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Nuclide radioactive decay data uncertainties library

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Abstract. The results of the developing the library of uncertainties of radioactive decay data in the ABBN data library format are described. Different evaluations of uncertainties were compared and their effects on the results of calculations of residual energy release were determined using the test problems and experiment. Tables were generated in the ABBN format with 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 decay data libraries are not so big, although they sometimes exceed the uncertainties assigned to the data in the ENDF/B-7 and JEFF-3.11 libraries, which as a rule, they agree with each other. On the basis of developed method it is supposed to create a library of data uncertainties for radioactive decay within the constant data system in FSUE RFNC-VNIIEF with its further connection with CRYSTAL module.

1. Introduction

In 2012 the CRYSTAL software module [1] was developed in the Institute of Theoretical and Computational Physics of All-Russian Scientific Research Institute of Experimental Physics. It is designed for solving computational problems of nuclear fuel burning up and residual energy release in both thermal and fast reactor facilities. CRYSTAL is used for isotopic kinetics calculations in CONCORD software package [2]. A specific characteristic of CRYSTAL module is that it includes production of a complete set of nuclides (more than 1300) in fuel material and can be used in both multigroup and Monte-Carlo computations.

Figure 1 demonstrates the task complexity exemplified in the scheme of ^{86}Kr transmutation which shows its production as a function of precursor and descendant nuclei. To find isotope concentrations it is necessary to solve a stiff linear set of differential equations using the Rosenbrock-Wanner method.

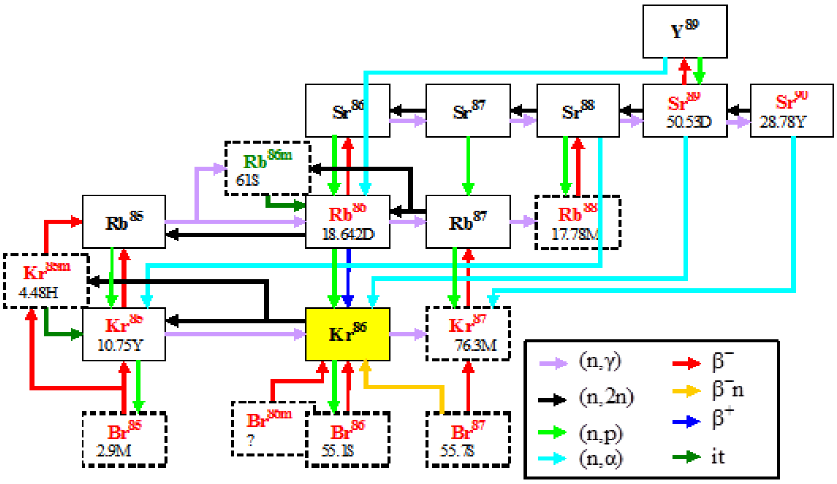

Figure 1. Implicit bonds character between ^{86}Kr descendants nuclei and ^{86}Kr precursor nuclei

Nuclear data uncertainties estimation used in calculations is an important factor in numerical simulation of isotopic composition change. This work describes the method to develop a library of the radioactive decay nuclear data uncertainties. The ABBN radioactive decay constant data system [3, 4] controlled and developed for many years by JSC «SSC RF – IPPE» in the city of Obninsk (earlier SSC RF – IPPE) is considered as a possible base for the CRYSTAL module. The library is widely used in the Russian Federation. This work contains methods of collecting radioactive decay data in the ABBN format.

2. Processing evaluated radionuclide radioactive decay data files

Russian (ABBN), American (ENDF/B-7), European (JEFF-3.11) and Japanese (JENDL-4.0) libraries were used in the work. Foreign libraries data are presented and stored in the internationally accepted ENDF-6 format [5, 6].

Fortran-based DECAPRO Code (Decay Processing) [7], which extracts radioactive decay data from MF=8 file of the library in the ENDF-6 format and generates decay data tables with its uncertainties in the ABBN format, was used for evaluated nuclear data file processing.

The same format as the one used for the data themselves was suggested for storing the uncertainties of the decay data, only with a different value of the MT identifier determining in this format the type of the data contained in the tables. It was suggested for tables of uncertainties to use the MT identifier with value of 81(MT=81).

ENDF/B-7, JEFF-3.11 and JENDL-4.0 libraries were processed using this program (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), and tables in the ABBN format were generated for these evaluations.

