AEEW - M 824

UNCLASSIFIED

AEEW - M 824

United Kingdom Atomic Energy Authority

REACTOR GROUP

THE U.K.A.E.A. NUCLEAR DATA LIBRARY

FEBRUARY, 1968

D. S. NORTON

General Reactor Physics Division,

Atomic Energy Establishment,

Winfrith, Dorchester,

Dorset.

1968

Available from H.M. Stationery Office,

FOUR SHILLINGS NET

U.D.C.
539.17
539.17.02

THE U.K.A.E.A. NUCLEAR DATA LIBRARY

FEBRUARY, 1968

D. S. Norton

A.E.E.,
Winfrith.

May, 1968

S.C. 20

W 9585

CONTENTS

Tables

1. Introduction

A general account of the various aspects of work on the U.K.A.E.A. Nuclear Data Library and the associated computer programmes was submitted to the 3rd Geneva Conference on the Peaceful Uses of Atomic Energy (1), and a fairly comprehensive bibliography on the work to the first half of 1964 may be found in that paper. Further developments up to the beginning of 1965 were outlined in a report presented to the AEC-ENEA seminar on the evaluation of neutron cross-section data, at Brookhaven in May 1965 (2). Since that time, a course of amendment and extension of the data library has been followed. An updated edition of the library was released at Winfrith in January 1967, copies of which were made available to users in the E.N.E.A. area through the Neutron Data Compilation Centre at Saclay. The contents of that edition of the data library were summarised in reference (3), which also decribes modifications to the labelling system.

During 1967 many new files became available and minor changes were made to a number of the older files. Therefore a new edition of the Nuclear Data Library was prepared at Winfrith, and released in February 1968, copies of which have since been sent to the E.N.E.A. Neutron Data Compilation Centre. The contents of the revised data tapes are summarised in Tables 1 to 5 of this report, and further comments on the more important changes are given in the appendices. All the files listed in Tables 2 to 4 span the energy range 0.0001 eV to 15 MeV unless otherwise noted in Table 1. The files listed in Table 5 give neutron capture cross-sections only, and span the range 0.0001 eV to 10 MeV. Also, for completeness sake, the contents of a magnetic tape containing photon cross-sections are given in Table 6; these data are in no way changed from those reported in ref. (3).

Attention may be drawn to the following particular features of the new edition of the Library:

(i) New complete files are given for H, B10, C, N, O, Fe, Cu, U233 and U238. There are also a number of new files giving fast neutron fission cross-sections only, in the range 1 keV to 14 MeV, together with new files for the Fe54 and Fe56 (n,p) cross-sections and (n,γ), (n,p), (n,α) and (n,2n) cross-sections of Cu63 and Cu65 from 1 keV to 15 MeV.

(ii) Substantial changes have been made to the principal files for Pu239 and Pu241.

(iii) Data files giving the capture cross-sections for 78 fission products, which were compounded from compilations by Cook (5) at Lucas Heights in the 0.0001 eV to the keV energy region, and from the files compiled by Benzi and Bortolani (4) of the C.N.E.N. at Bologna for for higher energy range up to 10 MeV.

Many contributions towards the U.K.A.E.A. Nuclear Data Library have been obtained from outside the United Kingdom, and we acknowledge this useful co-operation. The three complete files of Cr, Ni and U238 were evaluated by Ravier and Vastel in France, and compiled by them in our standard format. The file for Fe was compiled predominantly from Schmidt's file in the KEDAK data library. The files for B10, C, N and O are based on American compilations. The files for D, He3, He4, W, Au and Pu238 are predominantly from compilations by Howerton at Lawrence Radiation Laboratory, and that for Ti from the compilation by Tralli et al. at the United Nuclear Corporation. Fourteen files of activation cross-sections are from the compilations by Barrell and McElroy at the Illinois

Institute of Technology. The 78 files of fission product capture cross-sections have Australian and Italian origins as has already been stated. Several other files contain substantial contributions from German, Italian and Swedish sources.

2. Contents and Arrangement of the Nuclear Data Library Tapes

The U.K.A.E.A. Nuclear Data Library of February 1968 contains 89 data files for 72 different materials together with 78 files giving capture cross-sections for fission products. It has been so arranged that the library occupies four 7-track IBM tapes written in the B.C.D. mode (even parity) at low density (200 b.p.i.); these four tapes are formally entitled NDL1 (2.68), NDL2 (2.68), NDL3 (2.68) and NDL4 (2.68). A fifth tape has been prepared as a repository of obsolescent data files, the contents of which are listed in Table 7. It should be noted that copies of the information contained on this tape may only be obtained from the author.

3. Extension of Formats and Conventions

A few data files contain information in formats which have not been previously used in the Data Library, but which are described in the draft report by Parker (7).

(a) DFN34, oxygen; this file contains data for twenty-one inelastic scattering levels. The revised format guide allocates Particular Classification Numbers (P.C.N.) 5 to 14 and also 31 to 50 for inelastic scattering cross-sections to particular levels.

(b) DFN328, tantalum; the neutron secondary energy distribution for the inelastic scattering to continuum makes use of a new law, number 10. Law number 10 utilises the parametric representation of the evaporation spectrum.

$$f(E,E') = (E'/_T 2) \exp(-E'/_T), \quad \text{with } T = \sqrt{(E/a)}$$

The information given in the data file using this law is the value of the parameter a.

