howe R.E.: Nucl. Sci. Eng., 69, 375 (1979).
7) Ellis-Akovali Y.A.: Nucl. Data Sheets, 44, 407 (1985).
8) Pearlstein S.: J. Nucl. Energy 27, 81 (1973).
9) A.B. Smith et al. : ANL/NDM-50 (1979).

MAT number = 3962

96-Cm-242 JAERI Eval-Mar89 T.Nakagawa
Dist-Sep89

History
79-03 Evaluation for JENDL-2 was made by S.Igarasi and T.Nakagawa (JAERI) /1/.
89-03 Re-evaluation for JENDL-3 was made by T.Nakagawa(JAERI)/2/.

MF=1 General Information
MT=451 Descriptive data
MT=452 Number of neutrons per fission
Sum of MT=455 and MT=456.
MT=455 Delayed neutron data
Estimated from the systematics by Tuttle /3/.
MT=452 Number of neutrons per fission
Based on the empirical formula by Howerton /4/.

MF=2 Resonance Parameters
MT=151 Resonance parameters
Resolved resonance region : 1.0E-5 eV to 275 eV.
Resonance energies = Altamonov et al. /5/,
Neutron widths = Altamonov et al. /5/,
Radiative widths = 0.040 eV,
Fission widths = Alam et al. /6/ for the low-lying 4 levels, and the average value of 0.004 eV for other levels.
Scattering radius = 9.38 fm.
A negative resonance was added at -3.45 eV, and its parameters were adjusted so as to reproduce well the thermal cross sections/7/. Background cross section was given to the fission cross section.
Unresolved resonance parameters : 275 eV - 40 keV
Parameters were determined with a fitting code ASREP /8/ so as to reproduce the fission cross section measured by Alam et al./6/, and total cross section at 40 keV.
Energy independent parameters:
R=9.093 fm, S0=0.92E-4, S2=0.97E-4, WG=0.04 eV.
Energy dependent parameters at 1 keV:
S1=3.04E-4, WF=0.093 eV, D=17.16 eV.

Calculated 2200m/s cross sections and resonance integrals.

	2200 m/sec	Res. Integ.
total	32.57 b	---
elastic	11.61 b	---
fission	5.064 b	20.0 b
capture	15.90 b	109 b

MF=3 Neutron Cross Sections
Below 40 keV, cross sections were represented with resonance parameters.

MT=1,2,4,51-53,91,102,251 Total, Elastic and Inelastic scattering, Capture cross sections and Mu-L
Calculated with optical and statistical model code CASTHY/9/.
The spherical optical potential parameters (MeV,fm):

V =43.4-0.107*En, r =1.282, a =0.60
Ws =6.95-0.339*En+0.0531*En**2, rs =1.29 b =0.50
(derivative Woods-Saxon form)
Vso=7.0, rso=1.282, aso=0.60

This set of potential parameters was determined /1/ to reproduce well the total cross section of Am-241 by Phillips and Howe /10/.

In the statistical model calculation, competing processes of fission, (n,2n) and (n,3n), and level fluctuation were considered. The level scheme of Cm-242 was taken from ENSDF /11/:

No.	Energy(MeV)	Spin-Parity
g.s.	0.0	0 +
1	0.04213	2 +
2	0.138	4 +
3	0.284	6 +

Overlapping levels are assumed above 0.35 MeV. The level density parameters were determined on the basis of numbers of excited levels/11/.

	Cm-243	Cm-242
a(1/MeV)	28.0	28.0
T(MeV)	0.40	0.40
C(1/MeV)	7.5405	2.5771
E-x(MeV)	3.8863	4.3163
spin-cutoff(1/MeV**0.5)	30.08	30.00
pairing E(MeV)	0.72	0.15

Average radiative width = 0.040 eV and D = 18 eV obtained from the level density parameters were used for the capture cross section calculation.

MT=16, 17 (n,2n) and (n,3n) cross sections
Calculated with the evaporation model by Pearlstein /12/. Neutron emission cross section was assumed to be (compound nucleus formation cross section calculated with optical model - fission).

MT=18 Fission cross section
Below 1 MeV, cross section was determined on the basis of data measured by Alam et al./6/ and Vorotnikov et al./13/. Above 1 MeV, JENDL-2 evaluation was adopted, which was based on the shape of Cm-244 /14/ and the empirical formula on the fission-cross-section systematics around 4 MeV by Behrens and Howerton /15/.

MF=4 Angular Distributions of Secondary Neutrons
MT=2,51-53,91
Legendre coefficients calculated with the optical and statistical models were given.
MT=16,17,18
Isotropic distributions in the laboratory system.

MF=5 Energy Distributions of Secondary Neutrons
MT=16,17,91 Evaporation spectrum.
MT=18 Estimated from Z**2/A systematics by Smith et al. /16/, assuming E(Cf-252) = 2.13 MeV.

References
1) Igarasi S. and Nakagawa T.: JAERI-M 8342 (1979).
2) Nakagawa T.: to be published as JAERI-M report.
3) Tuttle R.J.: INDC(NDS)-107/G+Special, 29 (1979).
4) Howerton R.J.: Nucl. Sci. Eng. 62, 438 (1977).
5) Artamonov V.S. et al. : Proc. of 4th All Union Conf. on Neutron Physics, Kiev (1977), Vol. 2, 257.
6) Alam B. et al.: Nucl. Sci. Eng., 99, 267 (1988).
7) Mughabghab S.F.: "Neutron Cross Sections, vol. 1, part B", Academic Press (1984).
8) Kikuchi Y.: private communication.
9) Igarasi S.: J. Nucl. Sci. Technol., 12, 67 (1975).
10) Phillips T.W. and Howe R.E.: Nucl. Sci. Eng. 69, 375 (1979).
11) ENSDF, Evaluated Nuclear Structure Data File, as of Jan. 1989.
12) Pearlstein S.: J. Nucl. Energy 27, 81 (1973).
13) Vorotnikov P.E. et al.: Sov. J. Nucl. Phys., 40, 726 (1984).
14) Igarasi S. and Nakagawa T.: JAERI-M 7175 (1977).
15) Behrens J.W. and Howerton R.J.: Nucl. Sci. Eng., 65, 464 (1978).
16) Smith A.B. et al.: ANL/NDM-50 (1979).

MAT number = 3963

96-Cm-243 JAERI Eval-Mar89 T.Nakagawa
Dist-Sep89

History
81-03 Evaluation for JENDL-2 was made by T.Nakagawa and S.Igarasi (JAERI) /1/.
89-03 Re-evaluation for JENDL-3 was made by T.Nakagawa (JAERI)/2/.

MF=1 General Information
MT=451 Descriptive data
MT=452 Number of neutrons per fission
Sum of MT=455 and MT=456.
MT=455 Delayed neutron data
Estimated from the systematics by Tuttle /3/.
MT=456 Number of prompt neutrons per fission
Based on the experimental data at thermal energy by Jaffey and Lerner /4/, and Zhuravlev et al. /5/, and on the empirical formula by Howerton /6/.

MF=2 Resonance Parameters
MT=151 Resonance parameters
Resolved resonance region (SLBW): 1.0E-5 eV to 70 eV.
Resonance energies = Anufriev et al. /7/
Neutron widths = Anufriev et al. /7/ (assuming 2g=1)
Radiative widths = 0.040 eV (assumed)
Fission widths = total width /7/ - (WN+WG)
Scattering radius = 10 fm.
A negative resonance was adopted so as to reproduce well the thermal cross sections/8/.
Unresolved resonance parameters : 70 eV - 40 keV
Parameters were determined with a fitting code ASREP/9/ so as to reproduce the fission cross section based on Silbert /10/, and the total cross section calculated with optical model.
Energy independent parameters:
R=9.810 fm, S2=1.70E-4, WG=0.04 eV, WF=1.481 eV
Energy dependent parameters at 1 keV:
S0=1.32E-4, S1=1.06E-4, D=0.799 eV.

Calculated 2200m/s cross sections and resonance integrals.

	2200 m/sec	Res. Integ.
total	757.5 b	-
elastic	9.926 b	-
fission	617.4 b	1560 b
capture	130.2 b	199 b

MF=3 Neutron Cross Sections
Below 40 keV, cross sections were represented with resonance parameters.

MT=1,2,4,51-63,91,102,251 Total, Elastic and Inelastic scattering, Capture cross sections and Mu-L
Calculated with optical and statistical model code CASTHY/11/.
The spherical optical potential parameters (MeV,fm):
V =41.0-0.107*En, r =1.282, a =0.60

Ws =6.95-0.339*En+0.0531*En**2, rs =1.29, b =0.50
(derivative Woods-Saxon form)
Vso=7.0, rso=1.282, aso=0.60

This set of potential parameters was determined /12/ to reproduce well the total cross section of Am-241 by Phillips and Howe /13/, and a real part was modified a little to give a slightly large strength function in a low energy region.

In the statistical model calculation, competing processes of fission, (n,2n), (n,3n) and (n,4n), and level fluctuation were considered. The level scheme of Cm-243 was taken from the compilation by Ellis-Akovali /14/:

No.	Energy(MeV)	Spin-Parity
g.s.	0.0	5/2 +
1	0.042	7/2 +
2	0.0874	1/2 +
3	0.094	9/2 +
4	0.094	3/2 +
5	0.133	7/2 +
6	0.153	11/2 +
7	0.164	9/2 +
8	0.219	13/2 +
9	0.228	11/2 +
10	0.260	9/2 +
11	0.530	15/2 -
12	0.729	1/2 -
13	0.769	3/2 -

Overlapping levels are assumed above 0.82 MeV. The level density parameters were determined on the basis of numbers of excited levels/15/ and resonance level spacing/8/.

	Cm-244	Cm-243
a(1/MeV)	28.0	28.0
T(MeV)	0.395	0.40
C(1/MeV)	1.8807	7.5405
E-x(MeV)	4.2893	3.8863
spin-cutoff(1/MeV**0.5)	30.17	30.08
pairing E(MeV)	1.22	0.72

Average radiative width = 0.040 eV and D = 0.809 eV /7/ were used for the capture cross section calculation.

MT=16,17,37 (n,2n),(n,3n) and (n,4n) cross sections
Calculated with the evaporation model by Pearlstein/16/. Neutron emission cross section was assumed to be (compound nucleus formation cross section calculated with optical model - fission).

MT=18 Fission cross section
Below 10 keV : taken from JENDL-2 evaluation based on Silbert /10/.
10 keV - 3 MeV: determined from Fomushkin et al. /17/.
Above 3 MeV : estimated.

MF=4 Angular Distributions of Secondary Neutrons
MT=2,51-63,91
Legendre coefficients calculated with CASTHY /11/.

MT=16,17,18,37
Isotropic distributions in the laboratory system.

MF=5 *Energy Distributions of Secondary Neutrons*
MT=16,17,37,91 Evaporation Spectrum.
MT=18 Fission spectrum estimated from Z**2/A systematics by Smith et al. /18/ by assuming E(Cf-252) = 2.13 MeV.

References

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MAT number = 3964

96-Cm-244 JAERI Eval-Mar89 T.Nakagawa
Dist-Sep89

History
77-03 Evaluation for JENDL-2 was made by S.Igarasi and T.Nakagawa (JAERI) /1/.
89-03 Re-evaluation for JENDL-3 was made by T.Nakagawa(JAERI)/2/.

MF=1 General Information
  MT=451 Descriptive data
  MT=452 Number of neutrons per fission
    Sum of MT=455 and MT=456.
  MT=455 Number of delayed neutrons per fission
    Estimated from semi-empirical formula by Tuttle /3/.
  MT=456 Number of prompt neutrons per fission
    Determined from semi-empirical formula by Howerton /4/.

