APPENDIX B

Definition of Reaction Types

Reaction types (MT) are identified by an integer number from 1 through 999. Version 6 of the ENDF format supports incident charged particles and photons in a manner consistent with the definitions of MT's used in previous versions of the ENDF format to the extent possible. Users should beware of the few differences. In the following table, those MT numbers restricted to neutrons incident are labeled (n,xxx); those that are limited to incident charged particles and photons are labeled (y,xxx) and those that allow all particles in the entrance channel are labeled (z,xxx), where x can represent any exit particle. See Section 0.0 for complete descriptions of MT numbers. Refer to Sections 3.4 (incident neutrons) and 3.5 (incident charged particles and photons) for the list of MT numbers that should be included in each evaluation.

For the ENDF-6 format, all particles in the exit channel are named (within the parenthesis) ***except*** for the residual. The identity of this residual can be specified explicitly in File 6 or determined implicitly from the MT number. In cases where more than one MT might describe a reaction, the choice of MT number is then determined by the residual which is the heaviest of the particles (AZ,A) in the exit channel. For example, ^{6}Li(n,t)α is represented by MT=700, rather than my MT=800; and MT=32 represents the ^{6}Li(n,nd)α reaction rather than MT=22. Sequential reaction mechanism descriptions can be used, where necessary, for reactions such as X(n,np)Y. These are described in Sections 0.5.3 and 0.5.4.

MT		Description	Comments
1	(n,total)	Neutron total cross sections. Sum of MT=2, 4, 5, 11, 16-18, 22-26, 28-37, 41-42, , 44-45, 102-117.	Redundant. Undefined for incident charged particles.
2	(z,z_0)	Elastic scattering cross section for incident particles.	
3	(z,nonelastic)	Nonelastic neutron cross section. Sum of MT=4, 5, 11, 16-18, 22-26, 28-37, 41-42, , 44-45, 102-117.	Redundant. For photon production only.
4	(z,n)	Production of one neutron in the exit channel. Sum of the MT=50-91.	Redundant. For incident neutrons, this is inelastic scattering (MT=50 is undefined).
5	(z,anything)	Sum of all reactions not given explicitly in another MT number. This is a partial reaction to be added to obtain MT=1.	Each particle can be identified and its multiplicity given in File 6. Not allowed in Files 4, 5.
6-9		Not allowed in version 6.	^{9}Be(n,2n) in version 5.
10	(z,continuum)	Total continuum reaction; includes all continuum reactions and excludes all discrete reactions.	Redundant; to be used for derived files only.
11	(z,2nd)	Production of two neutrons and a deuteron, plus a residual.	
12-15		Unassigned.	
16	(z,2n)	Production of two neutrons and a residual[1]. Sum of MT=875-891, if they are present.	
17	(z,3n)		
18	(z,fission)		
19	(n,f)		
20	(n,nf)	Second-chance fission[2].	
21	(n,2nf)	Third-chance fission[2].	
22	(z,nα)	Production of a neutron and an alpha particle, plus a residual.	
23	(n,n3α)	Production of a neutron and three alpha particles, plus a residual.	
24	(z,2nα)	Production of two neutrons and an alpha particle, plus a residual.	

1 The "residual" is the remainder after the reaction specified by MT has taken place (for example, A-1 after an n,2n reaction on target A). This "residual" may break up further if LR>0.

2 Note that the partial fission cross section are not defined for incident charged particles.

MT		Description	Comments
25	(z,3nα)	Production of three neutrons and an alpha particle, plus a residual.	
26		Not allowed in version 6.	Version 5: (n,2n) isomeric state; used in file 8 and 6, 9, or 10.
27	(n,abs)	Absorption; sum of MT=18 and MT=102 through MT=117	Rarely used.
28	(z,np)	Production of a neutron and a proton, plus a residual.	
29	(z,n2α)	Production of a neutron and two alpha particles, plus a residual.	
30	(z,2n2α)	Production of two neutrons and two alpha particles, plus a residual.	
31		Not allowed for version 6.	Used only as an LR flag.
32	(z,nd)	Production of a neutron and a deuteron, plus a residual.	
33	(z,nt)	Production of a neutron and a triton, plus a residual.	
34	(z,n^{3}He)	Production of a neutron and a ^{3}He particle, plus a residual.	
35	(z,nd2α)	Production of a neutron, a deuteron, and 2 alpha particles, plus a residual.	
36	(z,nt2α)	Production of a neutron, a triton, and 2 alpha particles, plus a residual.	
37	(z,4n)	Production of 4 neutrons, plus a residual.	
38	(n,3nf)	Fourth-chance fission cross section[2].	
39		Not allowed for version 6.	Used only as an LR flag.
40		Not allowed for version 6.	Used only as an LR flag.
41	(z,2np)	Production of 2 neutrons and a proton, plus a residual.	
42	(z,3np)	Production of 3 neutrons and a proton, plus a residual.	
43		(Unassigned)	
44	(z,n2p)	Production of a neutron and 2 protons, plus a residual.	
45	(z,npα)	Production of a neutron, a proton, and an alpha particle, plus a residual.	
46-49		Not allowed in Version 6.	Version 5: description of 2nd neutron from ^{9}Be(n,2n) reactions to excited states.