3. Application of the data on the uncertainties of energy release

The data from libraries were analyzed earlier in [7]; energy release calculation uncertainties were evaluated for the test model of a reactor in comparison with models of different authors within the SKALA system [8, 9].

Then additional calculations of residual energy release and its uncertainties were performed for the same fast reactor model and for «Flash» experiment, the idea of which is in the short-term irradiation of samples followed by the measurement of energy release.

Figure 2 shows that uncertainty is two orders of magnitude smaller than energy release and almost doesn’t change. As shown in the Figure 3, for exposure time 1 – 10^4 seconds the uncertainty is small, and after that it increases and suffers sharp changes. It is presumably connected with fission products accumulation, on which less data is available.

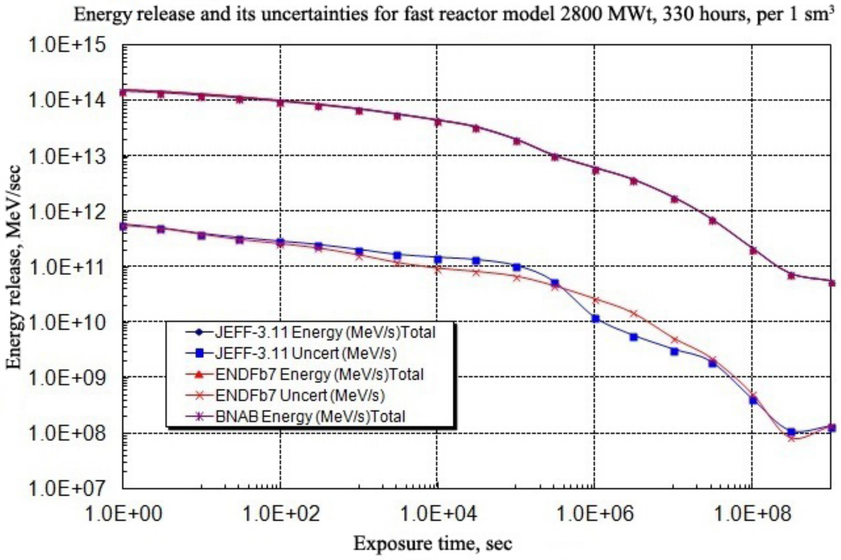

Figure 2. Dependence of energy release and absolute uncertainty on exposure time in different evaluations.

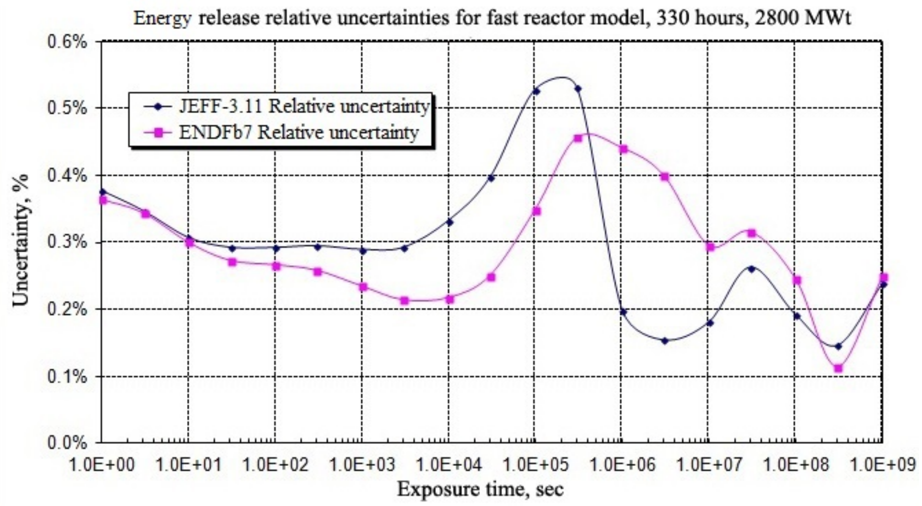

Figure 3. Dependence of relative uncertainty on exposure time in different evaluations.

Besides, different energy releases evaluations were compared to the ABBN data. Figure 4 illustrates that the ENDF/B7 and JEFF-3.11 data results differ by less than 1%, while difference from the ABBN can exceed 3%. Apparently, this can be attributed to the absence of data on short-lived isotopes in the earlier published ABBN library.

