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ENDL Transmittal Format

Brief Summary

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Abstract:

The LLNL Evaluated Neutron Data Library of 1982 (ENDL-82) and the LLNL Evaluated Charged Particle Library (ECPL-86) are available in the ENDL Transmittal Format, of which a brief user's guide is given in this document.

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Introduction

The Evaluated Neutron Data Library of 1982 (ENDL-82) and the Evaluated Charged Particle Library (ECPL-86) of the Lawrence Livermore National Laboratory (LLNL), USA, are available in the ENDL Transmittal Format. This is documented in:

> R.J. Howerton, R.E. Dye, S.T. Perkins: Evaluated Nuclear Data Library, report UCRL-50400 vol. 4, Rev. 1, 8 Oct. 1981.

This is summarized on the following pages which will be sufficient for data users to read the data.

In 1984, an ENDF/B-V formatted version of the ENDL-82 library was made available (ENDL-84/V, see document IAEA-NDS-11, Rev. 4). The contents of the two libraries is, however, not identical because the conversion from the Livermore internal format to ENDF/B creates some problems. The present "ENDL Transmittal Format"

- has the advantage that it permits to include several data types that are not defined in the ENDF/B format,

- but has the disadvantage that data processing computer codes are not available in the same way as they are for ENDF/B. Nevertheless, a large fraction of the data is presented in the same structure as ENDF/B data, so that computer processing of the data will not be impossible.

Therefore the ENDL-84/V library does not supersede the ENDL-82 library; they rather complement each other for use in a variety of applications.

The charged particle library ECPL-86 (see document IAEA-NDS-56, Rev. 1) is available only in the ENDL Transmittal Format. In the 1986 version some new "Reaction Identifiers" not yet defined in UCRL-50400, Vol. 4, Rev. 1 (1981) are used which are included on pages 4-6 of the present document.

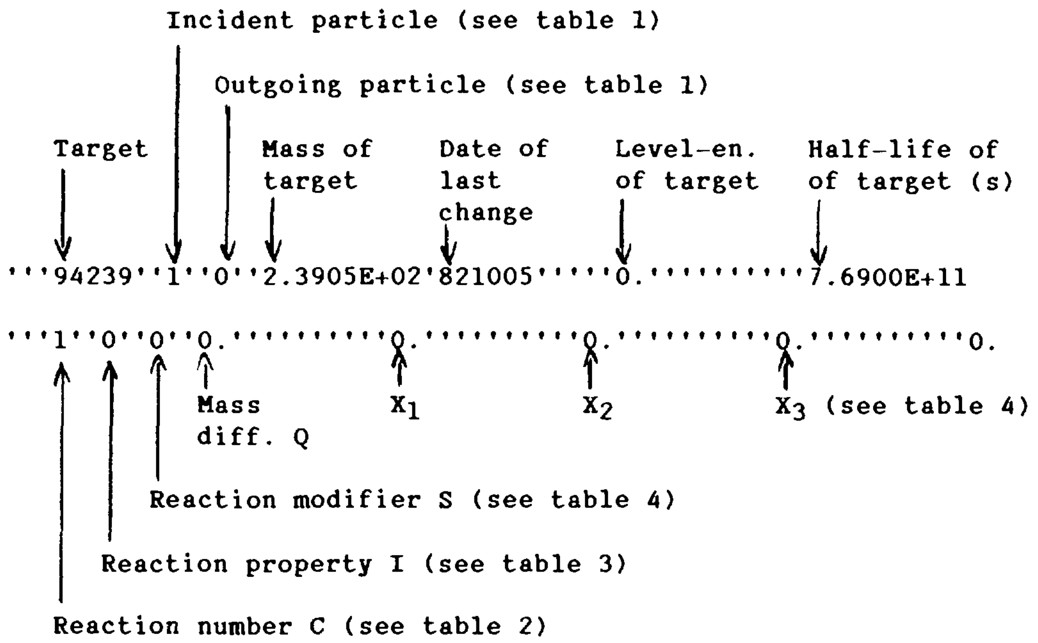
ENDL Transmittal Format:

Some characteristics

Record length:	80 characters.
Data format:	E11.4, plus some integers in the header records.
Energies in:	MeV, cross sections in barns.
Interpolation:	linear-linear (except for photon cross-sections).