(c) DFN401A, Uranium 238; This file has more than a thousand cards for each of several cross-sections. The last three columns of each card are reserved for sequential labelling of the cards in each section of the file. To avoid the overflow which occurs after card 999, the convention has been adopted to label sequentially (modulo 1000). However it should be noted that this convention may call for some modification of programmes which utilise this part of the label field.

The adoption of an alpha-numeric Mark Label to distinguish files which have had minor modifications has been described in reference (3). However, we repeat the following:

Note: Users should always quote the Mark Labels along with the data file numbers when reporting use of data from the U.K.A.E.A. Nuclear Data Library. However, the label should not be used in the input to GALAXY (44).

4. Further Developments

The programme GALAXY (44) has been used to compute 2200 metre/second cross-sections, resonance absorption integrals, maxwellian averaged cross-sections and fission spectrum averaged cross-sections from many of the data files. The results have drawn attention to a number of minor errors, which have since been eliminated. This work is being continued in a systematic way with the programme MINIGAL (6), and it is hoped that it will soon be possible to report the results of these calculations.

A file for Rh103 giving the (n,n') and $(n,2n)$ activation cross-sections has been prepared since the February 1968 version of the data library was assembled. Work is in progress on new files for Zr, Cd113 and natural Cd.

Revised GENEX data tapes (45) for U235, U238, Pu239 and Pu240 have been completed and a report is in preparation. These tapes will shortly be available as part of the Nuclear Data Library, but it must be noted that they are written in binary mode on English-Electric and IBM tapes.

An extended format has been designed for a Resonance Parameter Library, including resonance statistical parameters, and a descriptive report is in preparation.

TABLE 1

Contents of the U.K.A.E.A. Nuclear Data Library, February, 1968

Material	DFN and Mark Label	Available on tape	References and Comments
H	67	NDL 1	Hydrogen atom in water. Essentially data of DFN 212 but modified to agree with ref. (8) at lower energies; 0.0001 eV to 20 MeV.
H_2O	27E	NDL 1	Temperature revised to 300°K August 1967; ref. (9); 0.0001 eV to 0.5 eV only.
D	218D	NDL 1	Temperature revised to 300°K August 1967. From a compilation by Howerton R. J. of LRL.
D_2O	28E	NDL 1	Temperature revised to 300°K August 1967 Ref. (9); 0.0001 eV to 9 eV only.
T	219D	NDL 1	Temperature revised to 300°K August 1967. Ref. (10); 0.0001 eV to 19.4 MeV.
He3	220D	NDL 3	Temperature revised to 0°K August 1967. From a compilation by Howerton R. J. of LRL.
He4	221D	NDL 3	Temperature revised to 0°K August 1967. From a compilation by Howerton R. J. of LRL.
Li6	214D	NDL 3	$\sigma_{n\alpha}$ changed so that $\sigma_\alpha \sqrt{E} = 151.48$ barns $\sqrt{eV}$ up to 1 keV; σ_{nT} correspondingly amended August 1967, otherwise as ref. (11).
Li7	215D	NDL 3	Temperature revised to 0°K August 1967. Ref. (12), but the lower elastic cross-section between 10 and 200 keV.
Be9	50A	NDL 1	Temperature revised to 300°K August 1967. Refs. (13), (9) and (14).
BeO	7E	NDL 1	Temperature revised to 300°K; reaction type number 1102 changed to 1101 August 1967. Ref. (9); 0.0001 eV to 1 keV only.
B(nat)	57	NDL 2	See Appendix.
B10	43	NDL 2	See Appendix.
B11	49A	NDL 2	Some Q-values amended October 1967. Ref. (16).
C	51	NDL 1	See Appendix.
N	259	NDL 3	Atom of nitrogen in nitrogen gas. Data of Ref. (17) with minor improvements at low energies.

Material	DFN and Mark Label	Available on tape	References and Comments
O	33	NDL 3	Simplified inelastic scattering level data. See Appendix
	*34	NDL 1	Full inelastic scattering level data. See Appendix
F19	23D	NDL 3	Temperature revised to 300°K August 1967. Refs. (9) and (15).
Na23	*182D	NDL 2	Ref. (20), but with improved (n,n') spectrum.
Na23	224	NDL 3	Ref. (21), (n,γ) cross-section only; 0.1 eV to 18 MeV.
Mg24	225	NDL 3	Ref. (21); (n,p) cross-section only; 5.0 to 18 MeV.
Al27	*35E	NDL 2	Temperature revised to 300°K August 1967. Ref. (19).
Al27	226	NDL 3	Ref. (21); (n,p) and (n,γ) cross-sections only; 2.60 to 18 MeV.
Si	25D	NDL 2	Temperature revised to 300°K August 1967. Refs. (9) and (15).
Si28	227	NDL 3	Ref. (21); (n,p) cross-section only; 4.6 to 18 MeV.
P31	228	NDL 3	Ref. (21); (n,p) cross-section only; 2.02 to 18 MeV.
S32	229	NDL 3	Ref. (21); (n,p) cross-section only; 1.76 to 18 MeV.
S34	230	NDL 3	Ref. (21); (n,α) cross-section only; 4.80 to 18 MeV.
Cl	141D	NDL 3	Ref. (15).
Cl-35	231	NDL 3	Ref. (21); (n,α) cross-section only; 2.71 to 18 MeV.
Ca	138D	NDL 3	Ref. (15).
Sc45	207	NDL 3	Ref. (22); Sc44 3.92 hr and 2.44 d activation cross-section by the (n,2n) reaction; 11.86 to 15 MeV.
Ti	190A	NDL 3	Ref. (23); 0.0001 eV to 18 MeV.
Cr	45D	NDL 2	Temperature revised to 300°K August 1967. Some Q-values amended October 1967. Ref. (24).