MT		Description	Comments
50	(y,n_0)	Production of a neutron, leaving the residual nucleus in the ground state.	Not allowed for incident neutrons; use MT=2.
51	(z,n_1)	Production of a neutron, with residual in the 1st excited state.	
52	(z,n_2)	Production of a neutron, with residual in the 2nd excited state.	
	…		
	…		
90	(z,n_{40})	Production of a neutron, with residual in the 40th excited state.	
91	(z,n_c)	Production of a neutron in the continuum not included in the above discrete representation.	
92-100		(Unassigned)	
101	(n,disap)	Neutron disappearance; equal to sum of MT=102-117.	Rarely used.
102	(z,γ)	Radiative capture.	
103	(z,p)	Production of a proton, plus a residual. Sum of MT=600-649, if they are present.	For incident protons, this is inelastic scattering (MT=600 is undefined).
104	(z,d)	Production of a deuteron, plus a residual. Sum of MT=650-699, if they are present.	For incident deuterons, this is inelastic scattering (MT=650 is undefined).
105	(z,t)	Production of a triton, plus a residual. Sum of MT=700-749, if they are present.	For incident tritons, this is inelastic scattering (MT=700 is undefined).
106	$(z,^3He)$	Production of a ^3He particle plus a residual. Sum of MT=750-799, if they are present.	For incident ^3He particles, this is inelastic scattering (MT=750 is undefined).
107	(z,α)	Production of an alpha particle, plus a residual. Sum of MT=800-849, if they are present.	For incident alpha particles, this is inelastic scattering (MT=800 is undefined).
108	$(z,2\alpha)$	Production of 2 alpha particles, plus a residual.	
109	$(z,3\alpha)$	Production of 3 alpha particles, plus a residual.	
110		(Unassigned)	
111	(z,2p)	Production of 2 protons, plus a residual.	
112	$(z,p\alpha)$	Production a proton and an alpha particle, plus a residual.	

MT		Description	Comments
113	(z,t2α)	Production of a triton and 2 alpha particles, plus a residual.	
114	(z,d2α)	Production of a deuteron and 2 alpha particles, plus a residual.	
115	(z,pd)	Production of proton and a deuteron, plus a residual.	
116	(z,pt)	Production of proton and a triton, plus a residual.	
117	(z,dα)	Production of deuteron and an alpha particle, plus a residual.	
118-119		(Unassigned)	
120		Not allowed for version 6.	Version 5: target destruction - nonelastic minus total (n,n′γ)
121-150		(Unassigned)	
151	(n,RES)	Resonance parameters that can be used to calculate cross sections at different temperatures in the resolved and unresolved energy regions.	Incident neutrons only.
152-200		(Unassigned)	
201	(z,Xn)	Total neutron production.	Redundant; use in derived files only.
202	(z,Xγ)	Total gamma production.	Redundant; use in derived files only.
203	(z,Xp)	Total proton production.	Redundant; use in derived files only.
204	(z,Xd)	Total deuteron production.	Redundant; use in derived files only.
205	(z,Xt)	Total triton production.	Redundant; use in derived files only.
206	(z,X^{3}He)	Total ^{3}He production.	Redundant; use in derived files only.
207	(z,Xα)	Total alpha particle production.	Redundant; use in derived files only.
208	(z,Xπ^+)	Total π^+ production.	For use in high-energy evaluations.
209	(z,Xπ^0)	Total π^0 production.	For use in high-energy evaluations.
210	(z,Xπ^-)	Total π^- production.	For use in high-energy evaluations.
211	(z,Xμ^+)	Total μ^+ production.	For use in high-energy evaluations.

