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ENDF/B Format

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Abstract: This document is a brief user's description of the format of ENDF/B, the evaluated neutron nuclear data library of the US National Nuclear Data Center. This summary is an aid to customers of the IAEA Nuclear Data Section when receiving data retrievals in ENDF/B format. For more detailed information the report BNL-50274 (ENDF-102) should be consulted.

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ENDF/B Format

This report describes only the BCD card-image (not the binary) format. This being so because it is much easier to use the BCD card-image formats when translating evaluated data (cross sections) into the ENDF library. Photon production (induced by neutrons), photon interactions, resonance parameters (only the special case included in this report), part of the energy distribution and the energy-angular distribution are not included in this report, they will be reported separately.

Definitions

File = Evaluated data set for a material is divided into files. Each file contains data of a certain class of information, (identified by MF).

Section = Each file is divided into sections where each section contains the data for a particular reaction type (identified by MT).

Record = Each section is divided into records. Every record contains MAT, MF and MT numbers. These numbers are always in increasing numerical order.

MAT = Material Number, unique for each material. (Cols. 67 – 70).

MF = File Number (Cols. 71 – 72).

MT = Reaction Type Number (73 – 75).

* for details see BNL 50274 (ENDF-102) Vol. 1, October 1970.

File Number (MF)	Class of Data
1	General information
2	Resonance parameter data
3	Neutron cross sections
4	Angular distributions of secondary neutrons
5	Energy distributions of secondary neutrons
6	Energy-angular distributions of secondary neutrons
7	Thermal neutron scattering law data
12	Multiplicities for photons*
13	Photon production cross sections*
14	Angular distributions of photons*
15	Energy distribution of photons*
16	Energy-angular distributions of photons*
23	Photon interaction cross sections
24	Angular distributions of photons (from photon reactions).
25	Energy distributions of photons (from photon reactions).
26	Energy-angular distributions of photons (from photon reactions)
27	Atomic form factors (for photon interactions).

MT	Description
1	Total cross section
2	Elastic scattering cross section
3	Nonelastic cross section (total-elastic)
4	Inelastic cross section (= sum of MT = 51,52,53, ...,90,91).
16	(n,2n) cross section
17	(n,3n) cross section
18	Fission cross section (= sum of MT= 19,20,21, plus any undefined part).
19	(n,f) cross section
20	(n,n'f) cross section
21	(n,2nf) cross section
22	(n,n')α cross section
23	(n,n') 3α cross section
24	(n,2n) αcross section
25	(n,3n) α cross section
26	(to be assigned)
28	(n,n') p cross section
30-50	(to be assigned)
51	(n,n') to the 1st excited state
52	(n,n') " " 2nd " "
⋮	
90	(n,n') " " 40th" "
91	(n,n') to the continuum
92-100	(to be assigned)
101	parasitic absorption (sum of MT = 102, 103, 104, 105, 106, 107, 108, 109).
102	(n,γ) radiative capture cross section
103	(n,p) cross section

12*-16* cover photon production data for processes intiated by neutrons.

MT	Description
104	(n,d) cross section
105	(n,t) cross section
106	(n,He^3) " "
107	(n,α) " "
108	$(n,2\alpha)$ " "
109	$(n,3\alpha)$ " "
110-150	(to be assigned)
151	General designation for resonance information
152-200	(to be assigned for specific resonance information)
201-150	(to be assigned)
251	$\bar{\mu}_L$, the average cosine of the scattering angle (Laboratory system) for elastic scattering
252	ξ, the average logarithmic energy decrement for elastic scattering
253	γ- the average of the square of the logarithmic energy decrement, divided by twice the average logarithmic decrement for elastic scattering
254-300	(to be assigned)
301-450	Energy release rate parameters, $\bar{E}^* \sigma$, for total and partial cross sections. Subtract 300 from this number to obtain the specific reaction type identification. MT = 302 = (300 + 2) denotes elastic scattering.
451	Heading or title information (only given in File 1)
452	$\bar{\nu}$ (prompt + delayed)
453	Radioactive decay chain data
454	Fission product yield data
455	Delayed neutrons from fission
456-699	(to be assigned)
700	(n,P_o) cross section (residual nucleus is in the ground state)
701	(n,p_1) cross section for 1st excited state
⋮	
718	(n,P_{18}) " " " 18th " "
719	(n,P_c) " " " continuum
720-739	(n,d_o), (n,d_1),...,(n,d_c) as for 700-719
740-759	(n,t_o), (n,t_1),...,(n,t_c) as for 700-719
760-779	(n,He^3_o), (n,He^3_1),...,(n,He^3_c) as for 700-719
780-799	(n,α_o), (n,α_1),...,(n,α_c) as for 700-719
800-999	(to be assigned)