*If more than one file is available for a particular material, the preferred file (or files) is indicated with an asterisk.

Material	DFN and Mark Label	Available on tape	References and Comments
Mn55	232A	NDL 3	Ref. (21); (n,γ) cross-section only up to 18 MeV. Extended down to 0.0001 eV August 1967.
Fe	64	NDL 2	Data from ref. (9) together with some from DFN 36D.
Fe54	63	NDL 3	Ref. (25) (n,p) cross-section only; 0.8 to 20.6 MeV.
Fe56	62	NDL 3	Ref. (25) (n,p) cross-section only; 3.8 to 20.4 MeV.
Co59	235A	NDL 3	Ref. (21); (n,γ) cross-section only, up to 18 MeV. Extended down to 0.0001 eV August 1967.
Ni	46	NDL 2	Ref. (26).
Ni58	236	NDL 3	Ref. (21); (n,p) and (n,2n) cross-sections only; 1.0 to 18 MeV.
Cu	249	NDL 2	Ref. (27); Based on evaluations of Benzi and Häggblom listed in CCDN-NW/5.
Cu63	250	NDL 2	Data for reaction rate analyses compatible with DFN 249 data.
Cu63	237	NDL 3	Ref. (2); (n,γ) and (n,2n) cross-sections only; 0.01 eV to 18 MeV.
Cu65	251	NDL 2	Data for reaction rate analyses compatible with DFN 249 data.
Ga	105A	NDL 3	Ref. (28).
Y89	208	NDL 3	Ref. (22); (n,2n) cross-section only; 12.01 to 15 MeV.
Zr	9A	NDL 2	Refs. (29) and (30); 0.0001 eV to 17 MeV.
Zr90	238	NDL 3	Ref. (21); (n,2n) cross-section only; 12.2 to 18 MeV.
Rh103	204	NDL 3	Ref. (22); (n,2n) cross-section only; 9.5 to 15 MeV.
Cd	24D	NDL 2	Refs. (9) and (15).
In115	239	NDL 3	Ref. (21); cross-section for activation of 271 min. In115 by the (n,n') reaction; 338 keV to 18 MeV.
I127	240	NDL 3	Ref. (21); (n,2n) cross-section only; 9.5 to 18 MeV.

Material	DFN and Mark Label	Available on tape	References and Comments
Xe135	4E	NDL 2	Temperature revised to 300°K August 1967. Ref. (31); 0.0001 eV to 1 keV only.
Gd	223A	NDL 3	Ref. (32); total and (n,γ) cross-sections only 0.0001 to 3 eV.
Tm	209	NDL 3	Ref. (22); (n,2n) cross-section only; 8.1 to 15 MeV.
Lu175	210	NDL 3	Ref. (22); (n,2n) cross-section only; 7.86 to 15 MeV.
Ta181	328	NDL 3	Ref. (33).
W	213A	NDL 2	Ref. (34).
Au197	222A	NDL 3	Extended down to 0.0001 eV and up to 15 MeV. August 1967; otherwise as Ref. (35).
Pb	26A	NDL 2	Temperature revised to 300°K August 1967. Refs. (9) and (15).
Th232	22A	NDL 2	Refs. (9) and (15).
Th232	332	NDL 2	Ref. (37); Fission cross-section only; 1.22 to 14 MeV.
U233	333	NDL 2	Ref. (37); Fission cross-section only; 0.001 to 14 MeV.
U233	*345	NDL 1	Ref. (38).
U234	174	NDL 2	Ref. (36); 1 keV to 15 MeV only.
U234	334	NDL 2	Ref. (37); Fission cross-section only: 0.001 to 14 MeV.
U235	*66	NDL 1	See Appendix.
U235	335	NDL 2	Ref. (37); Fission cross-section only: 0.001 to 14 MeV.
U236	173	NDL 2	Ref. (39); 1 keV to 15 MeV only.
U236	336	NDL 2	Ref. (37); Fission cross-section only: 0.672 to 14 MeV.
U238	401A	NDL 1	Ref. (40); Now available from 0.0001 eV to 15 MeV.
U238	338	NDL 2	Ref. (37); Fission cross-section only: 0.55 to 14 MeV.

*If more than one file is available for a particular material, the preferred file (or files) is indicated with an asterisk.

