WORKING WITH 150-MeV EVALUATIONS: NJOY AND KERMA

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Abstract

New evaluations of neutron and proton data to 150 MeV will allow the accurate determination of radiation heating for several important applications. The NJOY Nuclear Data Processing System has been extended to convert these data into kerma factors for easy calculations of neutron heating. The results compare well with experimental kerma measurements.

Introduction

As new evaluations of neutron and proton data to 150 MeV become available from Los Alamos in support of accelerator-driven applications[1], it has been necessary to extend the NJOY Nuclear Data Processing System[2] in a number of ways. One set of extensions is designed to provide accurate kerma factors for the determination of radiation heating from neutrons. Heating is important in a variety of applications, including accelerator technologies and radiation therapy.

The kerma factor is proportional to the total energy emitted with secondary charged particles, including the residual nuclei. A full calculation of radiation heating would have to follow the slowing down of each particle in the medium, but when particle mean paths are fairly short, folding the kerma factor with the neutron fluence can provide a reasonably good approximation to the energy deposition (or "absorbed dose") by neutrons in matter. In addition, if total kerma factors derived from evaluated cross section data agree well with measurements, it helps to build confidence in the prediction of energy deposition by a transport code that uses these same data.

Kerma factors from ENDF below 20 MeV

Following the introduction of the ENDF-6 format, a number of evaluated nuclear data files that contain explicit information on the energies of emitted charged particles have become available. A processing code like NJOY can easily integrate these distributions, thus obtaining kerma factors that are directly traceable to the best judgment of the evaluator and that satisfy conservation of energy for all emitted radiations. However, even now, explicit charged-particle distributions are not available for many important materials. Thus, it is necessary to attempt to estimate emitted energies by using kinematics, rough estimates for reaction dynamics, or energy balance. The energy-balance approach takes advantage of the fact that many ENDF-format evaluations give
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explicit distributions for the emitted neutrons and photons. The energies needed for
the kerma factor can be obtained by subtracting the average emitted energies for the
neutrons and photons from the available energy (E+Q). This approach is used by the
HEATR module of NJOY. Unfortunately, this requires that extreme care be taken in
assuring energy balance in evaluations, and many current materials violate reasonable
limits on the kerma factor (for example, negative values are found). Negative kerma
factors may look absurd, but they serve to just cancel out the errors in the photon
heating for a large system.

**Kerma factors from ENDF above 20 MeV**

The new high-energy Los Alamos evaluated data libraries use GNASH model calcu-
lations, along with measured data, to extend existing ENDF/B-VI neutron libraries
from 20 MeV up to 150 MeV. Proton ENDF libraries from zero to 150 MeV have also
been generated with the GNASH code. These new evaluations use the File-6 format, in
which secondary inclusive emission spectra are represented. The evaluations allow total
neutron kerma factors to be determined unambiguously, because the emission spectra
of all secondary charged particles, including heavy recoils (A>4), are represented.

The light-particle ejectile (A≤4) angle-integrated spectra are represented in the
center-of-mass frame, as this is the natural frame from which the Kalbach angular
distribution systematics can be applied to determine angle-energy correlated emission
spectra. NJOY then performs a transformation into the lab frame to obtain the partial
kerma factors for the light particles. Lab-frame angle-integrated spectra are provided
for the heavy recoils by making use of a model recently developed for GNASH[3] that
facilitates the calculation of nonelastic recoil kerma factors. Finally, elastic recoil partial
kerma factors are determined from the neutron elastic scattering angular distributions
after having determined the P₁ component of a Legendre coefficient fit to the highly
forward-peaked distributions.

**Results and Comparison with Experiments**

In recent years, total kerma factors have been measured for a number of elements
(particularly those of importance in medical applications), allowing a test of evaluated
nuclear data and the NJOY processing methods. The measurements have been made
in two ways: direct determination of the ionization produced by the secondary charged
particles, and measurements of secondary charged-particle differential cross sections.
Both methods involve significant uncertainties; the latter, in particular, require extrap-
olations for data at unmeasured angles, energies (below detector thresholds), and for
elastic and nonelastic recoils, to determine the total kerma factor.

Figure 1 shows the total kerma factors determined by NJOY from the evaluated
ENDF data compared with measurements. The discontinuities seen at 20 MeV arise
because of the different evaluation methods used in the new high-energy evaluations
compared with the older <20 MeV evaluations. In general, the agreement is seen to
be good. For C and O, there is a tendency for the ENDF evaluations to overpredict
kerma factors in the 15-20 MeV range. The LAHET results shown were generated with
a special version using elastic cross sections from the new ENDF evaluation, and they
show reasonable agreement with the full calculation.
Figure 1: NJOY kerma factors compared with measurements[4]

References