Card Image (BCD) Formats

Standard 80-column card is used to contain data when preparing magnetic tapes with BDC card image records. Each card is divided into the following ten fields

Field	columns	Description
1	1-11	Datum
2	12-22	"
3	23-33	"
4	34-44	"
5	45-55	"
6	56-66	"
7*	67-70	Material Number (MAT)
8*	71-72	File Number (MF)
9*	73-75	Reaction Type Number (MT)
10*	76-80	Card sequence Number, starting with 1 for the first card of a material

*These fields will be punched on each record when preparing the magnetic tape

Descriptive Information and Index

File 1: MT = 451

Field 1	Field 2	Field 3	Field 4	Field 5	Field 6	Record Type
ZA	AWR	LRP	LFI	b*	NXC	HEAD
b	b	LDD	LFP	NWD	b	
Hollerith Information				1st card		
				2nd card		
-	-	-	-	-	-	
-	-	-	-	NWDth card		LIST
b	b	MF_{NXC}	MT_{NXC}	NC_{NXC}	b	CØNT
b	b	b	b	b	b	SEND

AWR = the ratio of the nuclear mass to that of the neutron
LRP = o (no parameters); if = 1 (parameters given)
LFI = o (material is not fissionable); if = 1 (fissionable)
NXC = is a count of cards in dictionary. Each section represented by a single card, which contains MF, MT and NC.
LDD = o (no radioactive decay data given); if = 1 (given in MT = 454).
LFP = o (no fission product data); if = 1 (data given in MT = 454).
NWD = No. of cards used to describe the data set.
MF_n = File number of the nth section
MT_n = Reaction " " " " "
NC_n = No. of cards in nth section

Neutrons per Fission $\bar{\nu}(E)$

File 1, MT = 452

LNU = 1

Field 1	Field 2	Field 3	Field 4	Field 5	Field 6	Record Type
ZA	AWR	b	LNU=1	b	b	HEAD
b	b	b	b	NC	b	
C_1	C_2	-	-	C_{NC}		LIST
b	b	b	b	b	b	SEND

b* - blank
Field 7 = MAT
Field 8 = MF = 1
Field 9 = MT = 451 (except SEND card)
Field 10 = card sequence number

LNU = 2

Field 1	Field 2	Field 3	Field 4	Field 5	Field 6	Record Type
ZA	AWR	b	LNU=2	b	b	HEAD
b NBT_1 E_1	b INT_1 $\bar{\nu}(E_1)$	b - -	b - -	NR NBT_{NR} E_{NP}	NP INT_{NR} $\bar{\nu}(E_{NP})$	TAB1
b	b	b	b	b	b	SEND

LNU = 1, Polynomial representation
2, $\bar{\nu}(E_1)$ is tabulated
NC = No. of terms used in the polynomial expansion
C_1, C_2, C_3, C_4, coefficients of the polynomial

NR = No. of interpolations ranges used
NP = total No. of energy points used in the tabulations
NBT(1), INT(1) = interpolation scheme for $\bar{\nu}(E)$
E_i = the energy (ith point) of the neutrons causing fission