Material	DFN and Mark Label	Available on tape	Reference and Comments
Np237	*61	NDL 2	DFN 337 spliced to data of DFN 245. Ref. (21).
Np 237	337	NDL 2	Ref. (37); fission cross-section only: 0.001 to 14 MeV.
Pu238	216A	NDL 2	Ref. (41).
Pu239	*65	NDL 1	See Appendix.
Pu239	339	NDL 2	Ref. (37); fission cross-section only; 0.001 to 14 MeV.
Pu240	201A	NDL 2	Refs. (42) and (9).
Pu240	340	NDL 2	Ref. (37); Fission cross-section only; 0.001 to 14 MeV.
Pu241	*60	NDL 2	See Appendix.
Pu241	341	NDL 2	Ref. (37); Fission cross-section only: 0.001 to 14 MeV.
Pu242	342	NDL 2	Ref. (37); Fission cross-section only: 0.001 to 14 MeV.
F.P.	106	NDL 2	Pseudo-fission products. Ref. (43).
VAC.	172D	NDL 3	Total cross-section = elastic = 10^{-10} barns; atomic no. 0; atomic wt. 10,000.
1/V	55A	NDL 3	1/V (n,γ) cross-section of 10^5 barns at 0.0001 eV; constant neglibible elastic scattering cross-section of 10^{-20} barns; atomic number changed to 10,000; atomic weight to 9999 August 1967.
SCAT	56	NDL 3	Elastic scattering cross-section only of 1000 barns; angular distribution isotropic in c.m. frame; atomic no. 999; atomic weight 1000.
ABS	151E	NDL 3	Total cross-section 1000 barns, elastic 1 millibarn, (n,γ) 1000 barns throughout; atomic no. 8. Atomic weight changed to 10000 August 1967.

*If more than one file is available for a particular material, the preferred file (or files) is indicated with an asterisk.

TABLE 2

Contents of NDL 1 (2.68)

Mark Label	DFN	No. of Cards	Chemical Symbol		Date of Compilation
	67	292	H	*	December 1967
E	27	39	H_2O	/	Spring 1963; data below 0.0006 eV added January 1965. Temperature revised August 1967.
D	218	221	D	/	June 1965; data below 0.025 eV and above 14.5 MeV added September 1966. Temperature revised August 1967.
E	28	103	D_2O	/	Spring 1963; data below 0.001 eV added January 1965.
D	219	184	T	/	August 1965; data below 0.0253 eV added September 1966. Temperature revised August 1967.
A	50	361	Be9	/	January 1965; temperature revised August 1967.
E	7	75	BeO	/	Spring 1963; data below 0.001 eV added January 1965. Temperature revised August 1967.
	51	2258	C	*	April 1967
	34	1092	O	*	October 1967
	66	4134	U235	*	January 1968
	65	3103	Pu239	*	January 1968
	345	1231	U233	*	September 1967
A	401	5945	U238	*	Spring 1967

*New evaluation or major modification to existing data file.

/Minor modification to existing data file.

TABLE 3

Contents of NDL 2 (2.68)

Mark Label	DFN	No. of Cards	Chemical Symbol		Date of Compilation
A	201	1055	Pu240		May 1964; data below 0.001 eV added September 1966.
	60	2155	Pu241	*	August 1967
A	22	764	Th232		Spring 1963
	174	111	U234		August 1962
	173	1036	U236		August 1962
A	216	436	Pu238		June 1965 data below 0.025 eV and above 14.6 MeV added September 1966.
	332	13	Th232	*	Spring 1967
	333	37	U233	*	" "
	334	37	U234	*	" "
	335	37	U235	*	" "
	336	15	U236	*	" "
	337	37	Np237	*	" "
	338	16	U238	*	" "
	339	37	Pu239	*	" "
	340	37	Pu240	*	" "
	341	37	Pu241	*	" "
	342	37	Pu242	*	" "
	61	72	Np237	*	September 1967
D	182	1582	Na23		June 1963; data below 0.01 eV added January 1965.
A	9	926	Zr		November 1965.
E	35	905	Al	/	January 1964; data below 0.0006 eV added January 1965.
	64	2132	Fe	*	October 1967.
	249	1253	Cu	*	August 1967.

*New evaluation or major modification to existing data file.

/Minor modification to existing data file.

Contents of NDL 2 (2.68) continued:

Mark Label	DFN	No. of cards	Chemical Symbol		Date of Compilation
	250	54	Cu63	*	August 1967
	251	58	Cu65	*	August 1967
A	213	238	N		March 1965
D	45	839	Cr	/	Spring 1966. Temperature revised August 1967. Q-values amended October 1967.
	46	1278	Ni		January 1965.
D	25	296	Si	/	Spring 1963; data below 0.0004 eV added January 1965. Temperature revised August 1967.
A	26	545	Pb	/	Spring 1963; temperature revised August 1967.
	43	303	B10		Spring 1963; data below 0.001 eV.
A	49	725	B11	/	October 1966. Q-values amended October 1967.
	57	250	B	*	April 1967.
D	24	383	Cd		Spring 1963.
E	4	66	Xe135		Spring 1962; data below 0.001 eV added January 1965.
	106	195	Fission Products		June 1959.

*New evaluation or major modification to existing data file.

/Minor modification to existing data file.

