Evaluated Nuclear Data

Background and Applications

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1 Evaluated Methodology

1.1 Introduction

Although sometimes overlooked or taken for granted, the importance of nuclear data for nuclear technology applications can not be overstated. Of equal paramount to its significance is the complexity in compiling the nuclear data. On one hand, the incident energies of interest represents an extremely broad range. When considering fission and fusion applications, the range required represents 13 orders of magnitude from 10^{-5} to 2.0×10^{7} eV (20 MeV). In the case of accelerator driven systems, the range is extended up to 200 MeV. Another challenge in generating the nuclear data libraries is the sheer number of atomic nuclei present in nuclear technology applications. This amounts to about 400 atomic nuclei, including everything from hydrogen to the actinides, the atomic mass range of $A = 1 - 250$.

Describing the physics of neutrons interacting with atomic nuclei over a broad energy range and for a vast number of nuclei is not an easy feat. Different approaches and various models are required to describe the underlying physics. While experimental data is crucial to the evaluation process, understanding the measured data must be used in conjunction with physics based models to corroborate and gain confidence that these values accurately represent the phenomena.

1.2 Evaluation Techniques

The basic building block of a nuclear data library is the microscopic neutron cross section, microscopic describes properties of individual nuclei and their interactions. Such that, a microscopic cross section is the interaction probability of one neutron incident on a single target nucleus. The low energy region, which includes thermal energy, resolved resonances and unresolved resonances is generated by methods that analyze neutron resonances. Whereas the fast neutron region is evaluated by nuclear reactor calculations and experimental data.

As a means to covering all incident projectile energies, outgoing particle and photon energies and angular distributions, experimental data must be complemented by nuclear theory and modeling codes. These codes also allow the interpolation and extrapolation of measured data while maintaining energy and momentum conservation. Some of the codes developed to generate evaluated nuclear data include:

- Statistical, pre-equilibrium, direct and fission models in modeling medium and heavy nucleus reactions in the codes GNASH [1, 2, 3] and EMPIRE[4].
- R-matrix codes for light nucleus reactions and for lower incident energy reactions on heavier nuclei with energy dependent analysis [5] and the SAMMY code [6].
- Atlas code [7] for analyzing neutron resonances using the multileveled Breit-Wigner formalism to produce the resonance parameters and thermal cross sections.

2 Neutron Data for Actinides

For the most part, actinides are the most important isotopes in nuclear technology applications. Primarily speaking, U^{235}, U^{238} and PU^{239}. The aforementioned isotopes in addition to TH^{232} make up the major actinides, while the other isotopes of U and Pu, in combination with Np, Am, and Cm constitute the minor actinides.

Given its importance, much care is taken in the evaluation of the neutron data for actinides. Greater detail may be found with the release of the ENDF/B-VII.0 library. [8]. Aside from the microscopic cross sections, other information of interest includes: thermal constants, fission product delayed neutrons and fission energy release.

3 Neutron Data for Other Materiales

Aside from actinides, within nuclear technology applications, other materials of interest include moderators and coolants, structural materials and fission products.

In the case of light nuclei used as moderators and coolants, their evaluations are based on R-Matrix analysis. Typical isotopes in this category include H^1, H^3, Li^6, Be^9 and B^{10}.

Structural materials are dominated by Cr, Fe and Ni. Specifically Cr^{52} (natural abundance of 83.8%), Fe^{56} (natural abundance of 91.7%) and Ni^{58} (natural abundance of 68.1%) and less abundant isotopes such as $Cr^{50,53}$, $Fe^{54,57}$, Ni^{60}, and so forth.

Fission products are the largest category of materials in the evaluated nuclear data libraries, in the case of the ENDF/B-VII.0 there are 219 nuclei. Primary fission products include: Mo^{95}, Tc^{95}, Ru^{101}, Rh^{103}, Pd^{105}, Ag^{109}, Xe^{131}, Cs^{133}, Pr^{141}, Eu^{153}, $Nd^{143,145}$, $Sm^{147,149,150,151,152}$, $Gd^{155,157}$. Additional, the fission chains are generated and included in the evaluated nuclear data libraries.

4 Evaluated Nuclear Data Libraries

4.1 General Purpose Libraries

Evaluations in a general purpose libraries are the most complete in regards to physical quantities present and nuclear reactions. In order to be suitable for transport calculations, these libraries must cover thermal, resolved and unresolved resonance energy region as well as fast neutron ranges up to at least 20 MeV. Additionally all the major reactions and their microscopic cross sections, angular distributions and photon production data need be present. Examples of some major general purpose libraries include:

- ENDF/B-VII.0, USA, released in 2006.
- JEFF-3.1, Europe, released in 2005.
- JENDL-3.3, Japan, released in 2002.
- BROND-2.2, Russia, released in 1992.
- CENDL-2, China, released in 1991.

4.2 Special Purpose Libraries

Although not as comprehensive as a general purpose library, it may contain certain features that may be impractical to implement in the general purpose files. For example, an activation library does not have to cover the full energy range nor spectra and angular distributions but does need to provide cross sections for the reactions leading to the radioactive products. These metastable states are rarely considered in general purpose libraries.

References

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