EPICS Formats and Content

The Electron Photon Interaction Cross Sections, EPICS, provides the atomic data needed to perform coupled Electron-Photon transport calculations, to produce accurate macroscopic results, such as energy deposit and dose. Atomic data is provided for elements, Z = 1 to 100, over the energy range 10 eV to 100 GeV; note that nuclear data, such as photo-nuclear, and data for compounds, are not included. The data are in a simple computer independent text format that is standard and presented to a high precision that can be easily read by computer codes written in any computer language, e.g., C, C++, and FORTRAN. EPICS2017 include three separate data bases that are designed to be used in combination, these include,

1) **The Evaluated Electron Data Library (EEDL),** to describe the interaction of electrons with matter [3].
2) **The Evaluated Photon Data Library (EPDL)**, to describe the interaction of photons with matter [1, 2].
3) **The Evaluated Atomic Data Library (EADL)**, to describe the emission of electrons and photons back to neutrality following an ionizing event, caused by either electron or photon interactions [8]

These are available in the Extended ENDL [9] format (ENDLX) in which the evaluations were originally performed, as well as in the ENDF format [4].

ENDF Format

The ENDF format is documented in ENDF-102 [5], and as such will not be described here. Here I will only suggest that you read refs. [6, 7]; these address standardizing and precision of data in the ENDF format, and how to guarantee that the data you use meets these criteria. **You can be assured that ALL of the EPICS2014 in the ENDF format meet these criteria.**

Extended ENDL Format (ENDLX)

Generally, the two header lines in the ENDL format contain a great deal of information. However, as applied to the EPICS atomic data the only fields of interest are as shown in the below table. For the definition of these quantities see ref. [9].

Header Line Formats for the EPICS Data Files

Line	Columns	Format	Definition
1	1-3	I3	Z - atomic number
1	4-6	I3	A - mass number (in all cases=0, for elemental data)
1	8-9	I2	Yi - incident particle designator
1	11-12	I2	Yo - outgoing particle designator
1	14-24	D11.4	AW - atomic mass (amu)
1	26-31	I6	Date - date of evaluation (YYMMDD)
1	32	I1	Iflag - interpolation flag =0 or 2, linear in x and y =3, logarithmic in x, linear in y =4, linear in x, logarithmic in y =5, logarithmic in x and y
2	1-2	I2	C - reaction descriptor
2	3-5	I3	I - reaction property
2	6-8	I3	S - reaction modifier
2	22-32	D11.4	X1 - subshell designator

The only differences between the standard and Extended ENDL format (ENDLX) are the header information is now in standard format and the data table uses D16.9, rather than D11.4 format; the objective is to assure the data is in a standard, high precision format that can easily be read using any computer language. **You can be assured that ALL of the EPICS2014 in the Extended ENDL format (ENDLX) meet these criteria.**

You might wonder why the ENDF format using 11 column fields is adequate, whereas ENDLX requires 16 column fields. **The simple answer is that ENDF defines energy in eV, whereas ENDL/ENDLX defines the energy in MeV.** Consider that in the ENDF 11 column format virtually all energies in EPICS in eV can be defined to nine (‘ 1.23456789’) or even ten (‘1.234567891’) digits accuracy. Unfortunately, in MeV these numbers would be truncated and rounded to (‘ 1.2346D-06’) on some computers, or even worse (‘ 0.1234D-05’) on other computers. For narrow neutron resonances this truncation and rounding would be disastrous. For atomic data it is also unacceptable if we are to maintain the accuracy of 6-digit binding energies for high-Z elements.

