International Atomic Energy Agency

INDC(CPR)-023
Distr.: L

INDC INTERNATIONAL NUCLEAR DATA COMMITTEE

EVALUATION OF NEUTRON NUCLEAR DATA OF Np-237 FOR CENDL-2

Tang Guoyou, Fan Jihong, Cao Wentian, Bao Shanglian
Institute of Heavy Ion Physics
Peking University
Beijing 100871, P.R. of China

and

Cai Chonghai
Physics Department, Nankai University
Tianjin 300086, P.R. of China

October 1991

INDC(CPR)-023
Distr.: L

EVALUATION OF NEUTRON NUCLEAR DATA OF Np-237 FOR CENDL-2

Tang Guoyou, Fan Jihong, Cao Wentian, Bao Shanglian
Institute of Heavy Ion Physics
Peking University
Beijing 100871, P.R. of China

and

Cai Chonghai
Physics Department, Nankai University
Tianjin 300086, P.R. of China

October 1991

Reproduced by the IAEA in Austria
October 1991

91-05856

EVALUATION OF NEUTRON NUCLEAR DATA OF Np-237 FOR CENDL-2*

Tang Guoyou, Fan Jihong, Cao Wentian, Bao Shanglian

Institute of Heavy Ion Physics
Peking University
Beijing 100871
P. R. China

Cai Chonghai

Physics Department, Nankai University
Tianjin 300086
P. R. China

ABSTRACT:

The measured data for the (n, f) and (n, gamma) reactions for Np-237 have been evaluated in the energy region from 30 Kev to 20 MeV. All the data of Np-237 for other reaction channels were theoretically calculated. The total cross section, absorption cross section and elastic angular distribution were calculated using the parameters got from Optical Model. All data were calculated using general computer code FUP1 (the parameters of the Optical model used as input data to FUP1). The recommended experimental data and the theoretically calculated data were adjusted and let $\sigma_{tot}=\sigma_{el}+\sigma_{non}$. The resonance parameters in the energy range below 30 keV were also added. All the data in the energy range 10^{-5} eV to 20 Mev were recommended as the data file of Np-237 for CENDL-2.

Keywords: evaluation, neutron nuclear data, Np-237, cross section, angular distribution, Optical Model, FUP1, fission parameter, resonance parameter, CENDL-2

1. Introduction

Np-237 is an important element in the fuel circle of the nuclear reactor:

U-235 + n = U-236, U-236 + n = U-237, U-237 β^- Np-237 Np-237 + n = Np-238, Np-238 β^- Pu-238. Because the long half life and higher α emission, Pu-238 is a useful nuclear source [via O-16(α, n) reaction, the large heat is produced] and widely used in artificial satellite, space detector, universal ship,

cardiac pacemaker and so on. In the nuclear waste material manage, Np-237 plays an important role to indicate and monitor the waste materials. In order to control the operation of the nuclear reactors, nuclear waste material storage and produce nuclear source, understanding the property of Np-237 and correctly knowing the knowledge of interaction between neutron and Np-237 is important. Sine 60'sth to 80'sth the neutron nuclear data of Np-237 were measured continually. Some evaluated data were also published[1, 2, 3]. After the evaluations, some new measurements came to us for reaction channels (n, f) and (n,Gamma). Therefore a new evaluation is necessary.

Our evaluation is mainly in the neutron energy range 30 keV to 20 MeV, but the resonance parameters below 30 keV were also recommended.

The comparison of our evaluated data and data of JANDL-2 and ENDF/BVI was shown in Fig. 4. For σ_{nf}, the ratio of ENDF/BVI and JANDL-2 data to our data was shown in Fig. 5.