MT		Description	Comments
212	(z,Xμ^-)	Total μ^- production.	For use in high-energy evaluations.
213	(z,Xκ^+)	Total κ^+ production.	For use in high-energy evaluations.
214	(z,X$\kappa^0_{(long)}$	Total $\kappa^0_{(long)}$ production.	For use in high-energy evaluations.
215	(z,X$\kappa^0_{(short)}$)	Total $\kappa^0_{(short)}$ production.	For use in high-energy evaluations.
216	(z,Xκ^-)	Total κ^- production.	For use in high-energy evaluations.
217	(z,Xp)	Total anti-proton production.	For use in high-energy evaluations.
218	(z,Xn)	Total anti-neutron production.	For use in high-energy evaluations.
219-250		(Unassigned)	
251	(n,...)	$\bar{\mu}_L$, average cosine of the scattering angle (laboratory system) for elastic scattering of neutrons.	Derived files only.
252	(n,...)	ξ, average logarithmic energy decrement for elastic scattering of neutrons.	Derived files only.
253	(n,...)	γ, average of the square of the logarithmic energy decrement divided by twice the average logarithmic energy decrement, for elastic scattering of neutrons.	Derived files only.
254-300		(Unassigned)	
301-450	(z,...)	Energy release parameters, $\overline{E}, \overline{\sigma}$, for total and partial cross sections; MT= 300 plus the reaction MT number, *e.g.*, MT=302 is the elastic scattering kerma.	Derived files only.
451	(z,...)	Heading or title information; given in File 1 only.	
452	(z,...)	$\bar{\nu}_T$, average total (prompt plus delayed) number of neutrons released per fission event.	
453		(Unassigned)	
454	(z,...)	Independent fission product yield data.	

MT		Description	Comments
455	(z,...)	$\bar{\nu}_d$, average number of delayed neutrons released per fission event.	
456	(z,...)	$\bar{\nu}_p$, average number of prompt neutrons released per fission event.	
457	(z,...)	Radioactive decay data.	
458	(n,...)	Energy release in fission for incident neutrons.	
459	(z,...)	Cumulative fission product yield data.	
460-464		(Unassigned)	
465-466		Not allowed in version 6.	Version 5: delayed and prompt neutrons from spontaneous fission.
467-499		(Unassigned)	
500		Total charged-particle stopping power.	
501		Total photon interaction.	
502		Photon coherent scattering.	
503		(Unassigned)	
504		Photon incoherent scattering.	
505		Imaginary scattering factor.	
506		Real scattering factor.	
507-514		(Unassigned)	
515		Pair production, electron field.	
516		Pair production; sum of MT=515, 517.	Redundant.
517		Pair production, nuclear field.	
518		Not allowed in version 6.	
519-521		(Unassigned)	
522		Photoelectric absorption.	Version 5: MT=602.
523		Photo-excitation cross section.	
524-525		(Unassigned)	
526		Electro-atomic scattering.	
527		Electro-atomic bremsstrahlung.	
528		Electro-atomic excitation cross section.	
529-531		(Unassigned)	
532		Not allowed in version 6.	Version 5: (γ,n).
533		Atomic relaxation data.	Version 5: total photonuclear
534	K	$(1s^1/_2)$ subshell photoelectric or electro-atomic cross section.	