The data definition for a given data table section is expressed by a set of integers defining the target, the incident particle, the outgoing particle for which a property is given, and the reaction which is further specified by "property" and "modifier". A data table section is identified by two header records containing the data definition and some parameters, and by an end-of-data record at the end.

Example of header records (records 1 and 2):



Record 3: Count of data points following, as specified further below

Data record (= record 4 and following): see further below

End-of-data record: Blank except '1' in col. 72. This record indicates the end of data for a given data-type within the evaluation for a given target nucleus. There is no specific flag for the end of the evaluation for a given target nucleus. One must search for a '1' in col. 72 and see what nuclide is given in field 1 of the following record.

TABLE 1. Particle designator, y.[a]

y	Particle
0	Not applicable[b] or none
1	n
2	p
3	d
4	t
5	^3He
6	α
7	γ
8	β^+
9	β^-
10	EC
11	n as residual nucleus
12	p as residual nucleus
13	d as residual nucleus
14	t as residual nucleus
15	^3He as residual nucleus
16	α as residual nucleus

[a]Used to identify both the incident particle, y_i, and the outgoing particle, y_o, to whcih any distribution data (e.g., energy, angle) pertain: y_i = 0 - 7 only; y_o = 0 - 16.

[b]If no property (e.g., energy distribution) is given, the y_o is zero or left blank in input. If y_i is zero or blank, the data that follow are nuclear structure data.

TABLE 2. Reaction identifier C, for I-values of 0 through 98.

Kind of data	C	Reaction type
Miscellaneous	1	Total[a]
	2-7	Unassigned
	8	Large-angle coulomb scattering
	9	Nuclear elastic plus interference
	10	Elastic
Nuetrons + gammas only	11	$(y_i, n'\gamma)$
	12	$(y_i, 2n\gamma)$
	13	$(y_i, 3n\gamma)$
	14	$(y_i, 4n\gamma)$
	15	(y_i, Xf) total fission
	16-19	Unassigned
Neutrons + charged particles + gammas	20	$(y_i, n'p\gamma)$
	21	$(y_i, pn'\gamma)$
	22	$(y_i, n'd\gamma)$
	23	$[y_i, n'd\alpha(\alpha)]$
	24	$(y_i, n't\gamma)$
	25	$(y_i, n'\,^3He\gamma)$
	26	$(y_i, n'\alpha\gamma)$
	27	$[y_i, n'2\alpha(\alpha)]$
	28	$[y_i, n't\alpha(\alpha)]$
	29	$(y_i, 2np)$
	30	$(y_i, \gamma n\alpha)$
	31	$[y_i, 2n\alpha(\alpha)]$
	32	Unassigned
	33	$(y_i, 2n\alpha)$
	34	$(y_i, np\alpha)$
	35-36	Unassigned
Charged particle and/or gamma formation	37	$[y_i, 2\alpha(\alpha)]$
	38	$[y_i, ^3He\alpha(\alpha)]$
	39	$[y_i, pt(\alpha)]$
	40	$(y_i, p\gamma)$

TABLE 2. (Continued)

Kind of data	C	Reaction type
	41	$(y_i,d\gamma)$
	42	$(y_i,t\gamma)$
	43	$[y_i,t\alpha(\alpha)]$
	44	$(y_i,{}^3He\gamma)$
	45	$(y_i,\alpha\gamma)$
	46	(y_i,γ)
	47	$(y_i,d\alpha\gamma)$
	48	$(y_i,p\alpha\gamma)$
	49	Unassigned
Particle or gamma production	50	(y_i,Xp)
	51	(y_i,Xd)
	53	$(y_i,X{}^3He)$
	54	$(y_i,X\alpha)$
	55	$(y_i,X\gamma)$
	56	(y_i,Xn)
	57	$(y_i,X\beta^-)$
	58-64	Unassigned
	65	Activation (undefined reaction)
	66-69	Unassigned
Photon interaction with cold material	70	Total[a]
	71	Coherent scattering
	72	Incoherent scattering
	73	Photoelectric
	74	Pair production
	75-79	Unassigned
	80-98	Unassigned

[a]Not stored in the system but obtained for output display and transmission format by combining other data.