Table 1 22 chosen data groups for (n,f) reaction

Author	Year	En(Mev)	Author	Year	En(MeV)
A.PROTOPOPOV[4]	1958	14.6	J.ALKNAIOV[15]	1977	14.8
B.GOKHBERG[5]	1958	0.012-1.5	D.GARDY[16]	1979	0.77-0.96
S.KALININ[6]	1958	2.5-8.3	J.BEHRENS[17]	1982	0.02-30
H.SCHMIT[7]	1959	1.64-7.63	M.CANCE[18]	1982	2.47
P.WHITE[8]	1965	0.04-14.1	J.MEADOWS[19]	1983	0.1-9.4
J.PERKIN[9]	1965	0.024	R.ARLT[20]	1981	8.7-14.7
J.GRUNDL[10]	1967	1.07-8.07	M.VARNAGY[21]	1982	13.5-14.8
W.BROWN[11]	1970	0.1-2.8	I.GARLEA[22]	1984	14.75
R.JIACOLETI[12]	1972	0.2-6.76	WU JINGXIA[23]	1984	4.0-5.5
W.KOBAYASKI[13]	1973	3.5-4.9	K.KANDA[24]	1985	0.51-15
S.PLATTARD[14]	1975	0.02-2.01	A.GOVERDOVSK[25]	1984	4.44-16.4

2. The Measured Data

The existed data of Np-237 are mainly in the reaction channels (n, f) and (n,Gamma).

(i). (n, f) Reaction

The data were measured since 1947 and mainly contributed by laboratories in USA(ORL, LAS, LAL), USSR(CCP, FEI, HUR), UK(ALD), France(SAC), Japan(KTO, TOH) and China(AEP). Up to now there were more than 30 data groups published and 10 groups were measured in 80'sth. The measurements were mainly relative to U-235, the accuracy was in 2 - 5%. All relatively measured data were re-normalized using U-235 data of ENDF/BVI file. total 22 data groups were chosen[14-25] for fitting. The fitting uncertainties were given according to their measuring techniques and their measuring accuracies. All the 22 data groups were listed in table 1 and shown in Fig. 1.

(ii). Capture reaction (n,Gamma)

Total 6 data groups were collected[26-29], but only 4 groups were recommended. All measured data were within the energy range 0.02 to 2.73 MeV. The standards of the relatively measured data, which were U-235 (n, f) cross sections and Au-197(n, Gamma) cross sections, were re-normalized using new data file of ENDF/BVI. The situations of the measured data were listed in table 2. and the recommended data were shown in Fig.2.

Table 2 4 chosen data group for (n.Gamma)

Author	Lab.	Year	En(MeV)
M.LINDER[26]	USALRL	1976	0.121-2.73
J.TROFIMOR[27]	CCPRI	1976	0.25-1.91
L.WESTON[28]	USAORL	1981	0.02-0.212
A.DAVLETSHIN[29]	CCPFEI	1985	0.174-1.15

(iii). The reaction (n, 2n)

All the data were measured using activation cross section measurement method. the cross sections of Np-237(n, 2n) were