MT		Description	Comments
535	L1	$(2s^{1}/_{2})$ subshell photoelectric or elctro-atomic cross section.	
536	L2	$(2p^{1}/_{2})$ subshell photoelectric or elctro-atomic cross section.	
537	L3	$(2p^{3}/_{2})$ subshell photoelectric or elctro-atomic cross section.	
538	M1	$(3s^{1}/_{2})$ subshell photoelectric or elctro-atomic cross section.	
539	M2	$(3p^{1}/_{2})$ subshell photoelectric or elctro-atomic cross section.	
540	M3	$(3p^{3}/_{2})$ subshell photoelectric or elctro-atomic cross section.	
541	M4	$(3d^{3}/_{2})$ subshell photoelectric or elctro-atomic cross section.	
542	M5	$(3d^{5}/_{2})$ subshell photoelectric or elctro-atomic cross section.	
543	N1	$(4s^{1}/_{2})$ subshell photoelectric or elctro-atomic cross section.	
544	N2	$(4p^{1}/_{2})$ subshell photoelectric or elctro-atomic cross section.	
545	N3	$(4p^{3}/_{2})$ subshell photoelectric or elctro-atomic cross section.	
546	N4	$(4dp^{3}/_{2})$ subshell photoelectric or elctro-atomic cross section.	
547	N5	$(4d^{5}/_{2})$ subshell photoelectric or elctro-atomic cross section.	
548	N6	$(4f^{5}/_{2})$ subshell photoelectric or elctro-atomic cross section.	
549	N7	$(4f^{7}/_{2})$ subshell photoelectric or elctro-atomic cross section.	
550	O1	$(5s^{1}/_{2})$ subshell photoelectric or elctro-atomic cross section.	
551	O2	$(5p^{1}/_{2})$ subshell photoelectric or elctro-atomic cross section.	
552	O3	$(5p^{3}/_{2})$ subshell photoelectric or elctro-atomic cross section.	
553	O4	$(5d^{3}/_{2})$ subshell photoelectric or elctro-atomic cross section.	
554	O5	$(5d^{5}/_{2})$ subshell photoelectric or elctro-atomic cross section.	

MT		Description	Comments
555	O6	($5f^{5}/_{2}$) subshell photoelectric or elctro-atomic cross section.	
556	O7	($5f^{7}/_{2}$) subshell photoelectric or elctro-atomic cross section.	
557	O8	($5g^{7}/_{2}$) subshell photoelectric or elctro-atomic cross section.	
558	O9	($5g^{9}/_{2}$) subshell photoelectric or elctro-atomic cross section.	
559	P1	($6s^{1}/_{2}$) subshell photoelectric or elctro-atomic cross section.	
560	P2	($6p^{1}/_{2}$) subshell photoelectric or elctro-atomic cross section.	
561	P3	($6p^{3}/_{2}$) subshell photoelectric or elctro-atomic cross section.	
562	P4	($6d^{3}/_{2}$) subshell photoelectric or elctro-atomic cross section.	
563	P5	($6d^{5}/_{2}$) subshell photoelectric or elctro-atomic cross section.	
564	P6	($6f^{5}/_{2}$) subshell photoelectric or elctro-atomic cross section.	
565	P7	($6f^{7}/_{2}$) subshell photoelectric or elctro-atomic cross section.	
566	P8	($6g^{7}/_{2}$) subshell photoelectric or elctro-atomic cross section.	
567	P9	($6g^{9}/_{2}$) subshell photoelectric or elctro-atomic cross section.	
568	P10	($6h^{9}/_{2}$) subshell photoelectric or elctro-atomic cross section.	
569	P11	($6h^{11}/_{2}$) subshell photoelectric or elctro-atomic cross section.	
570	Q1	($7s^{1}/_{2}$) subshell photoelectric or elctro-atomic cross section.	
571	Q2	($7p^{1}/_{2}$) subshell photoelectric or elctro-atomic cross section.	
572	Q3	($7p^{3}/_{2}$) subshell photoelectric or elctro-atomic cross section.	
573-599		(Unassigned)	
600	(z,p_0)	Production of a proton leaving the residual nucleus in the ground state.	Not allowed for incident protons; use MT=2.
601	(z,p_1)	Production of a proton, with residual in the 1st excited state.	

MT		Description	Comments
602	(z,p_2)	Production of a proton, with residual in the 2nd excited state.	Version 5: photoelectric absorption; see MT=522.
603	(z,p_3)	Production of a proton, with residual in the 3rd excited state.	
604	(z,p_4)	Production of a proton, with residual in the 4th excited state.	
	…		
	…		
649	(z,p_c)	Production of a proton in the continuum not included in the above discrete representation.	
650	(z,d_0)	Production of a deuteron leaving the residual nucleus in the ground state.	
651	(z,d_1)	Production of a deuteron, with the residual in the 1st excited state.	
652	(z,d_2)	Production of a deuteron, with the residual in the 2nd excited state.	
	…		
	…		
699	(z,d_c)	Production of a deuteron in the continuum not included in the above discrete representation.	
700	(z,t_0)	Production of a triton leaving the residual nucleus in the ground state.	
701	(z,t_1)	Production of a triton, with residual in the 1st excited state.	
702	(z,t_2)	Production of a triton, with residual in the 2nd excited state.	
	…		
	…		
749	(z,t_c)	Production of a triton in the continuum not included in the above discrete representation.	
750	$(n,{}^3He_0)$	Production of a ^{3}He particle leaving the residual nucleus in the ground state.	
751	$(n,{}^3He_1)$	Production of a ^{3}He, with residual in the 1st excited state.	
	…		
	…		