TABLE 3. Reaction property designator, I.[a]

I	Reaction property	Definition
0	Integrated cross sections (b)	$\sigma(E)$
1	Angular distributions, normalized probabilities (per unit cosine)[b]	$P(E,\mu)$
4	Energy-angle distributions, normalized Legendre coefficients. $\pi^0(E \rightarrow E') = p(E \rightarrow E')$, the usual normalized energy probability (per MeV)	$\pi^\ell(E \rightarrow E')$
7	Average number of neutrons per fission (prompt or delayed)	$\nu(E)$
8	Histogram form of energy distribution (MeV)	$\int P(E,E')dE'$
9	Photon or particle multiplicity	$M(E)$
10	Average energy of a secondary particle (MeV)	$\bar{E}'(y_o,E)$
11	Average energy of a residual nucleus (MeV)	$\bar{E}'(R,E)$
80	Maxwell average reaction rates (b-cm/sh)	$\overline{\sigma v}(kT)$
81	In-flight (Doppler-broadened) cross sections (b)	$\sigma(kT,E)$
84	Maxwell-averaged energy distributions (per MeV)	$P(kT,E')$
89	Mult. from therm.react.	
90	Maxwell-averaged total average energy of particle (MeV)	$\overline{E'}(y_o,kT)$
91	Maxwell-averaged average energy of residual	$\overline{E'}(R,kT)$
92	Maxwell-averaged total average energy of reacting particles (MeV)	$\overline{E}(y_i,kT)$

[a]We illustrate the use of these designations by constructing a reaction code for the energy distribtuion of protons from the $^{58}Ni(n,n'p)^{57}Co$ reaction:

Incident particle:	y_i = 01 (neutron)
Reaction property:	I = 04 (energy dist.)
Reaction type:	C = 20 (n,n'p)
Outgoing particle whose property is recorded:	y_o = 02 (proton)
Reaction modifier:	S = 00 (no x-field data)
QO of reaction:	QO = -8.02

This gives for the reaction code

y_i	I	C	y_o	S	QO	X_1
01	04	20	02	00	-8.02	0.0.

[b]Angular data are expressed in the center-of-mass (cm) system for all two-body breakups. Multibody breakups are, of course, in the Laboratory system.

TABLE 4. Reaction modifier, S.

S	Reaction parameter	X field definition
00 or blank	No X-field data	--
01[a]	Level excitation	W_i(MeV)
02	2nd particle from time sequential reaction	W_i(MeV)
03	Gamma-ray production	E_γ(MeV)
05[b]	Activation	$(ZA)_2$, W_2(MeV), half-life (s)
07	Delayed group half-lives	$\tau_{1/2}$(s)
08	Completely correlated n,2n	W_1(MeV)
10	Wide level excitation	W_1(MeV), Γ_1(MeV)
11	Second particle from wide level time-sequential reaction	W_2(MeV), Γ_2(MeV)
13[c]	Photon production from known level excitations	W_1(MeV), E_γ(MeV)

[a] X_1 corresponds to the initial nucleus, X_2 to the second nucleus in a sequence of de-excitations, etc.

[b] $(ZA)_2 = 1000*Z_2 + A_2$ of product nucleus.

[c] W_1 corresponds to the level excitation energy, and E_γ is the energy of the photon.

TABLE 5. Field definitions for input data (4E11.4 format with one set of data per record).[a]

		Data stored in field			
Reaction property	I	1	2	3	4
Integrated cross sections	0	E	$\sigma(E)$	--	--
Angular distributions	1	E	μ	$P(E,\mu)$	--
Energy-angle Legendre coefficients	4	E	E'	ℓ	$\pi^{\ell}(E \to E')$
Nu-bar	7	E	$\nu(E)$	--	--
Histogram energy	8	E	$E'1$	$\int_{E'_1}^{E'_2} P(E,E')dE'$	--
Gamma-ray multiplicity	9	E	$M(E)$	--	--
Total average energy of particle	10	E	$E'(y_o,E)$	--	--
Average energy of residual	11	E	$E'(R,E)$	--	--
Maxwell-averaged reaction rates	80	kT	$\sigma v(kT)$	--	--
In-flight cross sections	81	kT	E	$\sigma(kT,E)$	--
Maxwell-averaged energy distributions	84	kT	E'	$P(kT,E')$	--
Maxwell-averaged total average energy of particle	90	kT	$\bar{E}'(y_o,kT)$	--	--
Maxwell-averaged average energy of residual	91	kT	$\bar{E}'(R,kT)$	--	--