FIG 1

Np(N,G) EXPERIMENTAL AND CACULATED DATA

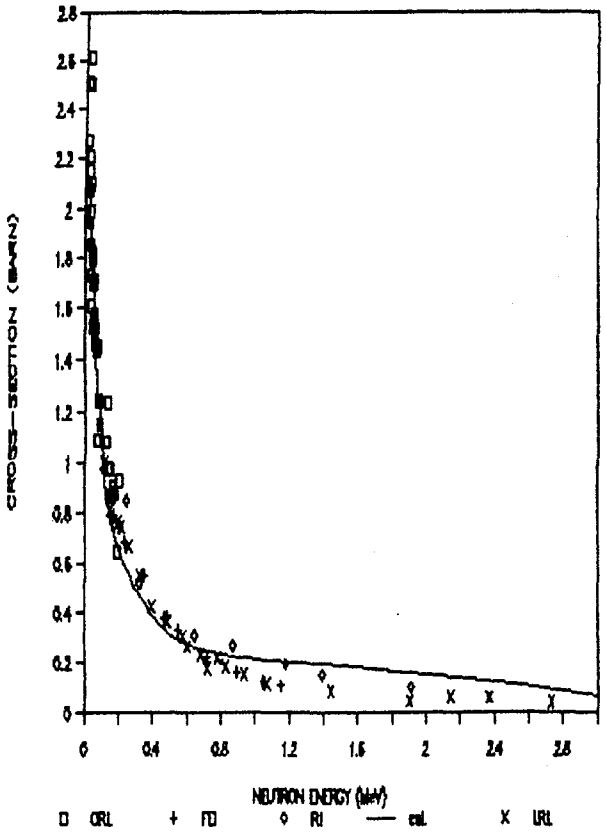


FIG 2

Np(N,2N) EXPERIMENTAL & CACULATED DATA