Example of the Same Data in Original and Extended ENDL Formatted (ENDLX) Data

Original

```
  1000  7  0  1.007970+0 9707045 2  0.0          0.0          0.0
71  0  0  0.0          0.0          0.0          0.0          0.0
 1.000000-6 9.887553-6
 1.059784-6 1.235246-5
 1.126020-6 1.538627-5
 1.196396-6 1.933495-5
 1.271171-6 2.449127-5
 1.350619-6 3.121326-5
 1.392826-6 3.537646-5
 1.481238-6 4.569015-5
 1.575262-6 5.929956-5
 1.727606-6 8.834929-5
 1.894683-6 1.326150-4
```

Extended

```
  1000  7  0  1.00797    9707045 2  0.0          0.0          0.0
71  0  0  0.0          0.0          0.0          0.0          0.0
 1.000000000D-06 9.887553000D-06
 1.059784000D-06 1.235246000D-05
 1.126020000D-06 1.538627000D-05
 1.196396000D-06 1.933495000D-05
 1.271171000D-06 2.449127000D-05
 1.350619000D-06 3.121326000D-05
 1.392826000D-06 3.537646000D-05
 1.481238000D-06 4.569015000D-05
 1.575262000D-06 5.929956000D-05
 1.727606000D-06 8.834929000D-05
 1.894683000D-06 1.326150000D-04
```

Note that the “E-less” floating point form (e.g. **`1.007970+0`)** is not used in the Extended ENDL format (ENDLX). This means that ALL of the Extended ENDL (ENDLX) data is in a standard format that can easily be read by C, C++, and FORMAT codes.

References

[1] D.E. Cullen, et al., "Tables and Graphs of Photon-Interaction Cross Sections from 10 eV to 100 GeV Derived from the LLNL Evaluated Photon Data Library (**EPDL**), UCRL-50400, Vol. 6, Rev. 4, Part A: Z = 1 to 50, Part B: Z=51 to 100, October 1989, Lawrence Livermore National Laboratory.

[2] D.E. Cullen, “**EPDL**97: the Evaluated Photon Data Library, '97 Version," Lawrence Livermore National Laboratory, UCRL--50400, Vol. 6, Rev. 5, September 1997.

[3] D.E. Cullen, S.T. Perkins and S.M. Seltzer, "Tables and Graphs of Electron Interaction Cross 10 eV to 100 GeV Derived from the LLNL Evaluated Electron Data Library (**EEDL**), Z = 1 - 100", Lawrence Livermore National Laboratory, UCRL-50400, Vol. 31, November 1991.

[4] M.B. Chadwick et al. “ENDF/B-VII.1 Nuclear Data for Science and Technology: Cross Sections, Covariances, Fission Product Yields and Decay Data”, Nuclear Data Sheets 112 (2011), pp. 2887-2996.

[5] A.Trkov, M. Herman and D.A. Brown “ENDF-6 Formats Manual: Data Formats and Procedures for the Evaluated Nuclear Data Files, ENDF/B-VI and ENDF/B-VII”, CSEWG Document **ENDF-102**, Report BNL-90365-2009 Rev. 2, December 2011, Brookhaven National Laboratory.

[6] D.E.Cullen, “How Accurate Are Our Processed ENDF Cross Sections?” INDC(NDS)-0666, Distr, J, Nuclear Data Section, IAEA, Vienna, Austria, May 2014.

[7] D.E. Cullen, PROGRAM **ENDF2C**: Convert ENDF Data to Standard FORTRAN, C and C++ Format (Version 2014-1), IAEA-NDS-217, Nuclear Data Section, IAEA, Vienna, Austria, April 2014.

[8] D.E. Cullen, etal, "Tables and Graphs of Atomic Subshell and Relaxation Data Derived from the LLNL Evaluated Atomic Data Library (EADL), Z = 1 - 100", Lawrence Livermore National Laboratory, UCRL-50400, Vol. 30, October 1991.

[9] D.E. Cullen, “ENDL Type Formats for the LLNL Evaluated Atomic Data Library (**EADL**), Evaluated Electron Data Library (**EEDL**), and Evaluated Photon Data Library (**EPDL**)”, Lawrence Livermore National Laboratory, UCRL-ID-117796, Rev. 1, May 2002.