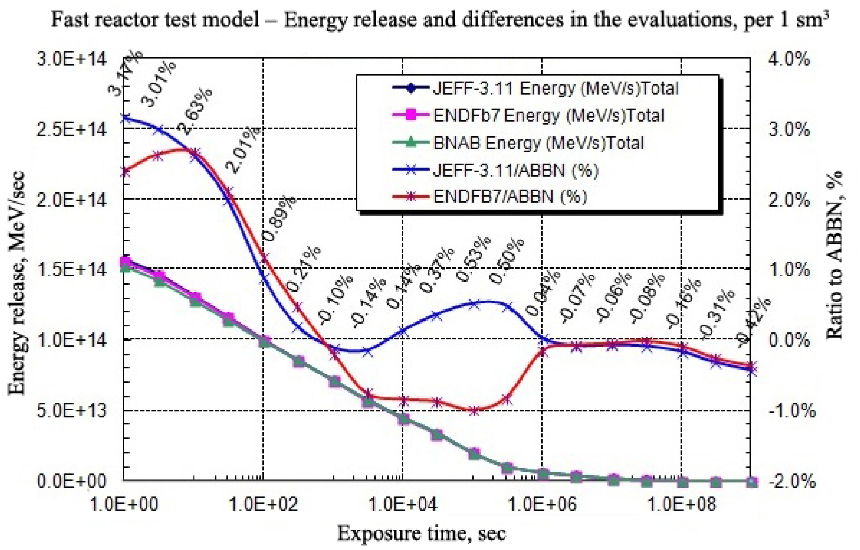

Figure 4. Dependence of energy releases and differences in the evaluations on exposure time.

«Flash» experiment [10] data are shown below. Dickens (ORNL), Karlsruhe, Yayoi (Tokyo University), Lowell (University of Massachusetts, Lowell) named in Figure 5 are experimental results, and JNDC (JAEA), AFPA (NRNU MEPhI), ORIGEN (ORNL), CARE-E (JSC «SSC RF – IPPE») are calculation results. The results of this work calculation are SKALA JEF. The plots in Figure 5 show that the calculation results in our work insignificantly differ from the results of other authors and agree with the experiment within uncertainties for times over 10 seconds both for U-235 (left plot) and Pu-239 (right plot).

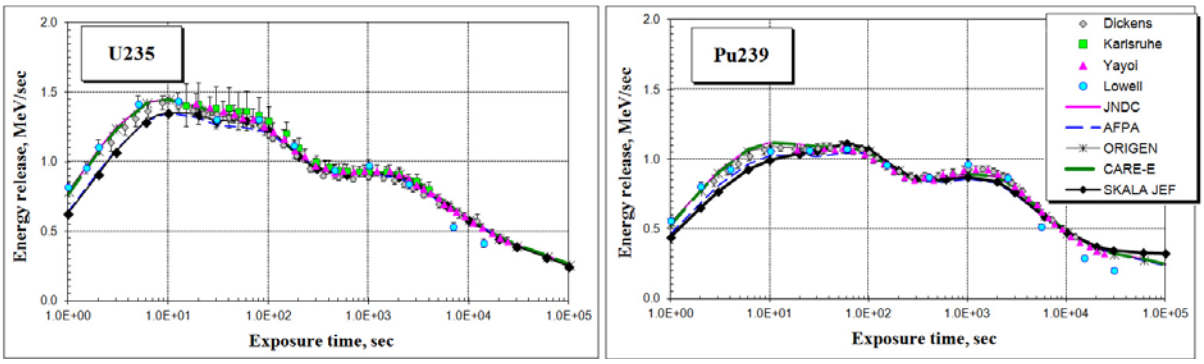

Figure 5. Comparison of the residual energy release value in benchmark experiments with the calculated values for the exposure time from 1 to 10^5 seconds for U-235 and Pu-239 («Flash» experiment).

4. Conclusions

- We have mastered the technology of evaluating radioactive nuclides decay data uncertainties in the ABBN format.
- Energy release and its uncertainties for test models within the SKALA system (JSC «SSC RF – IPPE») were calculated; calculation results were analyzed and compared with different authors and experiments.

- On the basis of developed method it is supposed to create a radioactive decay data uncertainties library within the FSUE RFNC-VNIIEF constant support system and that will be further linked with the CRYSTAL module.

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