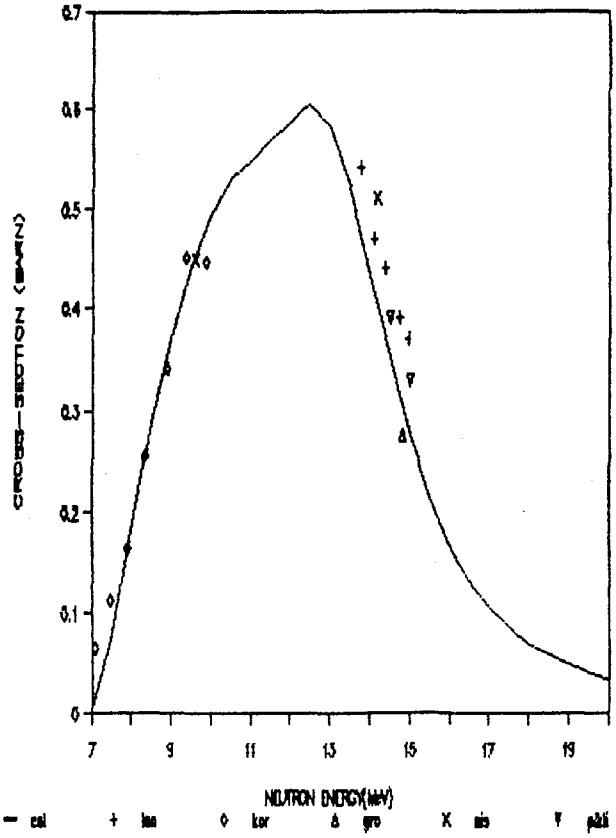


FIG 3

Np(n,f) experimental data and caculated

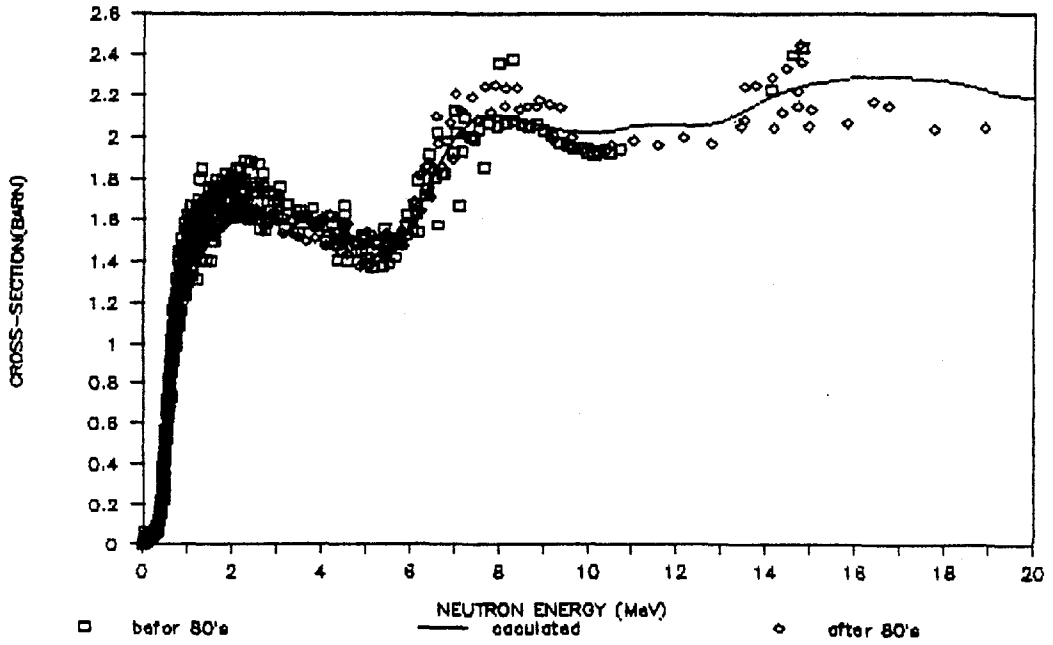


