9. FILE 9. MULTIPLICITIES FOR PRODUCTION OF RADIOACTIVE NUCLIDES

9.1. General Description

Neutron activation cross sections can be obtained by the use of multiplicities in File 9. The multiplicity represents that fraction of the cross section in File 3 that produces the LFS state in the daughter nucleus. The multiplicities are given as a function of energy, E, where E is the incident neutron energy (in eV) in the laboratory system. They are given as energy-multiplicity pairs. An interpolation scheme must be given to specify the energy variation of the data for incident energies between a given energy point and the next higher energy point. File 9 is divided into sections, each section containing 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 of the daughter product (LFS). File 9 is only allowed for evaluations that represent data for single nuclides.

9.2. Formats

File 9 is made up of sections where each section gives the multiplicity for a particular reaction type (MT number). Each section always starts with a HEAD record and ends with a SEND record. For File 9, 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 (ZA P) (as defined in MF=8) 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 $a+A \rightarrow b+c+\ldots + B$. 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 it is defined as QM minus the residual excitation energy of the isomer. For the ground state QI=QM.

ZAP 1000*Z+A for the product nucleus

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

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

NP Total number of energy points used to specify the data ($NP \leq 5000$)[2].

E_{int} Interpolation scheme for each energy range. (For details, see Section 0.6.2.)

Y(E) Multiplicity for a particular reaction type at incident energy E(eV). Data are given for energy-multiplicity 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, 9, MT/  ZA, AWR, LIS,   0,  NS,   0] HEAD
        <NS subsections, one for each value of LFS>
[MAT, 9,  0/ 0.0, 0.0,   0,   0,   0,   0] SEND
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The structure of a subsection is:

[MAT, 9, MT/ QM, QI, ZAP, LFS, NR, NP/ E_{int} / Y(E)] TAB1

9.3. Procedures

Multiplicities must be given in File 9 for those reactions described in MF=8 which have LMF=9 in the LIST record of the subsection for that particular MT number and value of LFS. The multiplicities in File 9 describe the fraction of the cross section that produces the LFS state in the daughter nucleus. For a reaction represented by resonance parameters in File 2, File 10 cannot be used; only multiplicities in File 9 are allowed.

The data in File 9 must cover the entire energy range for each reaction in File 3 from threshold to 20 MeV. That is, multiplicities cannot be used over a portion of the incident neutron energy range with cross sections covering another portion. For negative Q reactions, the first energy point should be at the threshold given in File 3. If a subsection QI is not equal to the QI in File 3, the multiplicity should be given as zero up to the energy point corresponding to the threshold of the subsection.

The set of points or energy mesh used for the total cross section in File 3 must include the union of all energy meshes in File 9 for each MT number. Although 50,000 incident energy points are allowed for the total cross section, every attempt should be made to minimize the number of points in File 9.

The multiplicities in File 9 should be equal to or less than unity since the cross sections to be generated must be equal to or less than the cross sections in File 3 for each MT number.

In summary, the proper procedure would be to not enter data in MF=8 and given MT ***until*** the File 9 multiplicities (or File l0 cross sections) are added to the evaluations. That is, every MT number (except MT=454, 457, or 459) in MF=8 with LMF=9 as an indicator in the LIST record of the subsection for that particular MT and value of LFS must have the corresponding multiplicities in File 9.