MF=2 Resonance Parameters
  MT=151 Resonance parameters
    Resolved resonance region (MLBW) : 1.0E-5 to 1 keV
      Above 20 eV, parameters by Moore and Keyworth /5/ were adopted assuming neutron width of 0.2 eV for 646.9, 759.7, 914.0 and 971.5-eV levels, and below 20 eV, evaluation by Benjamin et al. /6/. The fission widths of low-lying 4 levels were replaced with those by Maguire et al. /7/.
        Radiative width = 0.037 eV (assumed)
        Scattering radius = 11.2 fm (adjusted to 11.6 b at 0.0253 eV /8/.
      A negative resonance at -1.48 eV was adopted and its parameters were adjusted so as to reproduce well the thermal cross sections/8/.
    Unresolved resonance parameters : 70 eV - 40 keV
      Parameters were determined with a fitting code ASREP/9/ so as to reproduce the fission cross section of Maguire et al. /7/, and the total and capture cross sections calculated with optical and statistical models.
        Energy independent parameters:
          R=9.221 fm, S0=0.9E-4, S2=0.92E-4, WG=0.04 eV.
        Energy dependent parameters at 1 keV:
          S1=3.06E-4, WF=0.00244 eV, D=11.98 eV.

Calculated 2200m/s cross sections and resonance integrals.

	2200 m/sec	Res. Integ.
total	27.20 b	-
elastic	11.06 b	-
fission	1.037 b	13.2 b
capture	15.10 b	661 b

MF=3 Neutron Cross Sections
  Below 40 keV, cross sections were represented with resonance parameters.

  MT=1,2,4,51-62,91,102,251 Total, Elastic and Inelastic scattering, Capture cross sections and Mu-L
    Calculated with optical and statistical model code CASTHY/10/.

The spherical optical potential parameters (MeV,fm):
V =43.4-0.107•En, r =1.282, a =0.60
Ws =6.95-0.339•En+0.0531•En••2, rs =1.29, b =0.50
(derivative Woods-Saxon form)
Vso=7.0, rso=1.282, aso=0.60
This set of potential parameters was determined /11/ to reproduce well the total cross section of Am-241 by Phillips and Howe /12/. The strength function of 0.91E-4 calculated with this OMP is in very good agreement with experiments/8/.

In the statistical model calculation, competing processes of fission, (n,2n) and (n,3n), and level fluctuation were considered. The level scheme of Cm-244 was taken from the compilation by Shurshikov /13/:

No.	Energy(MeV)	Spin-Parity
g.s.	0.0	0 +
1	0.04297	2 +
2	0.14235	4 +
3	0.29621	6 +
4	0.50179	8 +
5	0.970	2 +
6	0.98491	0 +
7	1.0208	2 +
8	1.038	2 +
9	1.0402	6 +
10	1.0842	1 +
11	1.1059	1 -
12	1.187	2 +

Overlapping levels are assumed above 1.2 MeV. The level density parameters were determined on the basis of numbers of excited levels/14/ and resonance level spacing/8/.

	Cm-245	Cm-244
a(1/MeV)	30.0	28.0
T(MeV)	0.391	0.395
C(1/MeV)	11.288	1.8807
E-x(MeV)	4.0295	4.2893
spin-cutoff(1/MeV••0.5)	31.31	30.17
pairing E(MeV)	0.72	1.22

Average radiative width = 0.037 eV and D = 12 eV were used for the capture cross section calculation.

MT=16,17 (n,2n) and (n,3n) cross sections
Calculated with the evaporation model by Pearlstein /15/. Neutròn emission cross section was assumed to be (compound nucleus formation cross section calculated with optical model - fission).

MT=18 Fission cross section
Below 100 keV: smooth curve based on Maguire et al. /7/.
100 - 800 keV: JENDL-2 was adopted, which was obtained by fitting a semi-empirical formula to the experimental data of Ref. /5/.
0.8 - 8 MeV : estimated from experimental data/5,16,17/
Above 8 MeV : the same as JENDL-2.

MF=4 *Angular Distributions of Secondary Neutrons*
MT=2,51-62,91
Legendre coefficients were given by the optical and statistical model calculations.
MT=16,17,18
Isotropic distributions in the laboratory system.

MF=5 *Energy Distributions of Secondary Neutrons*
MT=16,17,91 Evaporation spectrum
MT=18 Fission spectrum estimated from Z**2/A systematics by Smith et al. /18/ by assuming E(Cf-252) = 2.13 MeV.

References

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MAT number = 3965

96-Cm-245 JAERI Eval-Mar89 T.Nakagawa
Dist-Mar89

History
78-03 Evaluation was made by S.Igarasi and T.Nakagawa (JAERI)/1/.
89-03 Re-evaluation for JENDL-3 was made by T.Nakagawa(JAERI)/2/.

MF=1 General Information
MT=451 Descriptive data
MT=452 Number of neutrons per fission
Sum of MT=455 and MT=456.
MT=455 Number of delayed neutrons per fission
Estimated from the systematics proposed by Tuttle /3/.
MT=456 Number of prompt neutrons per fission
Experimental data by Howe /4/ were adopted. Their data are much smaller than other experiments /5,6,7/.

MF=2 Resonance Parameters
MT=151 Resonance parameters
Resolved resonance region (SLBW) : 1.0E-5 to 60 eV
Parameters for Reich-Moore formula by Moore and Keyworth /8/ were adopted above 20 eV, and those by Browne et al. /9/ below 20 eV with a little modification of a negative resonance so that the thermal cross section could be in agreement with the experimental data. The differences between Reich-Moore and single-level B-W formulas are treated as the background cross sections.
Radiative width = 0.04 eV
Scattering radius = 10.0 fm
Unresolved resonance parameters : 60 eV - 40 keV
Parameters were determined with a fitting code ASREP/10/ so as to reproduce the fission cross section of Moore and Keyworth /8/, and the total and capture cross sections calculated with optical and statistical models.
Energy independent parameters:
R=9.43 fm, S0=1.02E-4, S1=2.24E-4, S2=0.9E-4, WG=0.04 eV.
Energy dependent parameters at 1 keV:
WF=2.01 eV, D=1.397 eV.

Calculated 2200m/s cross sections and resonance integrals.

	2200 m/sec	Res. Integ.
total	2359. b	-
elastic	11.59 b	-
fission	2001. b	801 b
capture	346.4 b	110 b

MF=3 Neutron Cross Sections
Below 40 keV, cross sections were represented with resonance parameters.

MT=1,2,4,51-73,91,102,251 Total, Elastic and Inelastic scattering, Capture cross sections and Mu-L
Calculated with optical and statistical model code CASTHY/11/.
The spherical optical potential parameters (MeV,fm):

```
V  =42.7-0.107*En,                     r  =1.282, a  =0.60
Ws =6.95-0.339*En+0.0531*En**2, rs =1.29,  b  =0.50
     (derivative Woods-Saxon form)
Vso=7.0,                               rso=1.282, aso=0.60
```

This set of potential parameters was determined /12/ to reproduce well the total cross section of Am-241 by Phillips and Howe /12/. The strength function of 1.02E-4 calculated with this OMP is in good agreement with 1.18E-4/14/.

In the statistical model calculation, competing processes of fission, (n,2n), (n,3n) and (n,4n), and level fluctuation were considered. The level scheme of Cm-245 was taken from the compilation by Ellis-Akovali /15/:

No.	Energy(MeV)	Spin-Parity
g.s.	0.0	7/2 +
1	0.0548	9/2 +
2	0.1215	11/2 +
3	0.1974	13/2 +
4	0.25285	5/2 +
5	0.2958	7/2 +
6	0.35086	9/2 +
7	0.35595	1/2 +
8	0.3615	3/2 +
9	0.3883	9/2 -
10	0.4167	11/2 +
11	0.4188	5/2 +
12	0.431	5/2 +
13	0.4429	11/2 -
14	0.498	13/2 +
15	0.5091	13/2 -
16	0.532	9/2 +
17	0.555	11/2 +
18	0.63365	3/2 -
19	0.6435	7/2 -
20	0.66155	5/2 -
21	0.7018	9/2 -
22	0.722	7/2 +
23	0.741	1/2 +

Overlapping levels are assumed above 0.82 MeV. Levels with higher spin than 13/2 or whose spin was unknown were neglected. The level density parameters were determined on the basis of numbers of excited levels/16/ and resonance level spacing/14/.

	Cm-246	Cm-245
a(1/MeV)	27.7	30.0
T(MeV)	0.395	0.391
C(1/MeV)	2.2560	11.288
E-x(MeV)	4.1307	4.0295
spin-cutoff(1/MeV**0.5)	30.17	31.31
pairing E(MeV)	1.11	0.72

Average radiative width = 0.040 eV and D = 1.4 eV /14/ were used for the capture cross section calculation.

MT=16,17,37 (n,2n), (n,3n) and (n,4n) cross sections
Calculated with the evaporation model by Pearlstein /17/.

Neutron emission cross section was assumed to be (compound nucleus formation cross section calculated with optical model − fission).

MT=18 Fission cross section

Below 100 keV: JENDL-2 was adopted, which was obtained by fitting a semi-empirical formula to the experimental data of Ref. /8/.

Above 100 keV: based on the experimental data of White and Browne /18/.

MF=4 Angular Distributions of Secondary Neutrons

MT=2,51-73,91

Legendre coefficients were given by the optical and statistical model calculations.

MT=16,17,18,37

Isotropic distributions in the laboratory system.

MF=5 Energy Distributions of Secondary Neutrons

MT=16,17,37,91 Evaporation spectrum

MT=18 Fission spectrum estimated from Z**2/A systematics by Smith et al./19/ by assuming E(Cf-252) = 2.13 MeV.

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MAT number = 3966

96-Cm-246 JAERI Eval-Mar87 Y.Kikuchi, T.Nakagawa
Dist-Sep89

History
87-03 New evaluation was made by Y.Kikuchi (JAERI) /1/.
89-03 Re-evaluation for JENDL-3 was made by T.Nakagawa(JAERI) /2/.

MF=1
MF=1 General Information
  MT=451 Descriptive data
  MT=452 Number of neutrons per fission
      Sum of MT=455 and MT=456.
  MT=455 Number of delayed neutrons
      Semi-empirical formula by Tuttle /3/.
  MT=456 Number of prompt neutrons per fission
      Semi-empirical formula by Howerton /4/.

MF=2 Resonance Parameters
  MT=151 Resonance parameters
    Resolved resonance region (MLBW) : 1.0E-5 to 330 eV
      Evaluation was based on the experimental data /5-9/ as follows:
        Resonance energies = Refs. 6 and 8.
        Neutron widths = Refs. 5, 6 and 7.
        Radiative widths = Refs. 6 and 8, and average width of 0.031 eV was assumed.
        Fission widths = Refs. 8 and 9. WF of 4.315-eV level was adjusted to the thermal cross section.
        Scattering radius = 9.85 fm. (adjusted to 11.1 b at 0.0253 eV/10/)
      1/v background data were given to fission cross section.
    Unresolved resonance region : 330 eV to 30 keV
      Obtained from optical model calculation:
        S0=0.94E-4, S1=3.17E-4, S2=0.88E-4, R=9.15 fm.
      Estimated from resolved resonances:
        D-obs=31.7 eV, WG=31 milli-eV.
      WF obtained by fitting the data of Stopa et al./9/.

    Calculated 2200 m/s cross sections and resonance integrals

	2200 m/sec	Res. Integ.
total	12.51 b	-
elastic	11.08 b	-
fission	0.14 b	9.90 b
capture	1.291 b	113 b

MF=3 Neutron Cross Sections
    Below 30 keV, cross sections were represented with resonance parameters.