TABLE 4

Contents of NDL 3 (2.68)

Mark Label	DFN	No. of Cards	Chemical Symbol		Date of Compilation
D	220	195	He3	/	August 1965; data below 0.025 eV and above 14.6 MeV added September 1966. Temperature revised August 1967.
D	221	230	He4	/	August 1965; data below 0.025 eV and above 14.6 MeV added September 1966. Temperature revised August 1967.
D	214	593	Li6	/	April 1965; data below 0.001 eV added September 1966. $\sigma_n T$ amended August 1967.
D	215	496	Li7	/	April 1963; data below 0.001 eV added September 1966. Temperature revised August 1967.
	259	3534	N	*	October 1967.
	33	1003	O	**	October 1967.
D	23	288	F	/	Spring 1963. Temperature revised August 1967.
A	105	292	Ga		November 1957; data below 0.025 eV added September 1966.
A	190	881	Ti		June 1964; data below 0.001 eV added September 1966.
	328	2022	Ta		July 1966.
A	222	682	Au197	/	October 1965; data extended down to 0.0001 eV and up to 15 MeV August 1967.
D	138	253	Ca		October 1958; data below 0.025 eV added September 1966.
D	141	408	Cl		February 1959.
A	223	22	Gd		April 1966.
	224	63	Na23		June 1965.
	225	42	Mg24		June 1965.
	226	63	Al27		June 1965.

*New evaluation or major modification to existing data file.

/Minor modification to existing data file.

**This file is currently being amended above 12 MeV.

Contents of NDL 3 (2.68) continued):

Mark Label	DFN	No. of Cards	Chemical Symbol		Date of Compilation
	226	63	Si28		June 1965.
	228	103	P31		June 1965.
	229	40	S32		June 1965.
	230	50	S34		June 1965.
	231	17	Cl35		June 1965.
	207	12	Sc45		August 1964.
A	232	87	Mn55	/	June 1965. Extended to 0.0001 eV August 1967.
	63	38	Fe54	*	September 1967.
	62	32	Fe56	*	September 1967.
A	235	71	Co59	/	June 1965. Extended to 0.0001 eV August 1967.
	236	39	Ni58		June 1965.
	237	71	Au63		June 1965.
	208	7	Y89		August 1964.
	238	12	Zr90		June 1965.
	204	12	Rh103		June 1964.
	239	27	In115		June 1965.
	240	13	I-127		June 1965.
	209	8	Tm169		August 1964.
	210	8	Lu175		August 1964.
D	172	12	VAC		September 1962; data below 0.025 eV added September 1966.
A	55	15	1/v	/	October 1966 Modification August 1967.
	56	12	SCAT		October 1966.
E	151	12	ABS		1961; data below 0.025 eV added September 1966.

*New evaluation or major modification to existing data file.

/Minor modification to existing data file.

TABLE 5

Fission Product Data

The data of Benzi and Bortolani (4) and Cook (5) have been combined to form data files for 78 fission products covering the energy range 10^{-10} to 10 MeV. A paper on this work is to be published (18).

Given below is the contents list of the fission product data tape:-

DFN	No. of Cards	Chemical Symbol	DFN	No. of Cards	Chemical Symbol
701	88	Br81	740	80	I129
702	88	Se82	741	83	Te130
703	80	Kr83	742	88	I131
704	80	Kr84	743	80	Xe131
705	80	Kr85	744	82	Xe132
706	80	Rb85	745	88	Xe133
707	85	Kr86	746	80	Cs133
708	83	Rb87	747	82	Xe134
709	88	Sr88	748	88	Cs134
710	88	Sr89	749	88	I135
711	83	Y89	750	88	Xe135
712	83	Sr90	751	80	Cs135
713	88	Y90	752	83	Xe136
714	88	Y91	753	88	Cs137
715	83	Zr91	754	85	Ba138
716	83	Zr92	755	82	La139
717	88	Zr93	756	80	Ce140
718	82	Zr94	757	80	Pr141
719	80	Mo95	758	82	Ce142
720	82	Zr96	759	88	Nd143
721	80	Mo97	760	83	Nd144
722	80	Mo98	761	80	Nd145
723	83	Tc99	762	83	Nd146
724	80	Mo100	763	80	Pm147
725	80	Ru101	764	80	Nd148
726	80	Ru102	765	88	Pm148
727	80	Rh103	766	88	Pm148m
728	80	Ru104	767	80	Sm149
729	88	Rh105	768	83	Nd150
730	80	Pd105	769	88	Sm150
731	80	Pd106	770	80	Sm151
732	80	Pd107	771	80	Sm152
733	80	Pd108	772	80	Eu153
734	80	Ag109	773	80	Sm154
735	80	Cd113	774	88	Eu154
736	80	In115	775	80	Eu155
737	80	Sb125	776	88	Gd155
738	80	I127	777	80	Gd156
739	83	Te128	778	80	Gd157

TABLE 6

Photon cross-section data files

The data files of photon cross-section data which are listed below were compiled by HEMMINGS and OFFORD (45). Data are given for the total cross-section (γ,T), incoherent elastic scattering (Compton effect), the photo-electric absorption cross-section (γ,e^-), and for the (γ,2γ) cross-section by the processes of pair production and annihilation; the data cover the range from 10 keV to 20 MeV. It is not clear from the reference that the "triplet production" process was taken into account (pair production in the field of an electron), so the (γ,2γ) cross-sections may be somewhat too small near 20 MeV, especially for the light elements.

DFN	Number of card images	Material
301	555	Hydrogen
302	557	Beryllium
303	558	Carbon
304	558	Nitrogen
305	558	Oxygen
306	559	Sodium
307	559	Magnesium
308	559	Aluminium
309	559	Silicon
310	559	Phosphorus
311	560	Sulphur
312	560	Argon
313	560	Potassium
314	560	Calcium
315	561	Iron
316	561	Copper
317	564	Molybdenum
318	564	Tin
319	564	Iodine
320	567	Tungsten
321	567	Platinum
322	567	Thallium
323	567	Lead
324	567	Uranium
325	558	Water
326	580	Plutonium

TABLE 7

Archival Data Tape

This tape contains obsolescent data files and has therefore not been copied to the E.N.E.A. Compilation Centre.