Radioactive Decay Scheme

File 1; MT = 453

1	2	3	4	5	6	Record Type
ZA	AWR	b	b	NS	b	HEAD
ZA ES(1)	AWR ES(2)	LIS ES(3)	b -	NE -	NPR ES(NE)	(ground state) LIST 1
$EREL_{NPR}$	Q_{NPR}	LFS_{NPR}	b	NE+3	b	
$RTYP_{NPR}$	ZA_{NPR}	DC_{NPR}	BR(1)	-	BR(NE)	LIST 2

(Structure is repeated for each original nuclide state until all NS states have been given. Start each state with the first LIST record)

NS = No. of excited states for the original nuclide (target nucleus)
LIS = 0 for ground state, etc.
NE = No. of incident energy points
NPR = total No. of product nuclide states
ES(N) = Incident energy point (Nth point)
EREL = total energy released by specified decay mode (includes gamma rays and particles)
Q = reaction Q-value
LFS = state of the product nuclide (0 = ground state, etc)
RTYP = floating point values of MT number
= 0.0 for spontaneous decay of the otiginal nuclide
DC = decay constant (see $^{-1}$)
BR(N)= branching ratio at the Nth energy point

Fission Product Yield Data

File 1; MT = 454

1	2	3	4	5	6	Record Type
ZA	AWR	LE+1	b	b	b	HEAD
E_1	b	LE	b	N1	NFP	(N1 = 3*NFP)
$ZAFP_1$	FPS_1	YLD_1	$ZAFP_2$	FPS_2	YLD_2	
-	-	-	$ZAFP_{NFP}$	FPS_{NFP}	YLD_{NFP}	LIST
E_2	b	I_2	b	N_1	NFP	
$ZAFP_1$	FPS_1	YLD_2	-	-	-	
-	-	-	$ZAFP_{NFP}$	FPS_{NFP}	YLD_{NFP}	LIST
E_N	b	I_N	b	N_1	NFP	
$ZAFP_1$	FPS_1	YLD_1	-	-	-	(N = LE+1)
-	-	-	$ZAFP_{NFP}$	FPS_{NFP}	YLD_{NFP}	LIST

NFP = No. of fission products to be specified at the ith incident neutron energy point (sets of 3 parameters: ZAFP, FPS, YLD)
E_i = incident energy causing fission
LE = o, no energy dependence
  >o, means that (LE+1) sets of fission product yield are given
I_i = interpolation scheme to be used between E_{i-1} and E_i energy points
ZAFP= the (ZA) identifier for a particular fission product
YLD = fractional yield for a particular fission product
FPS = o.o (ground state of fission product)
  = 1.o (ist excited state, etc)

Delayed Neutron Data, $\bar{\nu}_d$

File 1; MT = 455

LND = 1

1	2	3	4	5	6	Record Type
ZA	AWR	b	1	b	b	HEAD
b	b	b	b	NNF	b	
λ_1	λ_2	-	-	-	λ_{NNF}	LIST
b	b	b	b	NCD	b	
CD_1	CD_2	-	-	-	CD_{NCD}	LIST
b	b	b	b	b	b	SEND

1	2	3	4	5	6	Record Type
ZA	AWR	b	LND=2	b	b	HEAD
b	b	b	b	NNF	b	
λ_1	λ_2	λ_3	-	-	λ_{NNF}	LIST
b	b	b	b	NR	NP	
NBT_1	INT_1	-	-	NBT_{NR}	INT_{NR}	
E_1	$\nu_d(E_1)$	-	-	E_{NP}	$\nu_d(E_{NP})$	TAB1
b	b	b	b	b	b	SEND

LND = 1, polynomial expansion
= 2, tabulated values of $\bar{\nu}_d$
NNF = No. of precursor families given
λ_i = decay constant of the ith precursor (sec $^{-1}$)
NCD = No. of terms in the polynomial expansion
CD_1, CD_2,... = coefficients for the polynomial

Resonance Parameters Data

File 2; MT = 151

This special case (LRP = 0, i.e. no resonance parameters are given) will be described here. The only data given is effective scattering radius. The general description of resonance parameters data (LRP = 1) will be discussed in a separate sheet.