Fig 4a

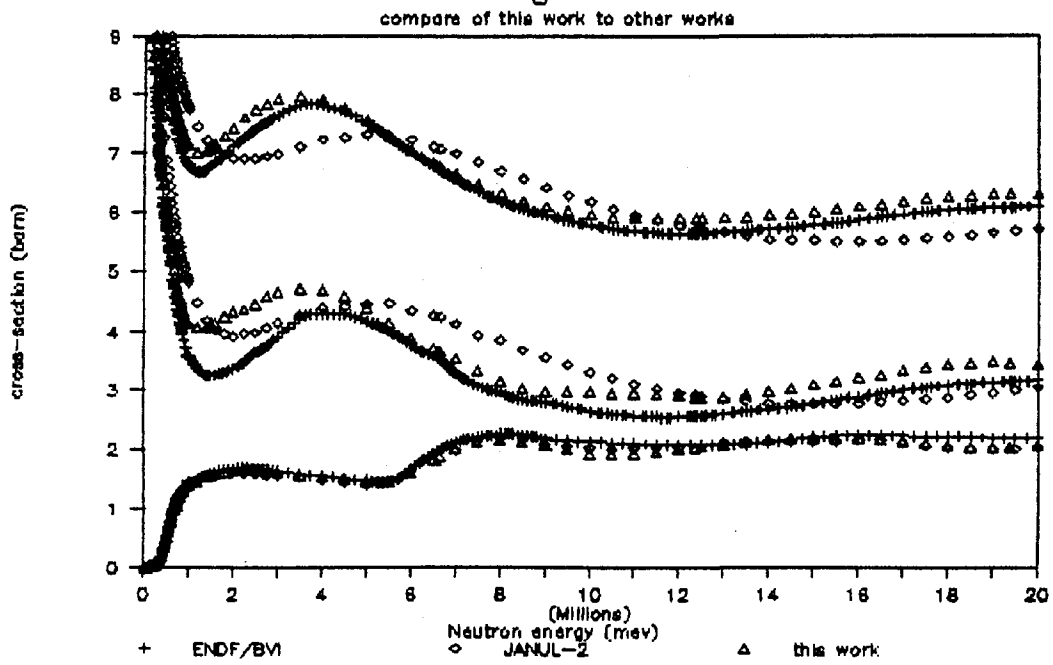
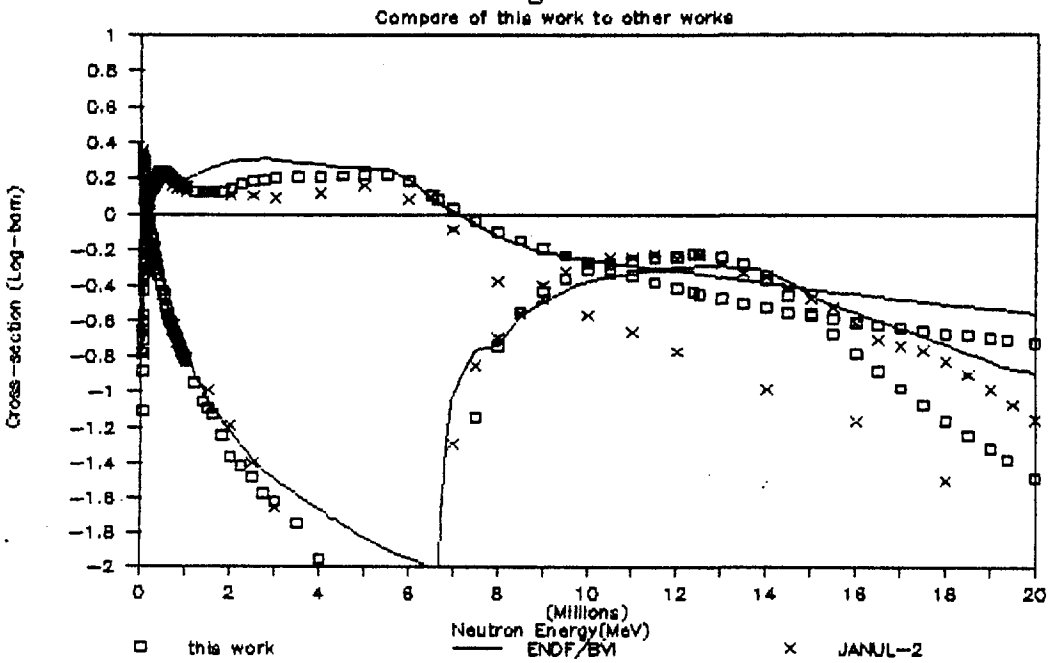
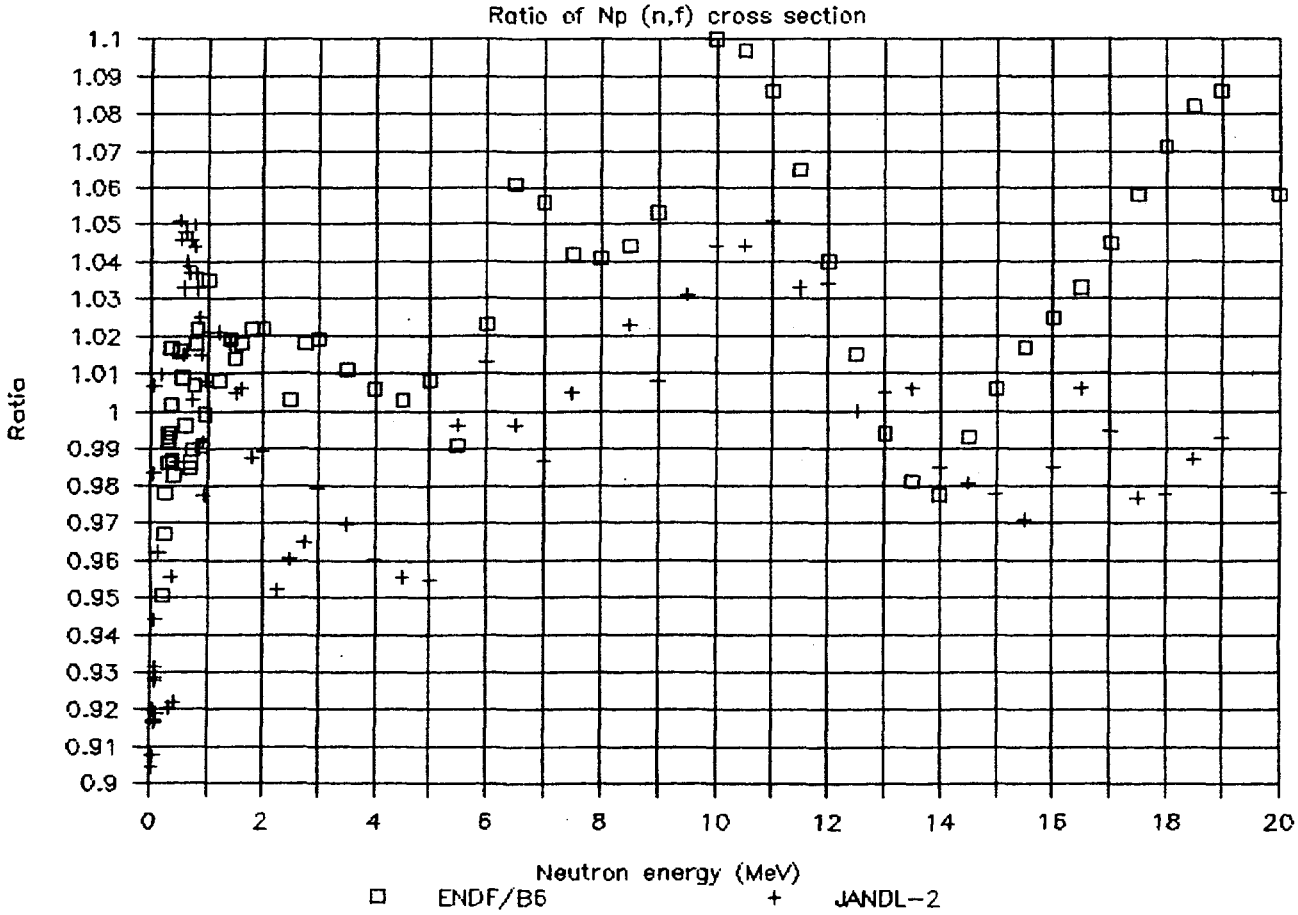