Mark Label	DFN	No. of Cards	Chemical Symbol
D	10	71	H
	211	292	H
	212	292	H
A	217	169	H
E	11	125	D
D	32	159	HE3
D	180	212	HE3
D	31	76	HE4
	181	593	LI6
	176	496	LI7
	8	363	BE9
D	13	212	B10
E	15	254	B
	21	1208	C
A	14	405	N
A	20	312	O
	37	1521	O
	12	1578	NA
A	16	516	AL
A	17	401	CR
	18	507	FE
D	36	1206	FE
	233	22	FE54
	234	19	FE56
A	19	373	NI
D	186	253	CU
	137	47	AU197
	241	96	AU197
D	202	876	U233
	41	1924	U235
	48	2614	U235
D	5	3567	U238
A	3	1408	Pu239
E	184	2016	Pu239
	246	157	Pu239
A	329	3103	Pu239
A	330	3103	Pu239
D	29	697	Pu240
	40	2136	Pu241
	203	922	Pu241

References

1. STORY J. S., JAMES M. F., KERR W. M. M., PARKER K., PULL I. C. and SCHOFIELD P. (Jan. 1964) Proceedings of the 3rd International Conference on the Peaceful Uses of Atomic Energy, Geneva, 1964, 2, P168.

2. JAMES M. F. and PARKER K. (Mar. 1965) "Neutron cross-section data evaluation by the UKAEA". Activity report UK-2 to the AEC-ENEA seminar on the evaluation of neutron cross-section data, Brookhaven, May 1965.

3. NORTON D. S. and STORY J. S. (Feb. 1968) "U.K.A.E.A. Nuclear Data Library Jan. 1967". AEEW - M 802.

4. BENZI V. and BORTOLANI M. V. (Oct. 1966) CN-23/115.

5. COOK J. L. Unpublished.

6. NORTON D. S. To be published.

7. PARKER K. To be published.

8. HORSLEY A. (Sept. 1966) Nuclear Data A2, 243.

9. BARRINGTON E. P., POPE A.L. and STORY J. S. (1964) AEEW - R 351.

10. STEWART L. (1965) LA - 3270

11. PENDLEBURY E. D. (July 1964) AWRE O-60/64

12. PENDLEBURY E. D. (July 1964) AWRE O-61/64

13. DOHERTY G. (Mar. 1965) AEEW - M 513

14. PARKER K. (Sept. 1960) AWRE O-27/60

15. BUCKINGHAM B. R. S., PARKER K. and PENDLEBURY E. D. (Mar. 1961) AWRE O-28/60.

16. JONES P. M. and NORTON D. S. (Oct. 1966) To be published.

17. CRAVEN C. W. (1967) ORNL; private communication to K. Parker.

18. SMITH R. W. To be published.

19. KING D. C. (Feb. 1962) AEEW - M 445

20. MOORHEAD T. P. (Apr. 1963) AEEW - R 254

21. BARRALL R. C. and McELROY N. N. (Aug. 1965) AFWL-TR 65-34 Vol. II.

22. PARKER K. and PENDLEBURY E. D. (Aug. 1964) Unpublished.

23. MILLER S. M. and PARKER K. (Oct. 1964) AWRE O-77/64; data taken predominantly from the compilation of TRALLI N., KALOS M. H., LONGANO A. J., RAY J. H., SULLIVAN R. P., TROUBETZKOY E. S. and TRUPIN B. H. (1962) UNC 5002.

24. RAVIER J. and VASTEL M. (Nov. 1965) PNR/SEFR - 65.041.

25. STORY J. S. Unpublished.

26. RAVIER J. (Mar. 1965) PNR/SEPR/CA/65.010.

27. OFFORD S. M. and PARKER K. (Dec. 1967) AWRE O-63/67.

28. PARKER K. (Nov. 1957) Unpublished.

29. POPE A. L. (Sept. 1966) AEEW - M 504.

30. HEMMINGS P. J. (1963) AHSB(S)R.62.

31. SUMNER H. M. (June 1962) AEEW - R 116.

32. PENDLEBURY E. D. (apr. 1966) Unpublished.

33. HART W. (July 1966) Unpublished.

34. GATELY P. and PARKER K. (Apr. 1965) Unpublished; data taken predominantly from a compilation by HOWERTON R. J. of LRL.

35. OFFORD S. M., PARKER K. and PROUT V. A. (Mar. 1966) Unpublished; based on a compilation by HOWERTON R. J. of LRL, but with improved (n,γ), (n,n') and (n,2n) data above 1 keV.

36. PARKER K. (July 1964) AWRE O-37/64.

37. HART W. (Feb. 1967) AHSB(S)R.124.

38. HEMMINGS P. J. To be published.

39. PARKER K. (July 1964) AWRE O-30/64.

40. RAVIER J. (Feb. 1968) PNR/SETR RO25
VASTEL M., Electricité de France report No. HX-1/1375/CL RA-FI-04 (Feb. 1968).

41. ADAMS M. J. and PARKER K. (July 1965) Unpublished; data taken from a compilation by HOWERTON R. J. of LRL.

42. DOUGLAS A. C. (Jan. 1965) AWRE O-91/64.

43. PARKER K. Unpublished.

44. BELL V. J., BLOTT L. W., KERR W. M. M., PARKER K., PULL I. C., WADE R. D., WILLIAMS D. V. J. (Aug. 1964) AEEW - M 422;
KERR W. M. M., PARKER K., WILLIAMS D. V. J. (Mar. 1965) AWRE O-97/64;
GATELY P., PARKER K., STANLEY P., WILLIAMS D. V. J. (Feb. 1966) AWRE O-103/65.

