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Neutron-Photon Multigroup Cross Sections for Neutron Energies ≤400 MeV (Revision 1)*

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For a variety of applications, e.g., accelerator shielding design,[1] neutrons in radiotherapy,[2] radiation damage studies,[3] etc., it is necessary to carry out transport calculations involving medium-energy (≥20 MeV) neutrons. A previous paper[4] described neutron-photon multigroup cross sections in the ANISN[5] format for neutrons from thermal to 400 MeV. In the present paper the cross-section data presented previously have been revised to make them agree with available experimental data.

The elements considered (hydrogen, ^{10}B, ^{11}B, carbon, nitrogen, oxygen, sodium, magnesium, aluminum, silicon, sulfur, potassium, calcium, chromium, iron, nickel, tungsten, and lead) and the basic approximations used in developing the revised cross sections are the same as those reported in Ref. 4. There are, however, two substantive differences between the two data sets. First, except for sulfur and lead, the cross sections at neutron energies below 19.6 MeV are based on ENDF/B-V and a P_5 Legendre expansion, while below 14.9 MeV the old cross sections were based on ENDF/B-IV and used a P_3 Legendre expansion. Second, the elastic cross sections for neutron energies ≥19.6 MeV have been chosen so that the total, i.e., elastic + nonelastic, cross sections agree with experimental data. The elastic cross sections in the earlier data set were based on optical model calculations using global parameters and, as pointed out by V. Herrnberger,[6] this led to total cross sections that were not always in good agreement with experimental data.

Except for the elements sulfur and lead, new multigroup cross sections at neutron energies below 19.6 MeV have been obtained by collapsing the 174-neutron, 38-photon VITAMIN-E data library[7] which is based on ENDF/B-V. For the elements sulfur and lead, the cross sections at neutron energies $\leq$19.6 MeV are the same as those in the earlier data set and are therefore more approximate than the cross sections for the other elements considered here. The neutron energy group boundaries below 14.9 MeV and the photon energy group boundaries are the same in the two data sets except that one photon group has been added above 14 MeV.

At neutron energies $\geq$19.6 MeV, the multigroup cross sections in both data sets are based on intranuclear cascade and optical model calculations; however, additional experimental data have been used in obtaining the revised cross sections. For the elements hydrogen, ^{10}B, ^{11}B, sulfur, potassium, calcium, chromium, and tungsten, the multigroup cross-section data in the two sets are the same. For all other elements, except lead, the neutron-nucleus nonelastic cross sections and the energy-angle distributions of neutrons from neutron-nucleus nonelastic collisions are also the same and the energy-angle distributions of neutrons from elastic scattering at energies $\geq$19.6 MeV are the same. Thus, for the elements carbon, nitrogen, oxygen, sodium, magnesium, aluminum, silicon, iron, and nickel, the only quantities that are revised are elastic scattering cross sections as a function of energy. These cross sections have been determined by adjusting them to make the total cross sections agree with experimental data. For lead, elastic scattering is neglected at energies $\geq$19.6 MeV and the nonelastic cross section is determined from experimental data.

In Ref. 6, V. Herrnberger proposed a "benchmark" configuration that may be used for the intercomparison of cross-section libraries and computational methods. Here this configuration has been used to compare transport results obtained with the original iron cross sections of Ref. 4 and the revised iron cross sections presented here. The original iron cross sections will hereinafter be referred to as HILO, while the revised iron cross sections will be referred to as HILO(R1). Briefly, the benchmark configuration is that of an iron sphere of radius 5 m with a spherical volumetric isotropic neutron source at its center. The neutron source has a radius of 5 cm and the incident neutron energy spectrum is uniform over the energy interval 300 to 400 MeV. The density of iron was taken to be 7.84 g/cm^3.

Calculations for this configuration were carried out with the discrete ordinates code ANISN[5] and an S_{12} angular quadrature. In the HILO(R1) calculations, a P_5 Legendre expansion was used at all energies, while in the HILO calculations a P_5 expansion was used at energies $\geq$14.9 MeV and a P_3 expansion was used below this energy. In the HILO library only, a P_3 expansion is available below 14.9 MeV.

The calculated total scalar neutron and photon fluxes are compared as a function of radius in Fig. 1. At the larger radii, the neutron and photon scalar fluxes from the HILO(R1) cross sections are significantly larger than the fluxes from the original HILO cross sections. The calculated neutron and photon fluxes per unit energy have also been obtained and will be compared in the presentation.

The multigroup cross-section data described here are available from the Radiation Shielding Information Center of the Oak Ridge National Laboratory.

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Fig. 1. Scalar neutron and photon fluxes vs. radius in an iron sphere. Results obtained with the older cross section library, HILO[4], and with the revised cross section library HILO(R1) are shown.