Fig 4b



calculated according the Pu-236 products. In order to know Pu-236 products the both data: (β/EC), the ratio of β emission and electron capture(EC) (β/EC), and R, the ratio of the products of Np-236 isomer and Np-236, need to be known well. But up to now R is not well known, especially R as the function of neutron energy E is not known. Therefore all the collected data[30-35] were only used as references during the parameter adjusting of the model calculation. The comparison of the theoretical and measured data was shown in Fig. 3.

Fig. 5



3. Theoretical Calculation

Without measured data, All data of other reaction channel of Np-237 were given by theoretical calculations.

These data were calculated using FUP1[36], in which the Coupled Channel Optical Model, F-H theory with width fluctuation(WFH) and Pr-equilibrium Evaporation Model based on Excitation Model(PE) were adopted. The parameters of the optical Model and fission parameters needed to be imputed from other calculations.

(i). The Parameters of Optical Model

Without the measured data of total cross section σ_t, non-elastic cross section σ_{non} and elastic angular distribution $\sigma_{nn}(\theta)$, the parameters of the Optical Model for Np-237 were got from systematic study of U-235 and Pu-239 because the three nuclei have the same odd A and Np-237 is in middle. Comparing the data of σ_t and σ_{nn}, the exiting curves for U-235 and Pu-239 are very close each other and the absolute data of σ_t are consistent in 5%. Therefore the parameters got from parameter adjusting for Pu-239[37] were used in the calculation:

U_0 = 43.7937MeV U_1 = -0.3983MeV
U_2 = 0.01925MeV S_0 = 3.3998MeV
S_1 = 0.1161MeV W_0 = 0.8459MeV
W_1 = 0.01029MeV R_1 = R_3 = 1.2601fm
R_2 = 1.5736fm a_1 = a_3 = 0.5628
a_2 = 0.6028fm

(ii). Fission Parameters

The fission parameters include the energy level density a, pair correlation δ, fission barrier width hw, equivalent fission barrier height V_{pf} and the energy density parameters at saddle states: P_{K1}, P_{K2}. These parameters were got from a auto parameter adjusting program ASFP[39]. In the adjusting, the parameters were got by the model fitting method. Below 3MeV, WHF theory was used. Above 3MeV, PE theory was employed. Because there were 3 fission proceeding included in the energy range up to 20 MeV, The measured data of Np-237 and its isotopes were used as input data. The parameters used in the evaluation were listed in table 3.

Table 3. fission Parameters

	1st fission	2d fission	3d fission	4th fission
V_{pf}	5.871492	5.678481	5.514621	5.68
P_{K1}	3.109137	1.638118	1.010123	1.64
P_{K2}	0.222279	0.054693	0.134143	0.055
δ	0.622767	1.116893	0.562664	0.756084
hw	0.441609	0.652	0.79	0.65
a	28.488922	29.175522	28.418579	29.07745

(iii). Direct Interaction

In the high neutron energy range the direct interaction need to be considered, which was got from an assistant Program based on Coupled Channel Optical Model by Shen Qingbiao[37].

4. The Results From Calculation And The Data Recommended

From Fig. 1 to Fig. 3, one sees that:

For $\sigma_{n,f}(E)$, the calculated data fully consistent with experimental data in E<14MeV. Above 14 MeV, The measured data by Behrens et al. were about 10% lower in maximum.

For $\sigma_{n,\gamma}(E)$, the data were consistent each others in E<1MeV. Above 1.2MeV, the calculated data were higher than measured ones.

For $\sigma_{n,2n}(E)$, the data were also consistent.