45. BRISSENDEN R. J. and DURSTON C. (1965) Proc. of the Conference on the Application of Computing Methods to Reactor Problems, ANL 7050, P51.

46. IRVING D. C. (Aug. 1967) ORNL-TM-1872.

47. SLAGGIE E. L. and REYNOLDS J. T. (June 1966) KAPL - 3099.

48. SLAGGIE E. L. and REYNOLDS J. T. (April 1965) KAPL - M-6452.

49. HART W., POPE A. L., STORY J. S. and WELLS J. F. (1966) Unpublished.

50. HART W. (Nov. 1967) Unpublished.

51. SOWERBY M. G. (June 1967) Private communication.

52. DOHERTY G. AEEW - M 714 (1966).

53. PATTENDEN N. J. (1964) Unpublished.

54. LOTTIN A., WESTON L. W., De SAUSSURE G., TODD J. H. ORNL P-2599 (1966).

55. SCHMIDT J. J., KFK 120, Part III (1962).

56. COLVIN D. W., SOWERBY M. G. Physics and Chemistry of Fission 2, IAEA, Vienna (1965).

57. BOLDEMAN J. W. (1967) AAEC E/172.

58. WESTCOTT C. H., EKBERG K., HANNA G. C., PATTENDEN N. J., SANATANI S., ATTREE P. M. "A Survey of Values of the 2200 m/s constants for four fissile nuclides" - Atomic Energy Review, IAEA Vol. 3, No. 2 (1965).

59. CONDÉ H., HANSEN J., HOLMBERG M. "Nuclear Data for Reactors" Vol. II, P51 IAEA, Vienna (1967).

60. JAMES G. D. (May 1964) AERE - R 4597.

APPENDIX A

Details are given below of the changes which have been made to some of the more important data files.

Boron — A revised data file (DFN 57) has been prepared as an interim measure. This is based on the existing file DFN 15E, but the scattering cross-section has been changed to 4.08 barns in the range up to 10 eV. The absorption cross-section is taken as 761 barns at 0.0253 eV and with 1/V variation up to 300 keV.

B.10 — The compilation prepared by Irving (46) at ORNL has been converted into the U.K. format, DFN 43, and is used as a replacement for DFN 13D.

Carbon — DFN 51 utilises the compilation of Slaggie and Reynolds (47) above 10 keV. Secondary energy distributions have been added for $(n,n'3\alpha)$. Below 10 keV, the data of DFN 21 is used and thermal scattering law data has been included in the new file.

Oxygen — Two new files (DFN 33 and DFN 34) have been prepared using the compilation of Slaggie and Reynolds (48) above 15 keV. Below 15 keV the total cross-section has been taken from BNL 325 (1958), and the absorption cross-section has been taken as 0.31 millibarns at 0.0253 eV, with 1/V variation. The KAPL evaluation provides inelastic scattering data to 22 different excited states of O16, and DFN 34 contains all these data in full detail. In DFN 33, inelastic scattering is given to only 10 discrete levels with a simplified representation to higher energy levels; the elastic angular distributions also are reduced in number.

U-235 — An interim file (DFN 66) has been prepared from DFN 30 (49) and DFN 335 (37). DFN 335 has fission cross-section data only, in the range 1 keV to 14 MeV. These data have been used to overwrite the fission cross-section data of DFN 30 in the same energy range, and the capture cross-section has been modified accordingly so that the capture to fission ratio (α) in the new file is the same as in DFN 30. The elastic scattering cross-section was modified so that the total cross-section remained unaltered. All these changes are quite small.

Pu-239 — Again this is an interim file (DFN 65), based on DFN 343 (50) and DFN 339 (37). The fission cross-section of DFN 339 was used to overwrite the fission cross-section of DFN 343 in the range 10 keV to 14 MeV. The capture cross-section was modified so that the capture to fission ratio remained unaltered, and the elastic scattering cross-section was adjusted, hence keeping the total cross-section the same as the original file.

Pu-241 — The original data file for Pu-241 (DFN 40) has been extensively revised as described in Appendix B following.

APPENDIX B

Revisions to the Data File for Pu241
by A. L. Pope

1. Sowerby (51) recently drew attention to an error in the evaluated cross-sections given by Doherty (52) in Data File Number 40 for Pu241 in the energy range 50 ev to 1 keV. Specifically some total cross-section data due to Pattenden (53) were misinterpreted as relating to Pu241 metal; in fact these data related to PuO_2, and have to be reduced by 7.4 barns to obtain equivalent values for Pu-241. These data were used by Doherty together with fission cross-section data by James (60) to estimate the effective capture-to-fission ratio in this energy range, and in consequence of the mistakes the derived capture cross-section was too high. A revised data file for Pu241, Data File No. 60, has now been prepared and is available. In this new file the material temperature is given as 3000K and the atomic weight as 241.056711 AMU. As well as the capture cross-section the scattering cross-section has also been amended above 50 eV. In addition, Hart's (37) new evaluation of the fission cross-section has been utilised in the range 1 keV to 15 MeV, and together with preferred values for $\alpha(E)$, associated changes have been made to the capture and elastic scattering cross-sections in this part of the range. The various changes are described briefly in the following sections.