TABLE 5. (Continued)

Reaction property	I	Data stored in field 1	2	3	4
Maxwell-averaged total average energy of reacting particles	92	kT	$\overline{E}(y_i,kT)$	--	--

[a]For certain applications, it is desirable to combine all reactions leading to a specific residual nucleus. Provision for such "activation" cross sections is made. For example, the (n,n'd) and (n,t) reactions both lead to the same residual nucleus, and the sum of the cross sections for these reactions <u>may</u> be entered, as with the following example:

^{70}Zn(n,n'd + n,t)^{68}Cu to the ground state with a half-life of 32 s.
Incident particle: y_i = 01
Reaction property: I = 00 (integrated cross section).
Reaction type: C = 65 (activation).

Outgoing particle whose property is recorded:
y_o = 00 (not applicable since no property of a secondary particle is given).

Reaction modifier:
S = 05 (activation).

Z_2A_2:
Z_2A_2 = 29068. (X_1 field).

W_2:
w_2 = 0. (X_2 field).

τ_2:
τ_2 = 32. (X_3 field).

For the reaction code this gives

y_i	I	C	y_o	S	QO	X_1	X_2	X_3
01	00	65	00	05		29068.	0.	32.

Data records

Case 1: ====== <u>Cross-sections</u> and other data as function of energy (I = 0, 7, 9, 10, 11, 80, 90, 91, 92)

Record 3: Count of data points, e.g. pairs of energy/cross-section values

Record 4 and following:
Three pairs per record (6 E11.4) of independent/dependent variables, as in ENDF/B.

Case 2: ====== <u>Angular distributions</u> and other data having a second independent variable (= <u>parameter</u>)

Record 3: Count of values of the parameter.
The parameter is
- the incident energy when I = 1,8
- kT when I = 81, 84

Record 4: Field 1: first value of the parameter
Field 2: count of data points for this parameter value

Record 5 and following:
Three pairs per record of independent/dependent variables

Then: Records 4, 5 and following correspondingly for each further value of the parameter

Note: Angular data are expressed in the center-of-mass system for all two-body breakups. Multibody breakups are in the laboratory system.

Case 3: ====== <u>Energy-angle distributions</u> (I=4), normalized Legendre coefficients ℓ (E → E')

Record 3: Count of values of ℓ (usually one value only)

Record 4: Field 1: first value of ℓ (usually ℓ=0 only)
Field 2: count of incident energies for this value of ℓ

Record 5: Field 1, first value of incident energy
Field 2,
count of data (= pairs of secondary energy/coefficient) to follow

Record 6 and following:
Three pairs per record of secondary energy/coefficient

Then: Records 5, 6 and following correspondingly for each further value of incident energy

Then: eventually data for the second value of ℓ; however, usually only the zero term is given.

APPENDIX A

TRANSMITTAL FORMAT

The various data files maintained at LLNL are available on magnetic tape, upon request from the National Nuclear Data Center, Brookhaven National Laboratory; the Radiation Shielding Information Center, Oak Ridge National Laboratory; and the Nuclear Data Section, International Atomic Energy Agency, Vienna, Austria. Because no other existing format makes provision for all the properties that are part of the LLNL data files, a transmittal format has been developed that is simple and closely related to the input format for the updating code described in Tables 6 and 7. The record layout for the first two records of each set of data is given in Table A-1. These first two records are called the header records. The records that follow the header records are appropriately called the data records, and the layout used for the

TABLE A-1. Field definitions for header records.

