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Radioactive decay data uncertainties library of isotopes for ABBN constant system

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Abstract

Results of studies aimed at the development of the library of uncertainties of radioactive decay data in the ABBN neutron data library format are presented. Different evaluations of uncertainties were compared and their effects on the results of calculations of residual heat release were determined using the test problem as the example.

Matrices were generated in the ABBN format containing the data obtained on the basis of libraries in ENDF-6 format. 3821 isotopes from the ENDF/B-7 data library, 3852 isotopes from the JEFF-3.11 data library and 1264 isotopes from the JENDL-4.0 data library were processed.

It was revealed that the differences in the evaluations accepted in different data libraries are comparatively not very significant, although they sometimes exceed the uncertainties assigned to the data in the ENDF/B-7 and LEFF-3.11 libraries (the latter are, as a rule, in agreement with each other).

Keywords: Uncertainties; Radioactive decay; Radionuclide; Library of radioactive decay data; Heat release; ABBN; ENDF/B-7; JEFF-3.11; JENDL-4.0; SKALA.

Introduction

The ABBN neutron data system developed for the purpose of implementation of engineering calculations is widely applied in the Russian Federation. The system includes, as well, characteristics of radioactive decay of radionuclides.

Abroad the Russian Federation such data are presented and stored, as a rule, using the internationally accepted ENDF-6 format [1]. Different data libraries – ENDF/B-7 in the USA, JEFF-3.11 in the EU countries and Jends-4.0 in Japan – are used in different countries. The ABBN data library applied in the RF contains characteristics of radioactive decay of radionuclides presented in the format designed to allow application of these data in engineering computer codes. ABBN format in contrast to the ENDF-6 format significantly simplifies the analysis and correction of the data by the experts, while standard procedures for getting access to the ABBN data library allow relatively easy use of the library in computer calculations. The data in the library are thoroughly verified to reveal any controversy and are on a from time to time basis upgraded and corrected using the data extracted from different sources.

The ABBN library of characteristics of radioactive decay of radionuclides [2] with data for isotopes included in it was compiled at the turn of the century. The isotopes which are not accounted for may release taken together up to 10% of the total residual heat. This refers, as a rule, to neutron deficient nuclei.

It seemed to be justified to expand the library and to equip it with the data needed for calculations of uncertainties of the aforesaid characteristics.

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In order to achieve this it was necessary to develop the tool for extraction of decay data from the libraries compiled in ENDF-6 format and to create on this basis the libraries in the ABBN format, as well as to gain the experience of work with uncertainties for the above data within the SKALA system [3,4].

The developed tool can be regarded, as well, as the method allowing the use of ENDF-6 files within the framework of the SKALA/ABBN system.

Processing evaluated radionuclide radioactive decay data files

Fortran-based DECAPRO Code (Decay Processing) was written allowing extracting the data from MF=8 file of the library in ENDF-6 format and generating on the basis of the extracted data matrices of decay data in the ABBN format (Tables 1-4). The same format as the one used for the data themselves was suggested for storing the uncertainties of the decay data with only the MT identifier determining in this format the type of the data contained in the matrices being different. It was suggested for matrices of uncertainties to use the MT identifier with value equal to 81 (MT=81).

The DECAPRO Code generates ABBN matrices with MF=90 (main decay data including half-lives, branching ratios according to different decay types and heat release components), MF=91 (gamma radiation line spectra), MF=92 (electron line spectra), MF – 93 (beta-radiation yields, average and maximum energies), and MF=94 (alpha radiation line spectra). Data from ENDF/B-7, JEFF-3.11 and JENDL4.0 libraries were subjected to processing to be transformed into the ABBN format. Simultaneously with decay data ABBN matrices containing uncertainties for these data (with MT=81) were generated as well.

Detailed description of the data processing procedure would be excessively complicated. In particular, generation of data on the probabilities of different beta-decay modes (with emission of secondary neutrons, alpha-particles, etc.), transformation of continuous spectra and other procedures represented a fairly difficult task.

Libraries in ABBN format used for implementation of expert analysis were obtained on the basis of evaluations of ENDF/B-7, JEFF-3.11 and JENDL4.0 libraries.

Data for the total number of isotopes equal to 3821 were obtained on the basis of ENDF/B-7 library (here, 671 isotopes were in the first metastable state, 66 isotopes in the second metastable state and one isotope in the third metastable state). Data for 3852 isotopes were obtained on the basis of JEFF-3.11 library (699 isotopes in the first metastable state, 67 isotopes in the second metastable state and two isotopes in the third metastable state). Data for 1264 isotopes were obtained using the JENDL4.0 library (230 isotopes in the first metastable state and 20 isotopes in the second metastable state). The scope of these data is significantly wider as compared to those currently contained in ABBN matrices - including 1565 isotopes with 299 isotopes in the first and 23 isotopes in the second metastable state.

It is intended that supplementing the ABBN library [5] with new data and modification of already available data will be implemented by skilled experts in nuclear physics on the basis of generated matrices containing the data taken from different sources taking into consideration the uncertainties of these data.

Let us note here that estimations of decay data uncertainties in many (if not in most) cases exceed the discrepancy between the evaluations of respective nuclear data accepted in different libraries. And this is only natural, because the same sets of experiments are used as the basis for the evaluations. This circumstance simplifies selection of the data to be added to the ABBN library. As to the uncertainties, they, as a rule, significantly exceed the discrepancies between the evaluated data.

Comparison of decay data from different libraries

ENDF/B-7 and JEFF-3.11 are the most complete among the existing data libraries. Version of the JENDL4.0 library available to us did not contain the data for actinides. Data on the local heat release and on the energy carried away by gamma radiation for the whole set of nuclides are presented in the following three tables (Tables 1-3).

Table 1
Energy carried away by gamma quanta after decay of isotopes in the residual heat release calculation.

Isotope	ABBN	ENDF/B-7	JEFF-3.11	JENDL-4.0	Average	Scatter	Uncertainty ENDF/B-7
Y-91	0.0036	0.0031	0.0031	0.0031	0.0032	0.00021	0.00048 (15%)
Zr-95	0.7370	0.7321	0.7328	0.7321	0.7336	0.00203	0.002300 (3%)
Nb-95	0.7670	0.7645	0.7645	0.7645	0.7651	**0.00109**	**0.00006** (0.01%)
Ru-103	0.4840	0.4958	0.4961	0.4960	0.4930	0.00518	0.00609 (1.2%)
Rh-106	0.2090	0.2061	0.2043	0.2060	0.2063	0.00169	0.00260 (1.3%)
Cs-134	1.5540	1.5544	1.5554	1.5544	1.5546	0.00053	0.00085 (0.05%)
Ba137m	0.5970	0.5972	0.5964	0.5948	0.5969	**0.00130**	**0.00093** (0.16%)
Ba-140	0.1830	0.1822	0.1802	0.1820	0.1818	0.00105	0.00123 (0.68%)
La-140	2.3150	2.3083	2.3126	2.3080	2.3110	0.00294	0.00389 (0.17%)
Ce-141	0.0766	0.0766	0.0765	0.0767	0.0766	0.00007	0.00047 (0.62%)
Pr-144	0.0318	0.0289	0.0338	0.0289	0.0308	**0.00207**	**0.00036** (1.2%)
Cm-242	0.0014	0.0019	0.0014		0.0015	0.00025	0.00013 (7%)