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Title: Improved Photon-Production Data for Thermal-Neutron Capture in ENDF

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Abstract. High-quality photon-production data from thermal-neutron-capture reactions are important for many applications, including oil-well logging, planetary gamma-ray spectroscopy, and environmental techniques. Radiation-transport codes usually access photon-production data from the national U.S. nuclear database, ENDF/B. To improve the photon-production data for thermal-neutron capture, we have compiled and evaluated the energies and intensities of gamma rays for most naturally occurring isotopes with Z<31 and for a few heavy isotopes. The new compilation of photon-production data is being incorporated into the latest ENDF/B evaluations for each isotope and will be provided for future releases of the ENDF/B database.

INTRODUCTION

The Evaluated Nuclear Data File (ENDF/B) is being developed under the direction of the Cross Section Evaluation Working Group (CSEWG), which is comprised of representatives from U.S. government and industrial laboratories. Originally organized to provide nuclear data for the fission-reactor program, the system has gradually broadened its scope to include nuclear cross-section data for all applications. Even with expanded applications coverage, major emphasis has continued to be placed on the incident-neutron energy range below 20 MeV. Since its inception in 1966, CSEWG has improved the evaluated database systematically as new experimental and theoretical information became available, periodically issuing new versions of the ENDF/B library. The present version (ENDF/B-VI) of the library was issued in 1989-1990 and has been followed by four updated releases, with a fifth to follow soon.

High-quality photon-production data from thermal-neutron-capture reactions are important for many applications such as oil-well logging, planetary gamma-ray spectroscopy, and environmental techniques. The nuclear data contained in the ENDF/B evaluations (1) are used for many radiation-transport codes such as MCNP (2). The photon-production data from radiative-neutron capture are often outdated in the ENDF evaluations and are of poor quality. To improve the photon-production data for thermal-neutron capture, we have compiled and evaluated the energies and

intensities of gamma rays for most naturally occurring isotopes with Z<31 and for a few heavy isotopes (3). The new compilation of photon-production data is being incorporated into the latest ENDF evaluation for each isotope. The improved ENDF evaluations will be submitted to the Cross Section Evaluation Working Group for inclusion into future releases of ENDF.

REPRESENTATION OF PHOTON-PRODUCTION DATA IN THE ENDF EVALUATIONS

There are a number of mechanisms by which an evaluator can incorporate secondary-energy distributions for gamma rays as a function of incident neutron energy. Gamma-ray spectra having discrete energies and intensities are usually given in File 12 of an evaluation but can also be given in File 6. When an evaluator has elected to use a histogram representation of the gamma-ray spectra, generally binned in 50-250 keV wide energy bins, the data are generally given in File 15. The evaluator may, or may not, choose to use an energy-dependent yield as a function of incident neutron energy to properly conserve energy.

INCORPORATION OF IMPROVED PHOTON-PRODUCTION DATA INTO ENDF

We have tried to minimize the impact to the original evaluation. The improved photon-production data for thermal-neutron-capture have been given in File 12 of the evaluation. The incident neutron energy range for which these data are to be utilized is determined by the original evaluation. For example, the new data are used for incident neutron energies up to 1 keV for the isotopic Fe evaluations and to 10 keV for ^{27}Al. For other evaluations where the thermal-neutron-capture spectrum is used for all incident neutron energies, we have specified a neutron energy-dependent total yield to ensure energy conservation. Additionally, when the total energy observed in the photon spectrum is within 10% of the available energy, we have normalized the intensities to the reaction Q-value. The exceptions to date are ^{43}Ca, ^{47,49}Ti, ^{61}Ni, and ^{182,183,184,186}W, where the total energy observed is far less than the available energy.

NEWLY AVAILABLE ^{35,37}CL ENDF EVALUATIONS

New evaluations at neutron energies from 10^{-5} eV to 20 MeV were performed for ^{35,37}Cl. At thermal-neutron energies, photon-production data from the new compilation (3) are incorporated directly in the evaluations. The evaluated data at higher energies are based on theoretical calculations using the GNASH code (4) optimized to the available experimental data. The calculations utilize Hauser-Feshbach statistical theory

with corrections for width fluctuations, preequilibrium, and direct-reaction processes. Spherical-optical-model calculations are used to obtain the neutron total cross-section as well as transmission coefficients for all emitted particles.

Cross sections and spectra for individual reactions are included for exiting neutron, proton, deuteron, alpha, and gamma rays. Multiplicities, angular distributions, and emission-energy spectra are given for gamma rays, particles, and recoil nuclei. Energy-angle-correlated spectra are given for all outgoing particles and photons, and energy distributions are included for residual nuclei produced in all significant reactions. A maximum of discrete-level information was included in the calculations in order to preserve full details of all photon-producing reactions at higher energies.

CONCLUSIONS

We are making substantial improvements to the photon-production data for thermal-neutron capture in the ENDF evaluations. The improved data will be incorporated into future releases of ENDF and will be processed for use with MCNP. We anticipate the first MCNP library will be distributed in 2000.

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