13. FILE 13. PHOTON PRODUCTION CROSS SECTION

The purpose of File 13 is the same as that of File 12, namely, it can be used to represent the neutron and photon energy dependence of photon production cross sections. In File 13, however, absolute cross sections in barns are tabulated, and there is no need to refer to the neutron files.

13.1. Formats

As in File 12, each section in File 13 gives information for a particular reaction type (MT number). Each section always starts with a HEAD record and ends with a SEND record.

The representation of the energy dependence of the cross sections is accomplished by tabulating a set of neutron energy-cross section pairs $\{E,\sigma_k^{\gamma}(E)\}$ for each discrete photon and for the photon energy continuum. The subscript k designates a particular discrete photon or the photon continuum, and the total number of such sets in NK. For discrete photons, $\sigma_k^{\gamma}(E)$ is the photon production cross section (b) for the photon designated by k. For the photon continuum, $\sigma_k^{\gamma}(E)$ is the integrated (over photon energy) cross section for the photon continuum[1] designated by k. In the continuum case,

$$\sigma_k^{\gamma}\left(E\right)=\int_0^{E_{\gamma}^{\max}}\frac{d\sigma_k^{\gamma}}{dE\gamma}\left(E_{\gamma}\leftarrow E\right)dE_{\gamma}\quad\text{(barns)}\tag{13.1}$$

where E_γ designates photon energy (eV), and $d\sigma_k^{\gamma}/dE_\gamma$ $(E_\gamma\leftarrow E)$ is the absolute photon energy distribution in b/eV. The energy distribution can be further broken down as

$$\frac{d\sigma_k^{\gamma}}{dE_{\gamma}}\left(E_{\gamma}\leftarrow E\right)=\sigma_k^{\gamma}\left(E\right)f_k\left(E_{\gamma}\leftarrow E\right),\tag{13.2}$$

which obviously requires that

$$\int_0^{E_{\gamma}^{\max}}f_k\left(E_{\gamma}\leftarrow E\right)dE_{\gamma}=1.$$

Any time a continuum representation is used for a given MT number in File 13, the normalized energy distribution, $f_k(E_\gamma\leftarrow E)$, must be given in File 15 under the same MT number.

As a check quantity, the total photon production cross section,

$$\sigma_{tot}^{\gamma}\left(E\right)=\sum_{k=1}^{NK}\sigma_k^{\gamma}\left(E\right)\quad\text{(barns)},\tag{13.3}$$

is also tabulated for each MT number, unless only one subsection is present (*i.e.*, NK=1).

The following quantities are defined.

NK	Number of discrete photons including the continuum.
ES_k	Energy of the level from which the photon originates. If the level is unknown or if a continuous photon spectrum is produced, then $ES_k\equiv0.0$ should be used.
EG_k	Photon energy for LP=0 or 1 or Binding Energy for LP=2. For a continuous photon energy distribution, $EG_k=0.0$ should be used.

[1] There should be no more than one energy continuum for each MT number used. If the decomposition of a continuum into several parts is desired, this can be accomplished in File 15.

LP Indicates whether or not the particular photon is a primary:
LP=0, origin of photons is not designated or not known, and the photon energy is EG_k;
LP=1, for non-primary photons where the photon energy is again simply Eg_k;

$$EG'_k = EG_k + \frac{AWR}{AWR+1} E_n$$

LP=2, for primary photons where the photon energy EG'_k is given by

LF Photon energy distribution law number, which presently has only two values defined:
LF=1, a normalized tabulated function (in File 15), and
LF=2, a discrete photon energy.

The structure of a section in File 13 is

```
[MAT, 13, MT/  ZA,  AWR,   0,   0,  NK,   0] HEAD
[MAT, 13, MT/ 0.0,  0.0,   0,   0,  NR,  NP/ E_int / σ_tot^γ (E)] TAB1 [2]
          <subsection for k=1>
          <subsection for k=2>
          <subsection for k=NK>
[MAT, 13,  0/ 0.0,  0.0,   0,   0,   0,   0] SEND
```

and the structure of each subsection is

```
[MAT, 13, MT/  Eg_k,  Es_k,  LP,  LF,  NR,  NP/ E_int / σ_k^γ(E)] TAB1,
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13.2. Procedures

1. The subsections are given in decreasing magnitude of EG_k.
2. The convention is that the subsection for the continuum photons, if present, is last. In this case, $EG_{NK} \equiv 0.0$.
3. The values of EG_k should be consistent to within four significant figures with the corresponding EG_k values in File 14.
4. ES_k is the energy of the level from which the photon originates, if known. Otherwise $ES_k \equiv 0.0$.
5. If capture and fission resonance parameters are given in File 2, the corresponding photon production should be given by using Option 1 of File 12, instead of using photon production cross sections.
6. The total photon production cross section table, $\sigma_{tot}^{\gamma}(E)$ should exactly span the same energy range as the combined energy range of all the $\sigma_k^{\gamma}(E)$. Within that range,

$$\sigma_{tot}^{\gamma}(E) = \sum_{k=1}^{NK} \sigma_k^{\gamma}(E)$$

should hold within four significant figures. If only one energy distribution is given, either discrete or continuous (NK=1), the TAB1 record for the $\sigma_{tot}^{\gamma}(E)$ is deleted.

[2] If the total number of discrete photons and photon continua is one (NK=1), this TAB1 record is omitted.

7. The join of all sections in File 12 and 13 combined should represent the photon production data with no redundancy. For example, MT=4 cannot include any photons given elsewhere under MT=51 through 91.
8. The limit on the number of energy points in a tabulation for any photon production subsection is 1000. This is an upper limit; in practice, the minimum number of points possible should be used. If there is extensive structure, the use of File 12 should be seriously considered, because yields are normally much smoother functions of incident neutron energy than cross sections.
9. The limit on the number of interpolation regions is 10.
10. Tabulations of non-threshold data should normally cover at least the energy range 10^{-5} eV $\leq$ E $\leq$ 2×10^{7} eV, where practical. Threshold data should be given from threshold energy up to $2\text{x}10^{7}$ eV, where practical.

13.3. Preferred Representations

1. The recommended representation for (n,n′γ) reactions is photon production cross section (File 13) using MT=4. All discrete and continuum γ rays are given in a series of subsections.
2. Photon production cross sections resemble the frequently measured or reported results.
3. The use of MT=4 eliminates confusion about whether the data represent an excitation or de-excitation cross section (see File 11).
4. If for any reason MT=51,52 ... is used, it is understood that these data represent de-excitation and not excitation cross sections (see 3 above). MT=51, 52, ... in File 3, of course, means excitation cross sections.
5. Combined use of MT=4 and MT=51, 52, ... is not allowed.
6. Above a certain energy point it probably will not be possible to separate the various components of the total γ production cross section. When this happens, it is preferred that the data be given as MT=3.
7. All other reactions. Data for other reactions should be given as photon production cross sections (File 13) using the appropriate MT numbers. The same general rule outlined above should be used.