	Columns	Format	Name	Description
Record 1	1-6	I6	ZA	1000Z + A.
	8-9	I2	y_i[a]	Incident particle descriptor.
	11-12	I2	y_o[a]	Outgoing particle descriptor.
	14-24	E11.4	A	Atomic mass for this ZA (amu).
	26-31	I6	DATE	Date last changed.
	36-46	E11.4		Level energy of the target (MeV).
	48-58	E11.4		Half-life of the target (s).
Record 2	1-2	I2	C[a]	Reaction number.
	3-5	I3	I[a]	Reaction property designator.
	6-8	I3	S[a]	Reaction modifier flag.
	10-20	E11.4	QO[a]	Mass difference Q for the reaction.
	22-32	E11.4	X_1[a]	Value depends upon the value of S.
	34-44	E11.4	X_2[a]	Value depends upon the value of S.
	46-56	E11.4	X_3[a]	Value depends upon the value of S.

[a] A more complete definition of these fields can be found in Tables 2-5.

data records is a function of the reaction property ("I-value") described in the second of the two header records. Only three types of layouts, or organizations, are required to handle the data for the 11 I-values defined in Table 3.

All numbers in the data records are in floating-point format, in particular, E11.4 format. Following the data records is an end-of-data record that is blank except for a 1 in column 72. This facilitates skipping unneeded data, if it is desirable to do so, by reading over a set of data until the end-of-data record is encountered. Each read-command following the two header records may be done with a 6E11.4, 5x, il format.

For I = 0, 7, 9, 10, 11, 80, 90, 91, and 92, the first data record gives the number of pairs of independent/dependent variables to follow. The significance of the independent and dependent variables is given in Table 6 for each I-value.

For I = 1, 8, 81, and 84, the first record gives the number of values of the factorable parameter (incident particle energy for I = 1, 8; kT for I = 81, 84). The following data records are given in sets, with the number of sets equal to the value given in the first-record described above. Each set has a first record that gives the value of the parameter (E or kT), followed by the number of pairs of independent/dependent variables, which are defined in Table 6 for each I-value.

For I = 4 there are two parameters (ℓ and E). The first data record gives the number of ℓ-values (sets of Legendre polynominal coefficients) that follow. For each set of coefficients, the first record gives the order of ℓ, followed by the number of incident-particle energies for which secondary-energy/coefficient pairs are given. For each incident-particle energy there is a record that gives the incident-particle energy and the number of pairs of secondary-energy/coefficient pairs that follow. The remainig data for that subset are the secondary-energy/coefficient values for that order of Legendre polynominals and that incident-particle energy.

Tables A-2, A-3, and A-4 give a shcematic for the three I-value-dependent layouts.

TABLE A-2. Field definitions for I = 0, 7, 9, 10, 11, 80, 90, 91, 92.

Record	
1	First header record, see Table A-1.
2	Second header record, see Table A-1.
3	Number of pairs of independent/dependent variables, e.g., energy/cross section (E11.4).
4 et seq.	Three pairs per record (6E11.4) of independent/dependent variables.
Last	End-of-data record (1 in column 72).

TABLE A-3. Field definitions for I = 1, 8, 81, 84.

Record	
1	First header record, see Table A-1.
2	Second header record, see Table A-1.
3	Number of values of the factorable parameter (NF) (E11.4). (E for I = 1, 8, kT = for I = 81, 84).
4[a]	Value of the factorable parameter, number of pairs of independent/dependent variables that follows (2E11.4).
5 et seq.[a]	Three pairs per record (6E11.4) of independent/dependent variables [e.g., for I = 1, ?, P(E,μ)].
Last	End-of-data record (1 in column 72).

[a]Repeated NF times.

TABLE A-4. Field definitions for I = 4.

Record	
1	First header record, see Table A-1.
2	Second header record, see Table A-1.
3	Number of values of ℓ (E11.4), NL.
4[a]	Value of ℓ, number of incident energies for this ℓ (2E11.4), NE.
5[b]	Incident energy; number of secondary energy coefficients to follow (2E11.4).
6 et seq.[b]	Three pairs per record of secondary energies and coefficients (6E11.4).
Last	End-of-data record (1 in column 72).

[a]Repeated NF times.
[b]Repeated NE times.