MT		Description	Comments
799	$(n,{}^3He_c)$	Production of a ^{3}He in the continuum not included in the above discrete representation.	
800	(z,α_0)	Production of an alpha particle leaving the residual nucleus in the ground state.	
801	(z,α_1)	Production of an alpha particle, with residual in the 1st excited state.	
	…		
	…		
849	(z,α_c)	Production of an alpha particle in the continuum not included in the above discrete representation.	
850		(Unassigned)	
851-870		Lumped reaction covariances.	
871-874		(Unassigned)	
875	$(z,2n_0)$	Production of 2 neutrons with residual in the ground state.	
876	$(z,2n_1$	Production of 2 neutrons with residual in the 1st excited state.	
	…		
891	$(z,2n_c)$	Production of 2 neutrons in the continuum not included in the above discrete representation.	
892-999		(Unassigned)	

LR Flags

Many reactions are sequential in nature. That is, a particle or gamma ray may be emitted first, then the residual nucleus decays by one or more paths. Most often, the first stage of the reaction proceeds through a well-defined discrete state of the residual nucleus and the angular dependence of the first emitted particle must be uniquely described. A simple, two-body reaction is one in which the incident particle is inelastically scattered from the target nucleus leaving the target in an excited state, which immediately decays by gamma emission. Other excited states of the same target may, however, decay by particle emission, electron-positron pair formation, or internal conversion. It is often necessary to completely specify the reaction mechanism, in particular for isotopic depletion and/or build-up calculations.

The following numbers can be used as flags to indicate the mode of decay of the residual nucleus.

LR	Description
0 or blank	Simple reaction. Identity of product is implicit in MT. Only gamma rays may be emitted additionally.
1	Complex or breakup reaction. The identity and multiplicity of all products are given explicitly in File 6.
22	α emitted (plus residual, if any).
23	3α emitted (plus residual, if any).
24	$n\alpha$ emitted (plus residual, if any).
25	$2n\alpha$ emitted (plus residual, if any).
28	p emitted (plus residual, if any).
29	2α emitted (plus residual, if any).
30	$n2\alpha$ emitted (plus residual, if any).
31	Residual nucleus decays only by gamma emission.
32	d emitted (plus residual, if any).
33	t emitted (plus residual, if any).
34	^3He emitted (plus residual, if any).
35	$d2\alpha$ emitted (plus residual, if any).
36	$t2\alpha$ emitted (plus residual, if any).
39	Internal conversion.
40	Electron-positron pair formation.

Examples

1. $T(d,\gamma)^5He^*(16.39)$ MeV MT=102 LR=24 (^5He decays via $n+\alpha$)
2. $^7Li(n,n')^7Li^*$ (0.48 MeV) MT=51 LR=31 (Residual decays by γ emission)
3. $^7Li(n,n')^7Li^*$ (4.63 MeV) MT=52 LR=33 ($^7Li^*$ decays via $t+\alpha$)

SUMMARY

Version 6 formats and procedures are recommended for all new evaluations. Version 6 format is the only format allowed for incident charged particles. It must be taken into account, however, that many version 5 materials for incident neutrons will be carried over without technical changes to the data.

A few files and several MT numbers are defined for the first time for version 6. A few MT numbers allowed for 5 have now been removed and must be replaced. Other MT numbers are allowed only in version 5 and these are ***not*** defined here--the reader is referred to the version 5 manual. Many MT numbers above the 600 series are redefined for 6 and all version 5 materials must be changed accordingly prior to reissue.

A few of the MT numbers are not defined for certain particles incident: for example, MT=1 is not defined for incident charged particles: MT=50 is not defined for incident neutrons: MT=600 is not defined for incident protons; etc. These exceptions are labeled but should be obvious if one follows the explicit definitions closely.

Several MT numbers cannot be used with File 4 or 5; other MT numbers must have a File 6 (File 4 and 5 are not allowed). The changes between previous format manuals are significant, therefore, much effort has been expended to explicitly define the MT numbers for version 6 and, hopefully to associate them with the proper files. For explicit information on usage, see Sections 0.0, 3.4, and 3.5.