2. Fission cross-sections

The data evaluated by Doherty (52) in DFN 40 are used in the range up to 1 keV, and the data of Hart's (37) file DFN 341 have been used from 1 keV to 15 MeV.

3. The capture to fission ratio

Below 50 eV the same data as in DFN 40 are used. However above 50 eV the value of α is derived from the preferred values of the average absorption and fission cross-sections given by Pattenden (4) and reproduced in Table 1 below.

Table 1

Average cross-sections from 32 to 1025 eV

E-range, eV	$\bar{\sigma}_A$, barns	$\bar{\sigma}_f$, barns	$\langle\alpha\rangle = \bar{\sigma}_\gamma/\bar{\sigma}_f$
32.02	46.6 ± 3.6	37.9 ± 2.8	0.229 ± 0.135
63.95	44.6 ± 3.2	41.8 ± 3.1	0.067 ± 0.115
128.01	36.6 ± 3.2	32.4 ± 2.4	0.130 ± 0.133
256.56	24.6 ± 3.1	22.2 ± 2.7	0.108 ± 0.194
512.24	16.4 ± 2.5	11.8 ± 1.4	0.389 ± 0.271
1024.66			

It is apparent from this table that α is but poorly determined over the range in question. The variations in $\langle\alpha\rangle$ are smaller than the uncertainties so it seems more realistic to use a single average value for the whole energy range.

The preferred mean value

$$\langle\alpha\rangle = 0.170 \pm 0.085$$

for the energy range from 50 eV to 1025 eV has been obtained by a 1/E weighting of the data presented above.

At higher energies, for want of data, we have assumed that the variation of $\alpha(E)$ will be similar to that for Pu239. Accordingly the value of 0.170 is retained up to about 67 keV where we follow the $\alpha(E)$ data for Pu239 quoted by Lottin et al. (54); these data extend to ~600 keV.

4. Capture cross-section

Below 600 keV the capture cross-section is derived from the product of $\alpha(E)$ and the fission cross-section.

We note that below 50 eV, the resonance structure is that presented in DFN 40; however in the range 50 eV to 1 keV, the structure is due solely to the resonance structure of the fission cross-section. Above 1 keV no resonance structure is shown.

Above 600 keV the capture cross-section is tapered away smoothly according to the formula

$$\sigma_\gamma(E) = K.E^{-3/2}$$

where $K = 0.02242$ barns $(MeV)^{3/2}$.

5. Non-elastic cross-section

The non-elastic cross-section given in DFN 40 has been amended to take into account the revised values of fission and capture cross-sections, but the other non-elastic components have been left unchanged.

6. Elastic scattering cross-section

Below 50 eV the data of DFN 40 remain unchanged.

In the range 50 eV to 1 keV the cross-section has been given a constant value of 12 barns, the perturbation due to resonance structure being ignored completely; this follows the same treatment used by Pattenden to derive $\bar{\sigma}_A$ from his total cross-section measurements.

Above 1 keV the elastic scattering cross-section is assumed to vary in a way similar to that of Pu239, and a curve similar in shape to that of Schmidt (55) for Pu239 renormalised to 12 barns at 1 keV has been taken.

7. The number of neutrons per fission

The thermal value for $\bar{\nu}$ is well known. The two most accurate measurements being those of Colvin et al. (56) and Boldeman (57). Westcott et al. (58) have evaluated the earlier data for $\bar{\nu}$, and Boldeman's result after correction for delayed neutrons and $\bar{\nu}$ [C_f 252] modifies Westcott's value to

$$\bar{\nu} = 2.960 \pm 0.014$$

at thermal energies.

Condé et al. (59) have made measurements of $\bar{\nu}$ at varying energies; they quote

$$\bar{\nu}(E) = 2.905 + 0.146E$$

However, since the thermal value, by far the most accurately determined, is not even considered by Condé, we prefer

$$\bar{\nu}(E) = 2.960 + 0.140E$$

as the best linear fit to the data.

These data differ from those of DFN 40, which follow

$$\bar{\nu}(E) = 2.969 + 0.124E$$

8. Total cross-section

Finally the total cross-section is obtained from the sum of the elastic scattering and the non-elastic cross-sections

$$\sigma_T(E) = \sigma_s(E) + \sigma_{nonel}(E)$$

It differs from that of DFN 40 only by amendments due to changes in the fission, capture and elastic scattering cross-sections.

Available from

HER MAJESTY'S STATIONERY OFFICE

TO BE PURCHASED FROM

49, High Holborn, London W.C.1.
423 Oxford Street, London W.1.
13a Castle Street, Edinburgh 2
109 St. Mary Street, Cardiff CF1 1JW
Brazennose Street, Manchester 2
50 Fairfax Street, Bristol 1
258-259 Broad Street, Birmingham 1
7-11 Linenhall Street, Belfast BT2 8AY
or through any bookseller.

Printed in Great Britain

S.O. Code No. 91 - 3 - 22 - 47