  MT=1,2,4,51-79,91,102,251 Total, Elastic and Inelastic scattering, Capture cross sections and Mu-L
      Calculated with optical and statistical model code CASTHY/11/.
      The spherical optical potential parameters (MeV,fm):
        V =43.4-0.107*En, r =1.282, a =0.60

Ws =6.95-0.339*En+0.0531*En**2, rs =1.29, b =0.50
(derivative Woods-Saxon form)
Vso=7.0, rso=1.282, aso=0.60

This set of potential parameters was determined /12/ to reproduce well the total cross section of Am-241 by Phillips and Howe /13/.

In the statistical model calculation, competing processes of fission, (n,2n), (n,3n) and (n,4n), and level fluctuation were considered. The level scheme of Cm-246 was taken from Ref./14/.

No.	Energy(keV)	Spin-Parity
g.s.	0	0 -
1	42.85	2 +
2	141.99	4 +
3	295.5	6 +
4	500.0	8 +
5	841.7	2 -
6	876.4	3 -
7	923.3	4 -
8	981.0	5 -
9	1051	6 -
10	1079	1 -
11	1105	2 -
12	1124	2 +
13	1128	3 -
14	1129	7 -
15	1165	3 +
16	1175	0 +
17	1179	8 -
18	1211	2 +
19	1220	4 +
20	1250	1 -
21	1289	0 +
22	1300	3 -
23	1318	2 +
24	1349	1 -
25	1367	2 -
26	1379	4 +
27	1452	1 +
28	1478	2 +
29	1509	3 +

continuum levels assumed above 1526 keV.

The level density parameters were taken from Gilbert and Cameron /15/. The gamma-ray strength function of 9.76E-4 deduced from resonance parameters.

MT=16,17,37 (n,2n), (n,3n), (n,4n) reaction cross sections
Calculated with evaporation model/16/.

MT=18 Fission
Evaluated on the basis of the measured data by Stopa et al./9/ and Fomushkin et al./17/.

MF=4 Angular Distributions of Secondary Neutrons
MT=2,51-79,91
Legendre coefficients were given by the optical and

statistical model calculations.
MT=16,17,18,37
Isotropic distributions in the laboratory system.

MF=5 Energy Distributions of Secondary Neutrons
MT=16,17,37,91 Evaporation spectrum
MT=18 Fission spectrum
Temperature of 1.48 MeV was estimated from data of Zhuravlav et al. /18/ for Cm-245 and Cm-247.

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MAT number = 3967

96-Cm-247 JAERI Eval-Mar89 T.Nakagawa, Y.Kikuchi
Dist-Mar89

History
83-03 Evaluation was by Y.Kikuchi(JAERI)/Ref.1/.
89-03 Re-evaluation was made for JENDL-3 by T.Nakagawa(JAERI)/2/.

MF=1 General Information
MT=451 Descriptive data
MT=452 Number of neutrons per fission
Sum of MT=455 and MT=456.
MT=455 Number of delayed neutrons per fission
Semi-empirical formula by Tuttle /3/.
MT=456 Number of prompt neutrons per fission
Thermal value of Zhuravlev et al./4/ and energy dependent term of Howerton /5/.

MF=2 Resonance Parameters
MT=151 Resonance parameters
Resolved resonance region (MLBW) : 1.0E-5 to 60 eV
Evaluation was based on the experimental data of Moore and Keyworth /6/ and Belanova et al./7/. The parameters of 1.25-eV level were taken from Mughabghab /8/.
Radiative widths = 0.040 eV was assumed.
Scattering radius = 9.14 fm.
A negative resonance was added at -0.3 eV.
Unresolved resonance region : 60 eV to 30 keV
Parameters were determined with a fitting code ASREP/9/ so as to reproduce the fission cross section of Moore and Keyworth /6/, and the total and capture cross sections calculated with optical and statistical models.
Energy independent parameters:
R=9.386 fm, S2=0.86E-4, WG=0.04 eV,.
WF(4-)=0.0534 eV, WF(5-)=0.5 eV, WF(3+)=0.08 eV,
WF(4+)=0.68 eV, WF(5+)=0.05 eV, WF(6+)=0.47 eV.
WF estimated by systematic survey /10/
Energy dependent parameters at 0.9 keV:
S0=0.774E-4, S1=2.89E-4, D=1.397 eV.

calculated 2200 m/s cross sections and resonance integrals

	2200 m/sec	Res. Integ.
total	147.8 b	-
elastic	8.775 b	-
fission	81.79 b	612 b
capture	57.20 b	535 b

MF=3 Neutron Cross Sections
Below 30 keV, cross sections were represented with resonance parameters.

MT=1,2,4,51-60,91,102,251 Total, Elastic and Inelastic scattering, Capture cross sections and Mu-L
Calculated with optical and statistical model code CASTHY/11/.
The spherical optical potential parameters (MeV,fm):
V =43.4-0.107*En, r =1.282, a =0.60

Ws =6.95-0.339•En+0.0531•En••2, rs =1.29, b =0.50
(derivative Woods-Saxon form)
Vso=7.0, rso=1.282, aso=0.60

This set of potential parameters was determined /12/ to reproduce well the total cross section of Am-241 by Phillips and Howe /13/.

In the statistical model calculation, competing processes of fission, (n,2n), (n,3n) and (n,4n), and level fluctuation were considered. The level scheme of Cm-247 was taken from Ref./14/.

No.	Energy(keV)	Spin-Parity
g.s.	0	9/2 -
1	61.5	11/2 -
2	133	13/2 -
3	227	5/2 +
4	266	7/2 +
5	285	7/2 +
6	317	9/2 +
7	342	9/2 +
8	404	1/2 +
9	433	3/2 +
10	449	5/2 +

Continuum levels assumed above 479 kev.

The level density parameters were taken from Gilbert and Cameron/15/. The gamma-ray strength function of 2.29E-2 was deduced from resonance parameters.

MT=16,17,37 (n,2n), (n,3n) and (n,4n) reaction cross sections
Calculated with evaporation model/16/.

MT=18 Fission
Evaluated on the basis of the measured data by Moore and Keyworth /6/ below 50 keV. Above this energy, the data of Fomushkin et al./17/ were adopted.

MF=4 Angular Distributions of Secondary Neutrons
MT=2,51-60,91
Legendre coefficients were given by the optical and statistical model calculations.
MT=16,17,18,37
Isotropic distributions in the laboratory system.

MF=5 Energy Distributions of Secondary Neutrons
MT=16,17,37,91 Evaporation spectrum
MT=18 Fission spectrum
Temperature of 1.47 MeV was estimated from data of Zhuravlev et al. /4/.

References
1) Kikuchi Y.: JAERI-M 83-236(1984).
2) Nakagawa T.: to be published as JAERI-M report.
3) Tuttle R.J.: INDC(NDS)-107/g+special, 29 (1979).
4) Zhuravlev K.D. et al.: 1973 Kiev, vol.4, 57 (1973).
5) Howerton R.J.: Nucl. Sci. Eng., 62, 438(1977).
6) Moore M.S. and Keyworth G.A.: Phys. Rev., C3, 1656(1971)
7) Belanova T.S. et al.: Sov. At. Energy, 47, 772(1979).

8) Mughabghab S.F.: "Neutron Cross Sections, vol.1, Part B", *Academic Press (1984)*.
9) Kikuchi Y.: private communication.
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11) Igarasi S.: J. Nucl. Sci. Technol., 12, 67 (1975).
12) Igarasi S. and Nakagawa T.: JAERI-M 8342 (1979).
13) Phillips T.W. and Howe F.R.: Nucl. Sci. Eng., 69, 375(1979).
14) Lederer C.M. and Shirley V.S.: *Table of Isotopes , 7th ed.*, (1978).
15) Gilbert A. and Cameron A.G.W. : Can. J. Phys., 43, 1446(1965).
16) Pearlstein S.: *Nucl. Sci. Eng.*, 23, 238 (1965).
17) Fomushkin E.F. et al.: Sov. At. Energy, 62, 340 (1987).

MAT number = 3968

```
 96-Cm-248 JAERI         Eval-Mar84 Y.Kikuchi and T.Nakagawa
JAERI-M 84-116           Dist-Sep89
History
84-03 New evaluation for JENDL-3 was made by Y.Kikuchi and
      T.Nakagawa (JAERI). Details are given in Ref. /1/.

MF=1  General Information
  MT=451  Comments and dictionary
  MT=452  Number of neutrons per fission
        Sum of MT=455 and MT=456.
  MT=455  Number of delayed neutrons per fission
        Semi-empirical formula by Tuttle /2/.
  MT=456  Number of neutrons per fission
        Semi-empirical formula by Howerton /3/.

MF=2  Resonance Parameters
  MT=151  Resonance parameters
     Resolved resonance region (MLBW) : 1.0E-5 to 1.5 keV
        Resonance energies, neutron and radiative widths were
        taken from the experimental data of Benjamin et al./4/.
        For resonances whose radiative width was unknown, the
        average value of 0.026 eV /4/ was adopted.  Fission widths
        and the average fission width of 0.0013 eV were adopted
        from Moore and Keyworth /5/.  The average fission width
        was used for all resonances of which fission width had not
        been measured.  R=9.1 fm was assumed to reproduce the
        potential scattering cross section of 10.4 barns assumed
        by Benjamin et al./4/.  The neutron width of the first
        resonance was slightly adjusted to reproduce the capture
        cross section of 2.57 barns at 0.0253 eV.  Background
        cross sections were given only for the fission and total
        cross sections by assuming the form of 1/v.  The thermal
        cross sections to be reproduced were estimated from
        available experimental data.
     Unresolved resonance region : 1.5 keV to 30 keV
        Obtained from optical model calculation:
          S1=3.32E-4, S2=0.844E-4, R=8.88 fm.
        Estimated from resolved resonances:
          D-obs=40.0 eV, Gam-g=26 milli-eV, S0=1.2E-4
        Gam-f obtained by fitting the data of Stopa et al./6/.

  calculated 2200 m/s cross sections and resonance integrals
                     2200 m/s value          res. int.
       total·           9.455  b                -
       elastic          6.514  b                -
       fission          0.370  b              17.5   b
       capture          2.570  b             260.    b

MF=3  Neutron Cross Sections
    Below 30 keV, cross sections were represented with resonance
    parameters.

  MT=1,2,4,51-58,91,102,251    Total, Elastic and Inelastic
    scattering, Capture cross sections and Mu-L
       Calculated with optical and statistical model code
```

CASTHY/7/.
The spherical optical potential parameters (MeV,fm):
V =43.4-0.107*En, r =1.282, a =0.60
Ws =6.95-0.339*En+0.0531*En**2, rs =1.29, b =0.50
(derivative Woods-Saxon form)
Vso=7.0, r o=1.282, aso=0.60
This set of potential parameters was determined /8/ to reproduce well the total cross section of Am-241 by Phillips and Howe /9/.

In the statistical model calculation, competing processes of fission, (n,2n), (n,3n) and (n,4n), and level fluctuation were considered. The level scheme of Cm-248 was taken from Ref./10/.

No.	Energy(keV)	Spin-parity
g.s.	0	0 +
1	43.40	2 +
2	143.6	4 +
3	297	6 +
4	510	8 +
5	1048	2 +
6	1050	1 -
7	1084	0 +
8	1094	3 -

Continuum levels assumed above 1126 keV.
The level density parameters : Gilbert and Cameron /11/.
Gamma-ray strength function of 6.5E-4 deduced from resonance parameters.

MT=16,17,37 (n,2n), (n,3n) and (n,4n) reaction cross sections
Calculated with evaporation model/12/.

MT=18 Fission
Evaluated on the basis of the measured data by Stopa et al./6/ and Fomushkin et al./13/.