Therefore our recommendation is following:

(i). In 30keV<E<20MeV

For $\sigma_{n,f}(E)$, the fitted experimental data were recommended. For $\sigma_{n,\gamma}(E)$, the fitted experimental data were recommended in 30keV<E<2.75MeV; above 3MeV the calculated data were used and the data were smoothly connected in 3MeV point. For all other data of reaction channels $\sigma_t(E)$, $\sigma_{n,2n}(E)$, $\sigma_{n,3n}(E)$, $\sigma_{el}(E)$, integrated inelastic cross section $\sigma_{in}(E)$, second neutron spectrum and the angular distribution of the second neutrons, the calculated data were used. During the self consistent adjusting, following relations were kept:

$$\sigma_{non}(E) = \sigma_{nf}(E) + \sigma_{n\gamma}(E) + \sigma_{in}(E) + \sigma_{n,2n}(E) + \sigma_{n,3n}(E)$$

$$\sigma_{el}(E) = \sigma_t(E) - \sigma_{non}(E)$$

(ii). In E<30keV

All data in the energy rang were given using resonant parameters. In the energy range 10^{-5}eV to 130 eV, the data treated as resolved resonances; In the energy range 130eV to 30 keV, the data treated as unresolved resonances. All the parameters in that energy range were token from the L. W. Westen and I. H. Tadd evaluated data[25].

All recommended data (include file 1 to file 5) were put into the computer of China Nuclear Data Center with ENDF form.

5. Acknowledgments

Many thanks for Dr. Liang Qichang, who gave us useful help during the evaluation, and for China Nuclear Data Center, from which we got financial support .

References

[1] USA ENDF/BVI
[2] N. Wachi et al. JAERI-M 84-103
[3] H.Derrien et al. INDC(FR)-42/L (1980)
[4] A.E. Protopopove et al. AE 4(2) (1958)
[5] B.G. Gokhery et al. DOK 128(6) (1959) 1157
[6] S.P. Kalinin et al. 58 Genva, 16,134(2149)
[7] H.W.Schmit et al. PR 116 (1959) 1575

[8] P.H. White et al. 65 Salzurg 1 219; JNE 21 (1967) 671
[9] J.L. Perkin et al. JNE/AB, 19 (1965) 423
[10] J.A. Grundl et al. NSE. 30 (1976) 39
[11] W.K. Brown et al. NP/A 156 (1970) 609
[12] R.J. Jiacoletti et al. NSE. 48 (1972) 412
[13] W. Kobayaski et al. KURRI-TR-6, 1 (1973)
[14] S.Plattard et al. Plattard-7311
[15] J.D. Alknaiov et al. 77 Kiev, 3 155
[16] D.J. Grady et al. 79 Knox 976
[17] J.W. Behrens et al. NSE 80 (1982) 393
[18] M. Cance et al, 82 Antwer 51
[19] J.W. Meadows et al. NSE 85(1983) 271
[20] R. arlt et al. KE 24(1984) 465
[21] M. Varnagy et al. Nim 196 (1982) 465
[22] I. Garlea et al. INDC (ROM)/15 (1983)
[23] Wu Jingxia et al. CNP 6 (1984) 369
[24] K. Kanda et al. JAERI-M-85-035 (1985) 220
[25] A.A. Goverdovskij et al. AE 58(2) (1985) 271; FEI-1552(1984)
[26] M. Lindner et al. NSE 59 (1976) 381
[27] J .N. Trofimor et al. 83 Kiev 2 142
[28] L. Weston et al. NSE 79 (1981) 184
[29] A. N. Davletshin. 83 Kiev 2 189
[30] J.L. Perkin et al. JNE 14 (1961) 69
[31] J.H. Landrum et al. PR/C 8 (1973) 1938
[32] K. Linere et al. PR/C 12 (1975) 1507
[33] T. Nishi et al. NEANDC(J)-421, 20 (1975)
[34] J.A. Gromova et al. AE 54 (1983) 117
[35] N.V. Kornilov et al. AE 58 (1985) 117
[36] Cai Chonghai et al. Internal Report of Nankai Univ. FUP1
[37] Shen Qingbiao et aql. Hsj-78224 (11js)
[38] Cai Chonghai et al. Internal Report of Naikai Univ. ASPF