10. FILE 10. CROSS SECTIONS FOR PRODUCTION OF RADIOACTIVE NUCLIDES

10.1. General Description

Neutron activation cross sections [such as the (n,p) and (n,2n) cross sections] and cross sections for a particular state of a radioactive target are given in File 10. These cross sections are given as a function of energy, E, where E is the incident particle or photon energy (in eV) in the laboratory system. They are given as energy-cross-section pairs. An interpolation scheme must specify the energy variation of the data for energies between a given energy point and the next higher energy point.

File 10 is divided into sections, each section containing the data for a particular reaction type (MT number). The sections are ordered by increasing MT number. Within a section for a given MT are subsections for different final states (LFS) of the daughter product nucleus. File 10 is allowed only for evaluations that represent the data for single isotopes.

10.2 Formats

File 10 is made up of sections where each section gives the cross section for a particular reaction type (MT number). Each section always starts with a HEAD record and ends with a SEND record.

For File 10, the following quantities are defined:

LIS Indicator to specify the level number of the target.

LFS Indicator to specify the level number of the nuclide (ZAP) produced in the reaction (MT) number. LFS = 0 the final state is the ground state.
LFS = 1 the final state is the first excited state.
LFS = 2 the final state is the second excited state.

LFS = 98 an unspecified range of final states.

QM Mass-difference Q value (eV) defined as the mass of the target and projectile minus the mass of the residual nucleus in the ground state and masses of all other reaction products; that is, for $a+A \rightarrow b+c+...+B$, if the masses are in amu,
$QM = [(m_a+m_A) - (m_b+m_c+...+m_B)]\times(amu/eV)$[1]

QI Reaction Q value (eV) for the state described by the subsection.
For isomeric, states QI is defined as QM minus the residual excitation energy of the isomer.
For the ground state, QI=QM.

NS Number of final states for each MT for which cross sections are to be given.

NR Number of energy ranges. A different interpolation scheme may be given for each range. (NR≤20).

NP Total number of energy points used to specify the data (NP≤5,000)[2].

E_{int} Interpolation scheme for each energy range. (For details, see Section 0.4.3.)

σ(E) Cross section in barns for a particular reaction type at incident energy E(eV). Data are given for energy, cross-section pairs.

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[1] See Appendix H for conversion factor.
[2] 50,000 energy points are allowed for the total cross section.

The structure of a section is:

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[MAT, 10, MT/  ZA,  AWR, LIS,   0, NS,  0] HEAD
         <NS subsections, one for each value of LFS>
[MAT, 10,  0/ 0.0,  0.0,   0,   0,  0,  0] SEND
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The structure of a subsection is:

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[MAT, 10, MT/  QM,   QI,   0, LFS, NR, NP/ Eint / σ(E)] TAB1
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10.3. Procedures

Isomer production cross sections must be given in File 10 for those reactions described in MF=8 which have LMF=10 in the LIST record of the subsection for that particular MT number and value of LFS. The data in File 10 are the cross sections for the production of a final state (LFS) of the daughter product nucleus. For a reaction represented by resonance parameters in File 2, File 10 ***cannot*** be used; only multiplicities in File 6 or File 9 are allowed.

The data in File 10 must cover the entire energy range for each reaction from the threshold of the subsection in File 10 up to 20 MeV. That is, cross sections cannot be used over a portion of the incident neutron energy range with multiplicities covering another portion. For negative Q reactions, the first energy point should be at the threshold of the subsection in File 10 and the cross section at this point must be zero.

The set of points or energy mesh used for the total cross section in File 3 must be the union of all energy meshes in File 10 for each MT number. Although 10000 incident energy points are allowed for the total cross section, every attempt should be made to minimize the number of points in File 10.

Using the ^{93}Nb(n,2n)^{92}Nb cross section as an example, only the cross section for the production of the 10.16-day isomer in ^{92}Nb would appear under MT=16 with LIS=0 and LFS=1 in File 10. The sum of all partial cross sections for the (n,2n) reaction would still be found in File 3 under MT=16 [note that this is the only (n,2n) cross section required for neutron transport calculations]. It should be noted, however, in this particular case, that the evaluator would have the choice of using energy-dependent multiplicities in File 9 instead of cross sections in File 10.

The cross sections that appear in File 10 are redundant; that is, they should not be included in the check sum for the total cross section. The cross sections in File 10 must be equal to or less than the cross sections for that MT number that appears in File 3.

In summary, the proper procedure would be to not enter data in MF=8 and given MT ***until*** the File 10 cross sections (or File 9 multiplicities) are added to the evaluations. That is, every MT number (except MT=454, 457, or 459) with LMF=10 as an indicator in the LIST record of the subsection for that particular MT and value of LFS must have the corresponding cross sections in File 10.