MF=4 Angular Distributions of Secondary Neutrons
MT=2,51-58 Calculated with optical model.
MT=16,17,18,37,91 Isotropic in the laboratory system.

MF=5 Energy Distributions of Secondary Neutrons
MT=16,17,37,91 Evaporation spectrum.
MT=18 Maxwellian fission spectrum.
Temperature estimated from systematics of Smith et al./14/.

References
1) Kikuchi Y. and Nakagawa T.: JAERI-M 84-116 (1984).
2) Tuttle R.J.: INDC(NDS)-107/g+special, 29 (1979).
3) Howerton R.J.: Nucl. Sci. Eng., 62, 438(1977).
4) Benjamin R.W et al.: Nucl. Sci. Eng., 55, 440(1974).
5) Moore M.S. and Keyworth G.A.: Phys. Rev., C3, 1656(1971)
6) Stopa C.R.S. et al.: 1982 Kiamesha, 1090 (1982), and Maguire Jr. H.T. et al.: Nucl. Sci. Eng., 89, 293 (1985).
7) Igarasi S.: J. Nucl. Sci. Technol., 12, 67 (1975).
8) Igarasi S. and Nakagawa T.: JAERI-M 8342 (1979).
9) Phillips T.W. and Howe F.R.: Nucl. Sci. Eng., 69, 375(1979).

10) Lederer C.M. and Shirley V.S.: Table of Isotopes , 7th ed. (1978).
11) Gilbert A. and Cameron A.G.W.: Can. J. Phys., 43, 1446(1965).
12) Pearlstein S.: Nucl. Sci. Eng., 23, 238 (1965).
13) Fomushkin E.F. et al.: Sov. J. Nucl. Phys., 31, 19(1980).
14) Smith A.B. et al.: ANL/NDM-50 (1979).

MAT number = 3969

```
 96-Cm-249 JAERI        Eval-Mar84 Y.Kikuchi and T.Nakagawa
JAERI-M 84-116          Dist-Sep89
History
84-03 New evaluation for JENDL-3 was made by Y.Kikuchi and
      T.Nakagawa (JAERI).  Details are given in Ref. /1/.

MF=1  General Information
  MT=451  Comments and dictionary
  MT=452  Number of neutrons per fission
        Sum of MT=455 and MT=456.
  MT=455  Number of delayed neutrons per fission
        Semi-empirical formula by Tuttle /2/.
  MT=456  Number of neutrons per fission
        Semi-empirical formula by Howerton /3/.

MF=2  Resonance Parameters
  MT=151  Resonance parameters
     1/v region : 1.0E-5 to 4.15 eV
        No resolved resonances were given.
     Unresolved resonance region : 4.15 eV to 30 keV
        Obtained from optical model calculation:
           S0=1.08E-4, S1=3.95E-4, S2=1.04E-4, R=8.8 fm.
        Estimated from level density parameters and systematics
           D-obs=8.3 eV, Gam-g=40 milli-eV
        Gam-f obtained by fitting the estimated fission cross
        section(see below).

     2200 m/s cross sections and calculated resonance integrals
                    2200 m/s value           res. int.
      total            13.22  b                -
      elastic          10.80  b                -
      fission           0.820 b               139  b
      capture           1.600 b               215  b

MF=3  Neutron Cross Sections
     Below 4.15 eV, pointwise cross sections were given as
     follows:
       MT=1(total)        : sum of partial cross sections,
       MT=2(elastic scat.): 10.8 b calculated with optical model,
       MT=18(fission)     : 1/v shape(0.82 b at 0.0253 eV estimated
                       from ratio of fission and capture cross
                       sections in unresolved resonance region),
       MT=102(capture)     : 1/v shape (1.6 b at 0.0253 eV
                       obtained from measurements by Diamond/4/)
     Between 4.15 eV and 30 keV, cross sections were represented
     with resonance parameters.

  MT=1,2,4,51-57,91,102,251   Total, Elastic and Inelastic
     scattering, Capture cross sections and Mu-L
        Calculated with optical and statistical model code
        CASTHY/5/.
        The spherical optical potential parameters (MeV,fm):
           V  =43.4-0.107*En,               r  =1.282, a  =0.60
           Ws =6.95-0.339*En+0.0531*En**2, rs =1.29,  b  =0.50
                (derivative Woods-Saxon form)
```

Vso=7.0, rso=1.282, aso=0.60
This set of potential parameters was determined /6/ to reproduce well the total cross section of Am-241 by Phillips and Howe /7/.

In the statistical model calculation, competing processes of fission, (n,2n), (n,3n) and (n,4n), and level fluctuation were considered. The level scheme of Cm-249 was taken from Ref./8/.

No.	Energy(keV)	Spin-parity
g.s.	0	1/2 +
1	26.22	3/2 +
2	42.4	5/2 +
3	52.18	7/2 +
4	110	9/2 +
5	110.1	7/2 +
6	146	9/2 +
7	208	3/2 +

Continuum levels assumed above 220 keV.
The level density parameters : Gilbert and Cameron /9/.
Gamma-ray strength function of 4.8E-4 deduced from unresolved resonance parameters.

MT=16,17,37 (*n*,2n), (n,3n) and (n,4n) reaction cross sections
Calculated with evaporation model/10/.

MT=18 Fission
Estimated as 0.95 • sig-f(Cm-247) by using systematics of Behrens and Howerton /11/.

MF=4 *Angular Distributions of Secondary Neutrons*
MT=2,51-57 Calculated with optical model.
MT=16,17,18,37,91 Isotropic in the laboratory system.

MF=5 Energy Distributions of Secondary Neutrons
MT=16,17,37,91 *Evaporation spectrum.*
MT=18 Maxwellian fission spectrum.
Temperature estimated from systematics of Smith et al./12/.

References

1) Kikuchi Y. and Nakagawa T.: JAERI-M 84-116 (1984).
2) Tuttle R.J.: INDC(NDS)-107/G+special, 29 (1979).
3) Howerton R.J.: Nucl. Sci. Eng., 62, 438(1977).
4) Diamond H. et al.: ANL-7330 (1967).
5) Igarasi S.: J. Nucl. Sci. Technol., 12, 67 (1975).
6) Igarasi S. and Nakagawa T.: JAERI-M 8342 (1979).
7) Phillips T.W. and Howe F.R.: Nucl. Sci. Eng., 69, 375 (1979).
8) Lederer C.M. and Shirley V.S.: Table of Isotopes , 7th ed. (1978).
9) Gilbert A. and Cameron A.G.W.: Can. J. Phys., 43, 1446(1965).
10) Pearlstein S.: Nucl. Sci. Eng., 23, 238 (1965).
11) Behrens J.W. and Howerton R.J.: Nucl. Sci. Eng., 65,464(1978).
12) Smith A.B. et al.: ANL/NDM-50 (1979).

MAT number = 3970

96-Cm-250 TIT Eval-Aug87 N.Takagi
Dist-Sep89

History
87-08 New evaluation was made by N. Takagi (Tokyo Institute of Technology, TIT)
89-08 Cross sections were modified below 90 eV.

MF=1 General Information
MT=451 Comment and dictionary
MT=452 Number of neutrons per fission
Evaluated with semi empirical formula of Howerton/1/.

MF=2 Resonance parameters
MT=151 Resonance parameters
No resonance parameters were given.

2200-m/s cross sections and resonance integrals

	2200 m/s value	Res. Int.
Total	11.20 b	-
Elastic	10.80 b	-
Fission	0.002 b	6.86 b
Capture	0.40 b	8.23 b

MF=3 Neutron Cross Sections
MT=1 Total cross section
Below 90 eV, calculated as sum of MT's = 2, 18 and 102. Above 90 eV, optical model calculation was made with CASTHY/2/. The potential parameters/3/ used are as follows,

V = 43.4 - 0.107•En (MeV)
Ws= 6.95 - 0.339•En + 0.0531•En••2 (MeV)
Wv= 0 , Vso = 7.0 (MeV)
r = rso = 1.282 , rs = 1.29 (fm)
a = aso = 0.60 , b = 0.5 (fm)

MT=2 Elastic scattering cross section
Below 90 eV, the constant cross section of 10.8 barns was assumed, which was the shape elastic scattering cross section calculated with optical model. Above this energy, optical model calculation was adopted.

MT=4,51-52,91 Inelastic scattering cross sections.
Optical and statistical model calculation was made with CASTHY/2/. The level scheme was taken from Ref. 4.

No	energy(keV)	spin-parity
g.s.	0	0 +
1	43	2 +
2	142	4 +

Levels above 200 keV were assumed to be overlapping.
The level density parameters were taken from Ref. 5.

MT=16,17,37 (n,2n), (n,3n) and (n,4n) reaction cross sections
Calculated with evaporation model.

MT=18 Fission cross section

The cross section was assumed to be 0.1 barn at 0.0253 eV from the systematics of Prince/6/, and assumed the form of 1/v below 90 eV. At energies above 90 eV, the shape of the Cm-248 fission cross section was adopted, and it was normalized to the systematics of Behrens and Howerton/7/.

MT=102 Capture cross section

The cross section was assumed to be 20 barns at 0.0253 eV from the systematics of Prince/6/ and the correlation of thermal cross sections with number of excess neutron. The 1/v form was assumed below 90 eV. Above 90 eV, the cross section was calculated with CASTHY. The gamma-ray strength function was estimated from Gamma-gamma = 0.040 eV and level spacing = 180 eV.

MT=251 Mu-L

Calculated with CASTHY.

MF=4 Angular Distributions of Secondary Neutrons

MT=2,51-52,91 Calculated with optical model.

MT=16,17,18,37 Isotropic in the lab system.

MF=5 Energy Distributions of Secondary Neutrons

MT=16,17,37,91 Evaporation spectra

Obtained from level density parameters.

MT=18 Maxwellian fission spectrum.

Temperature was estimated from Z**2/A dependence/8/.

References

1) Howerton R.J.: Nucl. Sci. Eng., 62, 438 (1977).
2) Igarasi S.: J.Nucl.Sci.Technol.,12,67 (1975).
3) Igarasi S., Nakagawa T.: JAERI-M 8342 (1979).
4) Schmorak M.R.: Nucl. Data Sheets, 32, 87 (1981).
5) Gilbert A., Cameron A.G.W.: Can. J. Phys., 43, 1446 (1965).
6) Prince A.: Proc. Conf. on Nucl. Cross Sections and Technol., Washington D.C., 4-7 March, (1968), NBS special publication 299, 2, 951 (1968)
7) Behrens J.W. and Howerton R.J: Nucl. Sci. Eng., 65, 464, (1978).
8) Smith A.B. et al.: ANL/NDM-50 (1979).