1	2	3	4	5	6	Record Type
ZA	AWR	b	b	NIS=1	b	HEAD
ZAI	ABN	b	LFW=o	NER=1	b	CØNT
EL	EH	LRU=0	LRF=o	b	b	CØNT
SPI	AP	b	b	NLS=0	b	CØNT
b	b	b	b	b	b	SEND
b	b	b	b	b	b	FEND

ZAI = is the (Z,A) designation for an isotope
ABN = Abundance (weight fraction) of an isotope
EL = Lower limit for the energy range
EH = Upper limit " " " "
SPI = Nuclear spin of the target nucleus, I.
AP = Spin-independent effective scattering radius (in units of 10^{-12} cm)
LRU = Test for resolved (=1) or unresolved (=2) resonance parameters
LRF = Test for the type of resonance formula

Field 7 = MAT
Field 8 = MF = 2 (except FEND card)
Field 9 = MT = 151 (except SEND card)
Field 10 = card sequence number
b = blank

Neutron Cross Section $\sigma(E)$

File 3

1	2	3	4	5	6	Record Type
ZA	AWR	LIS	LFS	b	b	HEAD
T	Q	LT	b	NR	NP	
NBT_1	INT_1	-	-	NBT_{NR}	INT_{NR}	
E_1	$\sigma(E_1)$	-	-	E_{NP}	$\sigma(E_{NP})$	TAB1
b	b	b	b	b	b	SEND

LFS = indicator that specifies the final excited state of the residual nucleus.
LFS = 3, means 3rd state

Neutron cross sections (in barns) are given as a function of incident neutron energy E (in L-system). The threshold energy for a reaction is:

$$E_{th} = \left(\frac{AWR + 1.0}{AWR}\right) |Q|$$

Energy Distributions of Secondary Neutrons*

File 5

NK = No. of partial energy distributions used for a particular reaction type (MT)
LF = Flag that specifies the type of distribution used
NP = No. of energy points at which fractional probabilities, $P(E_i)$, are given
NF = No. of secondary energy points for a particular distribution
NE = No. of incident energy points at which distributions are given

$g(E \rightarrow E')$ = Normalized prob bilities
NBT_i and INT_i = Interpolation scheme

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* The General evaporation spectrum (LF=5), the simple (Maxwellian) fission spectrum (LF=7), the evaporation spectrum (LF=9) and Watt spectrum (LF=10) will be discussed in a separate report with the resonance parameters, photon production and photon interaction.

I. Tabulated energy distributions, LF = 1, f(E -> E') = g(E -> E'):

ZA	AWR	b	b	NK	b	HEAD
T	b	LT	LF=1	NR	NP	
NBT_1	INT_1	-	-	NBT_{NR}	INT_{NR}	
E_1	$P(E_1)$	-	-	E_{NP}	$P(E_{NP})$	TAB1
b	b	b	b	NR	NE	
NBT_1	INT_1	-	-	NBT_{NR}	INT_{NR}	TAB2
T	E_{NE}	LT	b	NR	NF	(1-NE energy points)
NBT_1	INT_1	-	-	NBT_{NR}	INT_{NR}	
E'_1	$g(E_{NE} -> E'_1)$	-	-	E'_{NF}	$g(E_{NE} -> E'_{NF})$	TAB1
b	b	b	b	b	b	SEND

II. Discrete level excitation, LF = 3

ZA	AWR	b	b	NK	b	HEAD
T	0	LT	LF=3	NR	NP	
NBT_1	INT_1	-	-	NBT_{NR}	INT_{NR}	
E_1	$P(E_1)$	-	-	E_{NP}	$P(E_{NP})$	TAB1
b	b	b	b	b	b	SEND