MAT number = 3971

```
 97-Bk-249 JAERI        Eval-Mar85 Y.Kikuchi and T.Nakagawa
JAERI-M 85-138          Dist-Sep89
History
85-03 New evaluation for JENDL-3 was made by Y.Kikuchi and
      T.Nakagawa (JAERI).  Details are given in Ref. /1/.
88-02 Data were checked and copied into JENDL-3.

MF=1  General Information
  MT=451    Comments and dictionary
  MT=452    Number of neutrons per fission
              Sum of MT's =455 and 456.
  MT=455    Delayed neutron data
              Semi-empirical formula by Tuttle /2/.
  MT=456    Delayed neutron data
              Semi-empirical formula by Howerton /3/.

MF=2,MT=151  Resonance Parameters
  Resolved resonances for MLBW formula : 1.0E-5 eV to 60 eV
    Resonance energies, neutron and radiative widths were taken
    from the experimental data of Benjamin+ /4/.  For resonances
    whose radiative width was unknown, the average value of 0.0357
    eV /4/ was adopted.  Fission width of 0.0002 eV was estimated
    from the thermal fission cross section, which was estimated
    from the systematics of capture to fission ratio by Prince/5/.
    The parameters of the negative resonance were adjusted so as
    to reproduce the thermal cross sections. No background
    correction was applied.

  Unresolved resonances : 60 eV - 30 keV
    Obtained from optical model calculation:
        S1=3.0E-4   ,S2=0.83E-4   ,R=9.07 fm.
    Estimated from resolved resonances:
        Dobs=1.16 ev, gam-g=35.7 milli-eV ,S0=1.13E-4
        gam-f=0.2 milli-eV.

  Calculated 2200 m/s cross sections and resonance integrals
                     2200 m/s value          res. int.
       total          717.5    b                -
       elastic          3.93   b                -
       fission          3.96   b              12.1 b
       capture        709.6    b            1130   b

MF=3  Neutron Cross Sections
  MT=1,2,4,51-68,91,102,251   Sig-t,sig-el,sig-in,sig-c,mu-bar
        Calculated with optical and statistical models.
        Optical potential parameters were obtained by fitting the
        total cross section of Phillips and Howe /6/ for Am-241:
           V = 43.4 - 0.107*En                          (MeV)
           Ws= 6.95 - 0.339*En + 0.0531*En**2           (MeV)
           Wv= 0                 , Vso = 7.0            (MeV)
           r = rso = 1.282       , rs = 1.29            (fm)
           a = aso = 0.60        , b  = 0.5             (fm)
        Statistical model calculation with CASTHY code /7/.
           Competing processes : fission,(n,2n),(n,3n),(n,4n).
           Level fluctuation considered.
```

The level scheme taken from Ref. /8/.

No.	Energy(keV)	Spin-parity
g.s.	0	7/2 +
1	8.8	3/2 –
2	39.6	5/2 –
3	41.8	9/2 +
4	82.6	7/2 –
5	93.74	11/2 +
6	137.7	9/2 –
7	155.84	13/2 +
8	204.6	11/2 –
9	229.3	15/2 +
10	283.0	13/2 –
11	313.0	17/2 +
12	372.8	15/2 –
13	377.6	1/2 +
14	389.2	5/2 +
15	410.6	3/2 +
16	421.3	5/2 +
17	428.9	7/2 +
18	474.9	9/2 +

Continuum levels assumed above 519 keV.
The level density parameters : Gilbert and Cameron /9/.
Gamma-ray strength function of 3.2E-2 deduced from resonance parameters.

MT=16,17,37 (n,2n),(n,3n),(n,4n)
Calculated with evaporation model.

MT=18 Fission
Evaluated on the basis of the measured data by Silbert/10/, Vorotonikov+/11/ and Fomushkin+ /12/.

MF=4 Angular Distributions of Secondary Neutrons
MT=2,51-68 Calculated with optical model.
MT=16,17,18,37,91 Isotropic in the laboratory system.

MF=5 Energy Distributions of Secondary Neutrons
MT=16,17,37,91 Evaporation spectrum.
MT=18 Maxwellian fission spectrum.
Temperature estimated from systematics of Smith+/13/.

References

1) Kikuchi Y. and Nakagawa T.: JAERI-M 85-138 (1985).
2) Tuttle R.J.: INDC(NDS)-107/G+Special, p.29 (1979).
3) Howerton R.J.: Nucl. Sci. Eng., 62, 438 (1977).
4) Benjamin R.W. et al.: Nucl. Sci. Eng., 85, 261 (1983).
5) Prince A.: Trans. Am. Nucl. Soc., 10, 228 (1967)
6) Phillips T.W. and Howe F.R.: Nucl. Sci. Eng., 69, 375 (1979).
7) Igarasi S.: J. Nucl. Sci. Technol., 12, 67 (1975).
8) Lederer C.M. and Shirley V.S.: Table of Isotopes , 7th ed.
9) Gilbert A. and Cameron A.G.W.: Can. J. Phys., 43, 1446 (1965).
10) Silbert M.G.: Nucl. Sci. Eng., 63, 198 (1977).
11) Vorotnikov I.V. et al.: Sov. J. Nucl. Phys., 10, 419 (1970).
12) Fomshkin E.F. et al.: Sov. J. Nucl. Phys., 14, 41(1972).
13) Smith A.B. et al.: ANL/NDM-50 (1979).

MAT number = 3972

97-Bk-250 JAERI Eval-Mar87 T.Nakagawa
JAERI-M 88-004 Dist-Sep89
History
87-03 New evaluation was made by T.Nakagawa (JAERI).
Details are described in Ref. /1/.

MF=1 General Information
MT=451 Comments and dictionary
MT=452 Number of neutrons per fission
Sum of MT=455 and MT=456
MT=455 Delayed neutron data
Based on semi-empirical formula by Tuttle /2/.
MT=456 Number of prompt neutrons per fission
Based on semi-empirical formula by Howerton /3/.

MF=2,MT=151 Resonance Parameters
Resolved resonance parameters (MLBW) : 1.0E-5 eV TO 100 eV
Resonance parameters were hypothetically generated adopting the following average values.
D-obs = 2.09 eV (from level density parameters)
S0, S1= 0.83E-4, 3.37E-4 (from optical model calc.)
Radiative width = 0.035eV (same as Cf-252)
Fission width = 0.095 eV (assumed that the ratio of fission to radiative width is equal to cross section ratio)
The energy of first level was adjusted to reproduce the 2200-m/s cross sections of 350 barns /4/ and 960 barns /5/ for capture and fission, respectively.
Unresolved resonances : 0.1 to 30 keV
By adopting parameters used for resolved resonance generation as initial values, they were adjusted to reproduce the evaluated fission and capture cross sections by using ASREP /6/. Final values of the parameters are,
S0 = 0.82E-4, S1 = 3.9E-4, D-obs = 2.09 eV,
radiative width = 0.035 eV, R =9.02 fm,
fission width = 0.104 eV at 100 eV, 0.208 eV at 30 keV.

Calculated 2200 m/s cross sections and resonance integrals

	2200 m/s value	Res. Int.
Total	1325.0 B	-
Elastic	12.22 B	-
Fission	959.3 B	517. B
Capture	353.4 B	199. B

MF=3 Neutron Cross Sections

1) The optical model calculation was performed with code CASTHY /7/. Optical potential parameters used were obtained /8/ by fitting the total cross section measured by Phillips and Howe /9/ for Am-241:
V = 43.4 - 0.107*En (MeV)
Ws= 6.95 - 0.339*En + 0.0531*En**2 (MeV)
(in the Derivative Woods-Saxon form)
Wv= 0 , Vso = 7.0 (MeV)
r = rso = 1.282 , rs = 1.29 (fm)

a = aso = 0.60 , b = 0.6 (fm)

2) In the statistical calculation, the fission, (n,2n), (n,3n) and (n,4n) cross sections were considered as the competing proccess cross sections.
3) The level density parameters were derived from resonance level spacings and low laying excited levels on the basis of Gilbert-Cameron's formula /10/.

Isotope	247	248	249	250	251
a(1/MeV)	28.1	27.8	34.2	30.05	30.0
Spin-cutoff fact	30.47	30.39	33.79	31.76	31.82
Pairing E(MeV)	0.39	0.0	0.903	0.0	0.865
Temp.(MeV)	0.364	0.326	0.366	0.340	0.385
C(1/MeV)	2.90	10.8	12.2	24.6	6.56
Ex(MeV)	7.97	1.85	4.30	2.34	4.05

Below 30 keV, cross sections are represented with resonance parameters.

MT=1,2 Total and Elastic scattering
The optical model calculation was adopted.

MT=4, 51 to 68 and 91 Inelastic scattering
The level scheme was taken from Ref. /11/.

No.	Energy(keV)	spin-parity
Ground	0.0	2 -
1	34.5	3 -
2	35.6	4 +
3	78.1	5 +
4	86.4	7 +
5	97.0	5 -
6	104.1	1 -
7	125.4	2 -
8	129.0	6 +
9	131.9	3 +
10	157.0	8 +
11	167.0	6 -
12	175.4	1 +
13	191.0	7 +
14	211.8	2 +
15	237.0	3 +
16	242.0	9 +
17	248.0	7 -
18	270.0	4 +

Levels above 296 keV were assumed to be overlapping.

MT=16, 17 and 37 .(n,2n), (n,3n) and (n,4n)
Calculated with evaporation model by taking the compound nucleus formation cross section calculated with optical model.

MT=18 Fission
Shape of the Cf-251 fission cross section /12/ was adopted

and multiplied by the factor of 0.84.

MT=102 Radiative capture
Calculated with CASTHY. The average radiative width of 0.035 eV and s-wave level spacing of 2.09 eV were assumed.

MT=251 Mu-bar
Calculated with CASTHY.

MF=4 Angular Distributions of Secondary Neutrons
MT=2,51-68 Calculated with optical model.
MT=16,17,18,37,91 Isotropic distributions in the laboratory system were assumed.

MF=5 Energy Distributions of Secondary Neutrons
MT=16,17,37,91 Evaporation spectrum assumed.
MT=18 Maxwellian fission spectrum.
Temperature estimated from systematics of Smith et al./13/.

References

1) Nakagawa, T.: JAERI-M 88-004 (1987).
2) Tuttle, R.J.: INDC(NDS)-107/G+SPECIAL, P.29 (1979).
3) Howerton, R.J.: Nucl. Sci. Eng., 62, 438 (1977).
4) Mughabghab, S.F.: Neutron Cross Sections, Vol.1, part B, Academic Press (1984)
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6) Igarasi, S.: J. Nucl. Sci. Technol., 12, 67 (1975).
7) Kikuchi, Y.: private communication.
8) Igarasi, S. and Nakagawa T.: JAERI-M 8342 (1979).
9) Phillips, T.W. and Howe, F.R.: Nucl. Sci. Eng., 69, 375(1979).
10) Gilbert A. and Cameron A.G.W. : Can. J. Phys., 43, 1446(1965).
11) Schmorak, M.R.: Nucl. Data Sheets, 32, 87 (1981).
12) Nakagawa, T: JAERI-M 86-086 (1986).
13) Smith, A.B. et al.: ANL/NDM-50 (1979).

MAT number = 3981

```
 98-Cf-249 JAERI        Eval-Mar85 Y.Kikuchi and T.Nakagawa
 JAERI-M 85-138         Dist-Sep89
History
85-03 New evaluation for JENDL-3 was made by Y.Kikuchi and
      T.Nakagawa (JAERI).  Details are given in Ref. /1/.
88-02 Data were checked and adopted for JENDL-3.

MF=1  General Information
  MT=451   Comments and dictionary
  MT=452   Number of neutrons per fission
             Sum of MT's = 455 and 456.
  MT=455   Delayed neutron data
             Semi-empirical formula by Tuttle /1/.
  MT=456   Number of prompt neutrons per fission
             Semi-empirical formula by Howerton /3/.

MF=2,MT=151  Resonance Parameters
  Resolved resonances for MLBW formula : 1.0E-5 eV to 70 eV
    Resonance energies, neutron and fission widths were taken
    from the experimental data of Benjamin+ /4/.  The radiative
    width was assumed to be 0.04 eV according to Dabbs+ /5/.
    A negative resonance was added so as to reproduce the thermal
    cross sections. No background correction was applied.

  Unresolved resonances : 70 eV - 30 keV
    Obtained from optical model calculation:
        S1=3.15E-4, S2=0.83E-4, R=9.08 fm.
    Estimated from resolved resonances:
        Dobs=1.16 eV, gam-g=40 milli-eV ,S0=1.06E-4
    Fission widths were estimated from the channel theory of
    fission /6/. S0, S1 and S2 values were adjusted so as to
    reproduce the fission cross section measured by Dabbs+ /5/.

  Calculated 2200 m/s cross sections and resonance integrals
                    2200 m/s value           res. int.
      total         2176.7    b                 -
      elastic          6.22   b                 -
      fission       1666      b              2220  b
      capture        504.5    b               695  b

MF=3  Neutron Cross Sections
  MT=1,2,4,51-63,91,102,251   sig-t,sig-el,sig-in,sig-c,mu-bar
        Calculated with optical and statistical models.
        Optical potential parameters were obtained by fitting the
        total cross section of Phillips and Howe /7/ for Am-241:
           V = 43.4 - 0.107*En                         (MeV)
           Ws= 6.95 - 0.339*En + 0.0531*En**2          (MeV)
           Wv= 0                , Vso = 7.0            (MeV)
           r = rso = 1.282      , rs = 1.29            (fm)
           a = aso = 0.60       , b  = 0.5             (fm)
        Statistical model calculation with CASTHY code /8/.
           Competing processes : fission,(n,2n),(n,3n),(n,4n).
           Level fluctuation considered.
        The level scheme taken from Ref. /9/.
                    No.         Energy(keV)   Spin-parity
```

g.s.	0	9/2 -
1	62.47	11/2 -
2	136.2	13/2 -
3	145.0	5/2 +
4	188.0	7/2 +
5	219.0	15/2 -
6	243.1	9/2 +
7	379.5	7/2 +
8	416.6	1/2 +
9	437.5	9/2 +
10	440.0	3/2 +
11	443.0	7/2 +
12	460.0	5/2 +
13	500.6	9/2 +

Continuum levels assumed above 550 keV.
The level density parameters : Gilbert and Cameron /10/.
gamma-ray strength function of 3.3E-2 deduced from resonance parameters.

MT=16,17,37 (n,2n),(n,3n),(n,4n)
Calculated with evaporation model.

MT=18 Fission
Evaluated on the basis of the measured data by Silbert/11/, Dabbs+ /5/ and Kupriyanov+ /12/.

MF=4 Angular Distributions of Secondary Neutrons
MT=2,51-63 Calculated with optical model.
MT=16,17,18,37,91 Isotropic in the laboratory system.

MF=5 Energy Distributions of Secondary Neutrons
MT=16,17,37,91 Evaporation spectrum.
MT=18 Maxwellian fission spectrum.
Temperature estimated from systematics of Smith+/13/.

References

1) Kikuchi Y. and Nakagawa T.: JAERI-M 85-138 (1985).
2) Tuttle R.J.: INDC(NDS)-107/G+Special, p.29 (1979).
3) Howerton R.J.: Nucl. Sci. Eng., 62, 438 (1977).
4) Benjamin R.W. et al.: Nucl. Sci. Eng., 85, 261 (1983).
5) Dabbs J.W.T. et al.: ORNL-4973, p.181 (1974).
6) Kikuchi Y. and An S.: J. Nucl. Sci. Technol., 7, 157 (1970).
7) Phillips T.W. and Howe F.R.: Nucl. Sci. Eng., 69, 375 (1979).
8) Igarasi S.: J. Nucl. Sci. Technol., 12, 67 (1975).
9) Lederer C.M. and Shirley V.S.: Table of Isotopes , 7th ed.
10) Gilbert A. and Cameron A.G.W.: Can. J. Phys., 43, 1446(1965).
11) Silbert M.G.: Nucl. Sci. Eng., 51, 376 (1973).
12) Kupriyanov V.M. et al.: Sov. Atom. Energy, 55, 472 (1984).
13) Smith A.B. et al.: ANL/NDM-50 (1979).

MAT number = 3982

```
 98-Cf-250 JAERI        Eval-Mar86 T.Nakagawa
 JAERI-M 86-086         Dist-Sep89
History
86-03 New evaluation was made by T.Nakagawa (JAERI).
      Details are described in Ref. /1/.

MF=1  General Information
  MT=451   Comments and dictionary
  MT=452   Number of neutrons per fission
             Sum of MT=455 and MT=456
  MT=455   Delayed neutron data
             Based on semi-empirical formula by Tuttle /2/.
  MT=456   Number of prompt neutrons per fission
             Based on semi-empirical formula by Howerton /3/.

MF=2,MT=151  Resonance Parameters
  Resolved resonances for SLBW formula : 1.0E-5 eV to 150 eV
    Hypothetical resonance levels were generated, and their
    parameters were determined from the assumed average parameters
        D-0 = 16 eV,  radiative capture width = 0.0369 eV,
        S-0 = 1.0E-4, fission with = 0.0001 eV, R = 9.252 fm,
    Parameters of the negative and first positive levels were
    adjusted so as to reproduce the thermal cross sections and
    resonance integrals.
  Unresolved resonances                   : 150 eV to 30 keV
    S-0 = 1.0E-4, S-1 = 3.3E-4, D-0=16 eV, R = 9.11 fm,
    radiative width = 0.0369 eV, fission width = 0.0001 eV.
    The scattering radius was adjusted slightly.

  calculated 2200 m/s cross sections and resonance integrals
                  2200 m/s value          res. int.
      total       1950.7    b                -
      elastic      167.4    b                -
      fission        4.09   b              27.8 b
      capture     1779.2    b             8420   b

MF=3  Neutron Cross Sections
  MT=1    Total
  MT=2    Elastic scattering
  MT=4, 51 to 79 and 91 Inelastic scattering
  MT=102 Radiative capture
  MT=251 Mu-bar
    Calculated with the program CASTHY /4/ based on the optical
    and statistical models.  Optical potential parameters were
    obtained /5/ by fitting the total cross section of Phillips
    and Howe /6/ for Am-241:
           V = 43.4 - 0.107*En                        (MeV)
           Ws= 6.95 - 0.339*En + 0.0531*En**2         (MeV)
           Wv= 0                 , Vso = 7.0          (MeV)
           r = rso = 1.282     , rs = 1.29            (fm)
           a = aso = 0.60      , b  = 0.5             (fm)
    In the statistical calculation, level fluctuation and
    competing process (fission, (n,2n) and (n,3n)) were taken into
    account.  The level scheme was taken from Ref. /7/.
          No.  Energy(keV) J-parity     No.  Energy(keV) J-parity
```

ground	0.0	0 +	15	1209.98	2 -
1	42.722	2 +	16	1211.	3 -
2	141.886	4 +	17	1244.51	2 +
3	296.25	6 +	18	1255.47	4 -
4	871.64	2 -	19	1266.65	0 +
5	905.90	3 -	20	1296.64	2 +
6	952.07	4 -	21	1311.07	5 -
7	1008.6	5 -	22	1335.	3 -
8	1031.85	2 +	23	1377.83	6 -
9	1070.	6 -	24	1385.49	(1 +)
10	1071.38	3 +	25	1396.16	5 -
11	1123.	4 +	26	1411.34	(1 +)
12	1154.23	0 +	27	1426.86	3 -
13	1175.52	1 -	28	1457.83	6 -
14	1189.40	2 +	29	1478.45	5 -

Levels above 1.50 MeV were assumed to be overlapping. The level density parameters were derived from resonance level spacings and low laying excited levels on the basis of Gilbert-Cameron's foumula /8/. The average radiative capture width of 0.0369 eV and s-wave level spacing of 16 eV were assumed.

MT=16 and 17 (n,2n) and (n,3n)
Calculated with evaporation model.

MT=18 Fission
Evaluated on the basis of the systematics.

MF=4 Angular Distributions of Secondary Neutrons
MT=2,51-79 Calculated with optical model.
MT=16,17,18,91 Isotropic distributions in the laboratory system were assumed.

MF=5 Energy Distributions of Secondary Neutrons
MT=16,17,91 Evaporation spectrum.
MT=18 Maxwellian fission spectrum.
Temperature estimated from systematics of Smith et al./9/.

References
1) Nakagawa, T.: JAERI-M 86-086 (1986).
2) Tuttle, R.J.: INDC(NDS)-107/G+Special, p.29 (1979).
3) Howerton, R.J.: Nucl. Sci. Eng., 62, 438 (1977).
4) Igarasi, S.: J. Nucl. Sci. Technol., 12, 67 (1975).
5) Igarasi, S. and Nakasawa, T.: JAERI-M 8342 (1979).
6) Phillips, T.W. and Howe, F.R.: Nucl. Sci. Eng., 69, 375(1979).
7) Schmorak, M.R.: Nucl. Data Sheets, 32, 87 (1981).
8) Gilbert A. and Cameron A.G.W.: Can. J. Phys., 43, 1446 (1965).
9) Smith A.B. et al.: ANL/NDM-50 (1979).

MAT number = 3983

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 98-Cf-251 JAERI       Eval-Mar86 T.Nakagawa
 JAERI-M 86-086        Dist-Sep89
History
86-03 New evaluation was made by T.Nakagawa (JAERI).
      Details are described in Ref. /1/.

MF=1  General Information
  MT=451   Comments and dictionary
  MT=452   Number of neutrons per fission
             Sum of MT=455 and MT=456
  MT=455   Delayed neutron data
             Based on semi-empirical formula by Tuttle /2/.
  MT=456   Number of prompt neutrons per fission
             Based on semi-empirical formula by Howerton /3/.

MF=2,MT=151  Resonance Parameters
  Resolved resonances for SLBW formula : 1.0E-5 eV to 150 eV
    Hypothetical resonance levels were generated, and their
    parameters were determined from the assumed average parameters
        D-0 = 6.3 eV, radiative capture width = 0.0435 eV,
        S-0 = 1.0E-4, fission with = 0.0746 eV, R = 9.253 fm.
    Parameters of the negative and first positive levels were
    adjusted so as to reproduce the thermal cross sections and
    resonance integrals.
  Unresolved resonances                 : 150 eV to 30 keV
    Parameters were adjusted so as to reproduce the assumed
    fission and radiative capture cross sections.
        S-0 = 0.843E-4, S-1 = 4.56E-4, R = 8.842 fm,
        D-0 = 6.3 eV, radiative width = 0.0435 eV,
        fission width = 0.281 eV (for l=0), = 0.551 eV (for L=1)

  Calculated 2200 m/s cross sections and resonance integrals
                    2200-m/s value          res. int.
     total          7889.4    b               -
     elastic          76.04   b               -
     fission        4935.4    b             2780.  b
     capture        2877.9    b             1600.  b