Angular Distributions of Secondary Neutrons

File 4

Definitions

LTT	=	1 (Legendre coefficients)
	=	2 (Tabulated distributions)
LVT	=	0 (not given)
	=	1 (Transformation matrix given)
LCT	=	1 (Laboratory system)
	=	2 (center of mass system)
NK	=	No. of elements in the transformation matrix
NM	=	Maximum order Legendre polynomial (in CM or LAB system)
$U_{\ell,m}$	=	Elements of the transformation matrix
NR	=	No. of interpolation ranges for the distribution
NE	=	No. of energy points at which distribution will be given
NP	=	No. of cosine values for a particular distribution
NBT_i and INT_i	=	Interpolation scheme (to interpolate distribution between given energy points, or the coefficients, f_ℓ between given values)
E_i	=	Energy of the i^{th} point
NL	=	The order of the Legendre expansion at particular energy point
$f_\ell(E_i)$	=	value of the ℓ^{th} coefficient for the i^{th} point
μ_j	=	value of cosine at point j
$P(\mu_j, E_i)$	=	Normalized angular probability at μ_j for energy point E_i

when LTT = 1; LVT = o

1	2	3	4	5	6	Record Type
ZA	AWR	LVT=o	LTT=1	b	b	HEAD
b	AWR	b	LCT	NK=o	NM=o	CØNT
b	b	b	b	NR	NE	
NBT_1	INT_1	-	-	NBT_{NR}	INT_{NR}	TAB2
T	E_{NE}	LT	b	NL	b	(1-NE energy points)
$f_1(E_{NE})$	$f_2(E_{NE})$	-	-	-	$f_{NL}(E_{NE})$	LIST
b	b	b	b	b	b	SEND

when LTT = 1, LVT = 1

1	2	3	4	5	6	Record Type
ZA	AWR	LVT=1	LTT=1	b	b	HEAD
b	AWR	b	LCT	NK	NM	
$U_{o,o}$	$U_{1,o}$	$U_{2,o}$	-	-	$U_{NM,o}$	
$U_{o,1}$	$U_{1,1}$	$U_{2,1}$	-	-	$U_{NM,1}$	
-	-	-	-	-	-	
$U_{o,NM}$	$U_{1,NM}$	$U_{2,NM}$	-	-	$U_{NM,NM}$	LIST
b	b	b	b	NR	NE	
NBT_1	INT_1	-	-	NBT_{NR}	INT_{NR}	TAB2
T	E_{NE}	LT	b	NL	b	(1-NE energy points)
$f_1(E_{NE})$	$f_2(E_{NE})$	-	-	-	$f_{NL}(E_{NE})$	LIST
b	b	b	b	b	b	SEND

when LTT = 2, LVT = 1

1	2	3	4	5	6	Record Type
ZA	AWR	LVT=1	LTT=2	b	b	HEAD
b	AWR	b	LCT	NK	NM	
$U_{o,o}$	$U_{1,o}$	$U_{2,o}$	-	-	$U_{NM,o}$	
-	-	-	-	-	-	
$U_{o,NM}$	$U_{1,NM}$	$U_{2,NM}$	-	-	$U_{NM,NM}$	LIST
b	b	b	b	NR	NE	
NBT_1	INT_1	-	-	NBT_{NR}	INT_{NR}	TAB2
T	E_{NE}	LT	b	NR	NP	
NBT_1	INT_1	-	-	NBT_{NR}	INT_{NR}	(1-NE energy points)
μ_1	$P(\mu_1, E_{NE})$	-	-	μ_{NP}	$P(\mu_{NP}, E_{NE})$	TAB1
b	b	b	b	b	b	SEND

when LTT = 2; LVT = o

1	2	3	4	5	6	Record Types
ZA	AWR	LVT=o	b	b	b	HEAD
b	AWR	b	LCT	NK=o	NM=o	CØNT
b	b	b	b	NR	NE	
NBT_1	INT_1	-	-	NBT_{NR}	INT_{NR}	TAB2
T	E_{NE}	LT	b	NR	NP	(1-NE energy points)
NBT_1	INT_1	-	-	NBT_{NR}	INT_{NR}	
μ_1	$P(\mu_1, E_{NE})$	-	-	μ_{NP}	$P(\mu_{NP}, E_{NE})$	TAB1
b	b	b	b	b	b	SEND