MF=3  Neutron Cross Sections
  MT=1    Total
  MT=2    Elastic scattering
  MT=4, 51 to 73 and 91 Inelastic scattering
  MT=102 Radiative capture
  MT=251 Mu-bar
    Calculated with the program CASTHY /4/ based on the optical
    and statistical models.  Optical potential parameters were
    obtained /5/ by fitting the total cross section of Phillips
    and Howe /6/ for Am-241:
           V = 43.4 - 0.107*En                       (MeV)
           Ws= 6.95 - 0.339*En + 0.0531*En**2        (MeV)
           Wv= 0                  , Vso = 7.0        (MeV)
           r = rso = 1.282    , rs = 1.29            (fm)
           a = aso = 0.60     , b  = 0.5             (fm)
    In the statistical calculation, level fluctuation and
    competing process(fission, (n,2n), (n,3n) and (n,4n)) were
```

taken into account. The level scheme was taken from Ref. /7/.

No.	Energy(keV)	J-parity	No.	Energy(keV)	J-parity
ground	0.0	1/2 +	12	295.7	13/2 +
1	24.825	3/2 +	13	319.29	9/2 +
2	47.828	5/2 +	14	325.35	13/2 +
3	105.73	7/2 +	15	370.39	11/2 -
4	106.304	7/2 +	16	392.0	11/2 +
5	146.46	9/2 +	17	424.10	15/2 +
6	166.31	9/2 +	18	434.3	9/2 -
7	177.69	3/2 +	19	442.	13/2 -
8	211.72	5/2 +	20	514.	11/2 -
9	237.76	11/2 +	21	544.05	5/2 +
10	239.34	11/2 +	22	590.18	7/2 +
11	258.44	7/2 +	23	649.2	9/2 +

Levels above 700 keV were assumed to be overlapping. The level density parameters were derived from resonance level spacings and low laying excited levels on the basis of Gilbert-Cameron's foumula /8/. The average radiative capture width of 0.0435 eV and s-wave level spacing of 6.3 eV were assumed.

MT=16,17 and 37 (n,2n), (n,3n) and (n,4n)
Calculated with evaporation model.

MT=18 Fission
Evaluated on the basis of the systematics.

MF=4 Angular Distributions of Secondary Neutrons
MT=2,51-73 Calculated with optical model.
MT=16,17,18,37,91 Isotropic distributions in the laboratory system were assumed.

MF=5 Energy Distributions of Secondary Neutrons
MT=16,17,37,91 Evaporation spectrum.
MT=18 Maxwellian fission spectrum. Temperature estimated from systematics of Smith et al./9/.

References

1) Nakagawa, T.: JAERI-M 86-086 (1986).
2) Tuttle, R.J.: INDC(NDS)-107/G+Special, p.29 (1979).
3) Howerton, R.J.: Nucl. Sci. Eng., 62, 438 (1977).
4) Igarasi, S.: J. Nucl. Sci. Technol., 12, 67 (1975).
5) Igarasi, S. and Nakasawa, T. : JAERI-M 8342 (1979).
6) Phillips, T.W. and Howe, F.R.: Nucl. Sci. Eng., 69, 375(1979).
7) Schmorak, M.R.: Nucl. Data Sheets, 32, 87 (1981).
8) Gilbert, A. and Cameron, A.G.W.: Can. J. Phys., 43,1446(1965).
9) Smith A.B. et al.: ANL/NDM-50 (1979).

MAT number = 3984

```
 98-Cf-252 JAERI       Eval-Mar87 T.Nakagawa
 JAERI-M 88-004        Dist-Sep89
History
87-03 New evaluation was made by T.Nakagawa (JAERI).
      Details are described in Ref. /1/.

MF=1  General Information
  MT=451   Comments and dictionary
  MT=452   Number of neutrons per fission
             Sum of MT=455 and MT=456
  MT=455   Delayed neutron data
             Based on semi-empirical formula by Tuttle /2/.
  MT=456   Number of prompt neutrons per fission
             Based on semi-empirical formula by Howerton /3/.

MF=2,MT=151  Resonance Parameters
  Resolved resonance parameters (MLBW) : 1.0E-5 eV TO 1 keV
    Resonance parameters were taken from Moore el al. /4/ by
    assuming an average value of radiative capture width (0.035
    eV) and fission width (0.035 eV).  Two hypothetical resonances
    at 1.4 and -3.5 eV were adopted to reproduce the 2200-m/s
    cross sections and resonance integrals /5,6/.  Scattering
    radius of 9.23 fm was estimated from the shape elastic
    scattering cross section calculated with CASTHY /7/ from
    optical potential parameters given below.
  Unresolved resonances                : 1 to 30 keV
    Parameters were estimated from resolved resonances and
    adjusted so as to reproduce the evaluated fission and capture
    cross sections by using ASREP /8/.  Values of the parameters
    are D-obs = 27 eV, R = 8.9 fm and S0, S1, capture and fission
    widths are as follows.
           Energy     S0        S1      Capt-width  Fiss-width
            1.0 keV  1.22-4    3.37-4    0.035 eV    0.056 eV
           30.0      1.22-4    3.37-4    0.035       0.096

  Calculated 2200 m/s cross sections and resonance integrals
                     2200 m/s value           Res. Int.
      Total           64.77   B                 -
      Elastic         11.04   B                 -
      Fission         33.03   B               111.  B
      Capture         20.71   B                47.4 B

MF=3  Neutron Cross Sections
    Below 30 keV, cross sections are represented with resonance
    parameters.  Above 30 keV, data were mainly calculated with
    optical and statistical models.

 1) The optical model calculation was performed with code CASTHY
    /7/.  Optical potential parameters used were obtained /9/ by
    fitting the total cross section measured by Phillips and Howe
    /10/ for Am-241:
           V = 43.4 - 0.107*En                          (MeV)
           Ws= 6.95 - 0.339*En + 0.0531*En**2           (MeV)
                  (in the Derivative Woods-Saxon form)
           Wv= 0                , Vso = 7.0             (MeV)
```

r = rso = 1.282 , rs = 1.29 (fm)
a = aso = 0.60 , b = 0.5 (fm)

2) In the statistical calculation, the fission, (n,2n), (n,3n) and (n,4n) cross sections were considered as the competing process cross sections.
3) The level density parameters were derived from resonance level spacings and low laying excited levels on the basis of Gilbert-Cameron's formula /11/.

Isotope	249	250	251	252	253
a(1/MeV)	29.4	31.2	32.2	31.6	32.2
Spin-cutoff fact	31.25	32.36	32.97	32.74	33.14
Pairing E(MeV)	1.16	1.673	0.77	1.635	0.77
Temp.(MeV)	0.3693	0.4025	0.3809	0.3927	0.3322
C(1/MeV)	1.625	2.093	14.84	1.895	3.59
Ex(MeV)	3.954	5.418	4.204	5.233	3.226

MT=1,2 Total and elastic scattering
The optical model calculation was adopted.

MT=4, 51 to 59 and 91 Inelastic scattering
The level scheme was taken from Ref. /12/.

No.	Energy(keV)	spin-parity
Ground	0.0	0 +
1	45.75	2 +
2	151.73	4 +
3	804.82	2 +
4	830.81	2 -
5	845.72	3 +
6	867.51	3 -
7	900.3	4 +
8	917.03	4 -
9	969.83	3 +

Levels above 1.03 MeV were assumed to be overlapping.

MT=16, 17 and 37 (n,2n), (n,3n) and (n,4n)
Calculated with evaporation model by taking the compound nucleus formation cross section calculated with optical model.

MT=18 Fission
Evaluated on the basis of experimental data by Moore el al. /4/.

MT=102 Radiative capture
Calculated with CASTHY. The average radiative width of 0.035 eV and s-wave level spacing of 27 eV were assumed.

MT=251 Mu-bar
Calculated with CASTHY.

MF=4 Angular Distributions of Secondary Neutrons
MT=2,51-59 Calculated with optical model.

MT=16,17,18,37,91 Isotropic distributions in the laboratory system were assumed.

MF=5 Energy Distributions of Secondary Neutrons
MT=16,17,37,91 Evaporation spectrum assumed.
MT=18 Maxwellian fission spectrum.
Temperature estimated from systematics of Smith et al./13/.

References
1) Nakagawa, T.: JAERI-M 88-004 (1987).
2) Tuttle, R.J.: INDG(NDS)-107/G+SPECIAL, P.29 (1979).
3) Howerton, R.J.: Nucl. Sci. Eng., 62, 438 (1977).
4) Moore, M.S., et al.: Phys. Rev., C4, 273 (1971).
5) Halperin, J., et al.: Nucl. Sci. Eng., 37, 228 (1969).
6) Halperin, J., et al.: ORNL 4706, 53 (1971).
7) Igarasi, S.: J. Nucl. Sci. Technol., 12, 67 (1975).
8) Kikuchi, Y.: private communication.
9) Igarasi, S. and Nakagawa T.: JAERI-M 8342 (1979).
10) Phillips, T.W. and Howe, F.R.: Nucl. Sci. Eng., 69, 375(1979).
11) Gilbert A. and Cameron A.G.W. : Can. J. Phys., 43, 1446(1965).
12) Schmorak, M.R.: Nucl. Data Sheets, 32, 87 (1981)
13) Smith A.B. et al.: ANL/NDM-50 (1979).

MAT number = 3985

98-Cf-254 TIT Eval-Aug87 N.Takagi
Dist-Sep89

History
87-08 New evaluation was made by N. Takagi (Tokyo Institute of Technology, TIT)

MF=1 General Information
MT=451 Comment and dictionary
MT=452 Number of neutrons per fission
Evaluated with semi empirical formula of Howerton/1/.

MF=2 Resonance parameters
MT=151 Resonance parameters
No resonance parameters were given.

2200-m/s cross sections and resonance integrals

	2200 m/s value	Res. Int.
Total	17.10 b	-
Elastic	10.60 b	-
Fission	2.00 b	24.3 b
Capture	4.50 b	6.5 b

MF=3 Neutron Cross Sections
MT=1 Total cross section
Below 120 eV, calculated as sum of MT's = 2, 18 and 102. Above 120 eV, optical model calculation was made with CASTHY/2/. The potential parameters/3/ used are as follows,

```
V = 43.4 - 0.107*En                             (MeV)
Ws= 6.95 - 0.339*En + 0.0531*En**2              (MeV)
Wv= 0                 , Vso = 7.0               (MeV)
r = rso = 1.282       , rs = 1.29               (fm)
a = aso = 0.60        , b  = 0.5                (fm)
```

MT=2 Elastic scattering cross section
Below 120 eV, the constant cross section of 10.6 barns was assumed, which was the shape elastic scattering cross section calculated with optical model. Above this energy, optical model calculation was adopted.

MT=4,51,91 Inelastic scattering cross sections.
Optical and statistical model calculation was made with CASTHY/2/. The level scheme was taken from Ref. 4.

No	energy(keV)	spin-parity
g.s.	0.0	0 +
1	45.0	2 +

Levels above 140 keV were assumed to be overlapping.
The level density parameters were taken from Ref. 5.

MT=16,17,37 (n,2n), (n,3n) and (n,4n) reaction cross sections
Calculated with evaporation model.

MT=18 Fission cross section
The thermal cross section of 2.0 barns was estimated from the ratio of fission and capture cross sections at 1 eV

and measured capture cross section at 0.0253 eV. The form of 1/v was assumed below 120 eV. For energy above 120 eV, the shape of Cf-252 fission cross section was adopted and it was normalized to the systematics of Behrens and Howerton/6/.

MT=102 Capture cross section
Measured thermal cross section of 4.5 barns was taken from Ref. 7 , and 1/v form was assumed below 120 eV. Above 120 eV, the cross section was calculated with CASTHY.
The gamma-ray strength function was estimated from Gamma-gamma = 0.040 eV and level spacing = 240 eV.

MT=251 Mu-L
Calculated with CASTHY.

MF=4 Angular Distributions of Secondary Neutrons
MT=2,51,91 Calculated with optical model.
MT=16,17,18,37 Isotropic in the lab system.

MF=5 Energy Distributions of Secondary Neutrons
MT=16,17,37,91 Evaporation spectra.
Obtained from level density parameters.

MT=18 Maxwellian fission spectrum.
Temperature was estimated from Z**2/A dependence/8/.

References

1) Howerton R.J.: Nucl. Sci. Eng., 62, 438 (1977).
2) Igarasi S.: J.Nucl.Sci.Technol.,12,67 (1975).
3) Igarasi S., Nakagawa T.: JAERI-M 8342 (1979).
4) Schmorak M.R.: Nucl. Data Sheets, 32, 87 (1981).
5) Gilbert A., Cameron A.G.W.: Can. J. Phys., 43, 1446 (1965).
6) Behrens J.W. and Howerton R.J: Nucl. Sci. Eng., 65, 464, (1978).
7) Mughabghab S.F.: "Neutron Cross Sections, Vol.1, Neutron Resonance Parameters and Thermal Cross Sections , Part B, Z=61-100", Academic Press (1984).
8) Smith A.B. et al. : ANL/NDM-50 (1979).

MAT number = 3991

99-Es-254 TIT Eval-Aug87 N.Takagi
Dist-Sep89

History
87-08 New evaluation was made by N. Takagi (Tokyo Institute of Technology, TIT)

MF=1 General Information
MT=451 Comment and dictionary
MT=452 Number of neutrons per fission
Evaluated with semi empirical formula of Howerton/1/.

MF=2 Resonance parameters
MT=151 Resonance parameters
No resonance parameters were given.

2200-m/s cross sections and resonance integrals

	2200 m/s value	Res. Int.
Total	2004.90 b	-
Elastic	10.60 b	-
Fission	1966.00 b	1220 b
Capture	28.30 b	18.0 b

MF=3 Neutron Cross Sections
MT=1 Total cross section
Below 5 eV, calculated as sum of MT's = 2, 18 and 102. Above 5 eV, optical model calculation was made with CASTHY/2/. The potential parameters/3/ used are as follows,

```
V = 43.4 - 0.107*En                      (MeV)
Ws= 6.95 - 0.339*En + 0.0531*En**2       (MeV)
Wv= 0              , Vso = 7.0           (MeV)
r = rso = 1.282    , rs = 1.29           (fm)
a = a   = 0.60     , b  = 0.5            (fm)
```

MT=2 Elastic scattering cross section
Below 5 eV, the constant cross section of 10.6 barns was assumed, which was the shape elastic scattering cross section calculated with optical model. Above this energy, optical model calculation was adopted.

MT=4,51-52,91 Inelastic scattering cross sections.
Optical and statistical model calculation was made with CASTHY/2/. The level scheme was taken from Ref. 4.

No	energy(keV)	spin-parity
g.s.	0.0	7 +
1	78.0	2 +

Levels above 503 keV were assumed to be overlapping. The level density parameters were taken from Ref 5.

MT=16,17,37 (n,2n), (n,3n) and (n,4n) reaction cross sections
Calculated with evaporation model.

MT=18 Fission cross section
Measured thermal cross section of 1966 barns was taken from Ref. 6. The 1/v form was assumed below 5 eV. The

shape of cross section near 5 eV was adjusted so as to reproduce the measured resonance integral of 1200+-250 barns/6/. Above 5 eV, the cross section shape was assumed to be the same as Bk-250 fission cross section and it was normalized to systematics of Behrens and Howerton/7/.

MT=102 Capture cross section
Measured thermal cross section of 28.3 barns was taken from Ref. 6 , and 1/v form was assumed below 5 eV. The cross section near 5 eV was adjusted so as to reproduce the measured resonance integral of 18.2+-1.5 barns/6/. Above 5 eV, calculated with CASTHY. The gamma-ray strength function was estimated from Gamma-gamma = 0.040 eV and level spacing = 2 eV.

MT=251 Mu-L
Calculated with CASTHY.

MF=4 Angular Distributions of Secondary Neutrons
MT=2,51-52,91 Calculated with optical model
MT=16,17,18,37 Isotropic in the lab system.

MF=5 Energy Distributions of Secondary Neutrons
MT=16,17,37,91 Evaporation spectra
Obtained from level density parameters

MT=18 Maxwellian fission spectrum
Temperature was estimated from Z**2/A dependence/8/

References

1) Howerton R J Nucl Sci Eng , 62, 438 (1977)
2) Igarasi S J Nucl Sci Technol ,12,67 (1975)
3) Igarasi S , Nakagawa T JAERI-M 8342 (1979)
4) Schmorak M R Nucl Data Sheets, 32, 87 (1981)
5) Gilbert A , Cameron A G W Can J Phys , 43, 1446 (1965)
6) Mughabghab S F "Neutron Cross Sections, Vol 1, Neutron Resonance Parameters and Thermal Cross Sections , Part B, Z=61-100", Academic Press (1984)
7) Behrens J W , Howerton R J Nucl Sci Eng , 65, 464, (1978)
8) Smith A B et al ANL/NDM-50 (1979)

MAT number = 3992

99-Es-255 TIT Eval-Aug87 N.Takagi
Dist-Sep89

History
87-08 New evaluation was made by N. Takagi (Tokyo Institute of Technology, TIT)

MF=1 General Information
MT=451 Comment and dictionary
MT=452 Number of neutrons per fission
Evaluated with semi empirical formula of Howerton/1/.

MF=2 Resonance parameters
MT=151 Resonance parameters
No resonance parameters were given.

2200-m/s cross sections and resonance integrals

	2200 m/s value	Res. Int.
Total	79.03 b	-
Elastic	10.60 b	-
Fission	13.43 b	93.3 b
Capture	55.00 b	278 b

MF=3 Neutron Cross Sections
MT=1 Total cross section
Below 2.47 eV, calculated as sum of MT's = 2, 18 and 102. Above 2.47 eV, optical model calculation was made with CASTHY/2/. The potential parameters/3/ used are as follows,

V = 43.4 - 0.107*En (MeV)
Ws= 6.95 - 0.339*En + 0.0531*En**2 (MeV)
Wv= 0 , Vso = 7.0 (MeV)
r = rso = 1.282 , rs = 1.29 (fm)
a = aso = 0.60 , b = 0.5 (fm)

MT=2 Elastic scattering cross section
Below 2.47 eV, the constant cross section of 10.6 barns was assumed, which was the shape elastic scattering cross section calculated with optical model. Above this energy, optical model calculation was adopted.

MT=4,51-53,91 Inelastic scattering cross sections.
Optical and statistical model calculation was made with CASTHY/2/. The level scheme was assumed to be the same as that of Es-253 taken from Ref. 4.

No	energy(keV)	spin-parity
g.s.	0.0	7/2 +
1	46.0	9/2 +
2	50.0	3/2 -
3	420.0	7/2 -

Levels above 500 keV were assumed to be overlapping.
The level density parameters were taken from Ref. 5.

MT=16,17,37 (n,2n), (n,3n) and (n,4n) reaction cross sections
Calculated with evaporation model.

MT=18 Fission cross section
Measured thermal cross section of 13.43 barns was taken from Ref. 6 , and 1/v form was assumed below 2.47 eV. Above 2.47 eV, the cross section shape was assumed to be the same as Cf-252 fission cross section and it was normalized to the systematics by Behrens and Howerton/7/.

MT=102 Capture cross section
Measured thermal cross section of 55.0 barns was taken from Ref. 6. , and 1/v form was assumed below 2.47 eV. Above 2.47 eV, calculated with CASTHY. The gamma-ray strength function was estimated from Gamma-gamma = 0.040 eV and level spacing = 4.94 eV.

MT=251 Mu-L
Calculated with CASTHY.

MF=4 Angular Distributions of Secondary Neutrons
MT=2,51-53,91 Calculated with optical model.
MT=16,17,18,37 Isotropic in the lab system.

MF=5 Energy Distributions of Secondary Neutrons
MT=16,17,37,91 Evaporation spectra.
Obtained from level density parameters.

MT=18 Maxwellian fission spectrum.
Temperature was estimated from Z**2/A dependence/8/.

References
1) Howerton R.J.: Nucl. Sci. Eng., 62, 438 (1977).
2) Igarasi S.: J.Nucl.Sci.Technol.,12,67 (1975).
3) Igarasi S., Nakagawa T.: JAERI-M 8342 (1979).
4) Schmorak M.R.: Nucl. Data Sheets, 34, 1 (1981).
5) Gilbert A., Cameron A.G.W.: Can. J. Phys., 43, 1446 (1965).
6) Mughabghab S.F.: "Neutron Cross Sections, Vol.1, Neutron Resonance Parameters and Thermal Cross Sections , Part B, Z=61-100", Academic Press (1984).
7) Behrens J.W., Howerton R.J: Nucl. Sci. Eng., 65, 464, (1978).
8) Smith A.B. et al.: ANL/NDM-50 (1979).

MAT number = 3995

100-Fm-255 TIT Eval-Aug87 N.Takagi
Dist-Sep89

History
87-08 New evaluation was made by N. Takagi (Tokyo Institute of Technology, TIT)

MF=1 General Information
  MT=451 Comment and dictionary
  MT=452 Number of neutrons per fission
    Evaluated with semi empirical formula of Howerton/1/.

MF=2 Resonance parameters
  MT=151 Resonance parameters
    No resonance parameters were given.

  2200-m/s cross sections and resonance integrals

	2200 m/s value	Res. Int.
Total	3396.60 b	-
Elastic	10.60 b	-
Fission	3360.00 b	1170 b
Capture	26.00 b	101 b

MF=3 Neutron Cross Sections
  MT=1 Total cross section
    Below 3.8 eV, calculated as sum of MT's = 2, 18 and 102. Above 3.8 eV, optical model calculation was made with CASTHY/2/. The potential parameters/3/ used are as follows,

```
V = 43.4 - 0.107*En                       (MeV)
Ws= 6.95 - 0.339*En + 0.0531*En**2        (MeV)
Wv= 0                 , Vso = 7.0         (MeV)
r = rso = 1.282       , rs = 1.29         (fm)
a = aso = 0.60        , b  = 0.5          (fm)
```

  MT=2 Elastic scattering cross section
    Below 3.8 eV, the constant cross section of 10.6 barns was assumed, which was the shape elastic scattering cross section calculated with optical model. Above this energy, optical model calculation was adopted.

  MT=4,51,91 Inelastic scattering cross sections.
    Optical and statistical model calculation was made with CASTHY/2/. The level scheme was taken from Ref. 4.

No	energy(keV)	spin-parity
g.s.	0	7/2 +
1	60	9/2 +

    Levels above 94 keV were assumed to be overlapping.
    The level density parameters were taken from Ref. 5.

  MT=16,17,37 (n,2n), (n,3n) and (n,4n) reaction cross sections
    Calculated with evaporation model.

  MT=18 Fission cross section
    Measured thermal cross section of 3360 barns was taken from Ref. 6 , and 1/v form was assumed below 3.8 eV.

Above 3.8 eV, the shape was assumed to be the same as Bk-250 fission cross section and it was normalized to the systematics by Behrens and Howerton/7/.

MT=102 Capture cross section
Measured thermal cross section of 26 barns was taken from Ref. 6 , and 1/v form was assumed below 3.8 eV. Above 3.8 eV, calculated with CASTHY. The gamma-ray strength function was estimated from Gamma-gamma = 0.040 eV and level spacing = 7.6 eV.

MT=251 Mu-L
Calculated with CASTHY.

MF=4 Angular Distributions of Secondary Neutrons
MT=2,51,91 Calculated with optical model.
MT=16,17,18,37 Isotropic in the lab system.

MF=5 Energy Distributions of Secondary Neutrons
MT=16,17,37,91 Evaporation spectra.
Obtained from level density parameters.

MT=18 Maxwellian fission spectrum.
Temperature was estimated from Z**2/A dependence/8/.

References
1) Howerton R.J.: Nucl. Sci. Eng., 62, 438 (1977).
2) Igarasi S.: J.Nucl.Sci.Technol.,12,67 (1975).
3) Igarasi S., Nakagawa T.: JAERI-M 8342 (1979).
4) Schmorak M.R.: Nucl. Data Sheets, 34, 1 (1981).
5) Gilbert A., Cameron A.G.W.: Can. J. Phys., 43, 1446 (1965).
6) Mughabghab S.F.: "Neutron Cross Sections, Vol.1, Neutron Resonance Parameters and Thermal Cross Sections , Part B, Z=61-100", Academic Press (1984).
7) Behrens J.W., Howerton R.J: Nucl. Sci. Eng., 65, 464, (1978).
8) Smith A.B. et al.: ANL/NDM-50 (1979).