Expectation for Nuclear Data Development (I)

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The nuclear data has a crucial role in development of nuclear power systems. From a point of view for future nuclear systems, expectation for nuclear data development is discussed in this paper. The purpose of this paper is to give some proposal for the future improvement of nuclear data.

1. Introduction

The nuclear data has played an important role in the development of the nuclear power development. There is no practical meaning in the reactor physics without the nuclear data. It provides a fundamental database for various research fields, such as astrophysics. However, will it continue to play a crucial role in the development of future nuclear system? Many nuclear plants are now operated in the world. Some people say that the current data has sufficient accuracy In this paper, from the view point of future nuclear system, expectation for the nuclear data development will be discussed.

2. Future Nuclear Power System

In the development of future nuclear power system, first of all, it is necessary to think about extrapolation of the present nuclear power plant, such as high-burn up and recycling of Pu. For the reactor performance, nuclear data of the higher actinides will become increasingly essential to reduce the potential uncertainties. As far as the fuel cycle, it will be desired to reduce the uncertainties of the isotope contents of the discharged fuel from viewpoint of critical safety issues.

One of the most important issues for sustainable utilization of nuclear energy is steady implementation of High Level Waste (HLW) disposal. The long-term radio-toxicity of the HLW is mainly dominated by the minor actinides (MA). The Partitioning and Transmutation (P&T) technology is aiming at the reduction of the radio-toxicity by transmuting MA and other long-lived fission products. Various P&T conceptual studies were performed over the past dozen years or so. The Japan Atomic Energy Agency (JAEA) has developed a concept of double-strata fuel cycle, in which P&T is carried out in a dedicated and small-scale fuel cycle attached to the commercial fuel cycle[1). For a dedicated transmutation system, JAEA has been proceeding with the research and development on accelerator-driven subcritical system (ADS)[2). In this concept, the ADS loaded with MA nitride fuel is considered as the most powerful tool for transmutation because such dedicated fuel cannot be loaded in critical nuclear reactors for safety reasons.

For the future systems, it will be strongly desired by minimizing the long-lived radioactive waste. To develop future-generation nuclear systems, the Generation-IV International Forum (GIF) was launched in 2000 by US-DOE. The six systems, GFR, LFR, MSR, SFR, SCWR, and VHTR, were selected as Generation-IV systems to be developed. Three out of the six concepts in Gen-IV foresee the full TRU recycling in Fast Reactors (FR) in order to meet the requirement for waste minimization.

As described above, the nuclear data, especially neutron cross-sections, of MA will play important role in future nuclear systems. The present status and the potential needs for nuclear data of

MA are discussed in following section.

3. Current Status and Data Needs

The reduction of analytical uncertainties for core parameters, such as subcriticality and burnup swing, are very important issues for design study of ADS. In the operation of ADS, the system must be subcritical in any case because there are no control rods in present design of ADS proposed by JAEA. Moreover, the proton beam current required to keep predefined power level is directly related to the subcriticality (k_{eff}). To indicate the current status for nuclear cross-section of MA, the results of the burnup calculations using JENDL-3.3, ENDF/B-VI and JEF-3.0 libraries, respectively, are presented in Fig.1(a). The calculated core was a Pb-Bi cooled ADS[3)]. For the core fuel, mixture of mono-nitride of MA (60%) and plutonium (40%) was used with an inert matrix, ZrN. The isotopic composition of MA and Pu were assumed as the spent PWR fuel of 50 GWd/t burnup. As shown in Fig.1, even at initial core, the difference among calculated keff is about 2%. The burnup reactivity swings also show very different trend with the libraries. To clear the reason of discrepancy for calculated results, contributions of each nuclide for difference of k-eff at initial state are shown in Fig.1(b). The results show that the discrepancy among the nuclear data libraries is mainly attributed to the uncertainties of MA cross-section data.

The sensitivity and uncertainty analysis are very strong tools to investigate the impact of nuclear data uncertainties on the core parameters. These analyses will help to indicate future direction for improvement of the nuclear data. For sound uncertainty studies, variance-covariance data to be associated to nuclear data library are absolutely essential. Recently, new evaluations for variance-covariance data for MA and other nuclides related to ADS were carried out by Nuclear Data Center in JAEA. The results of the uncertainty analysis for k_{eff} at initial state are given in Fig.2 together with main contributor for the total uncertainties. Total value is the square root of the sum of the squares. The total value (±0.9%) for k_{eff} is higher than corresponding values for critical fast reactor. The major contributor among the actinide nuclides is ^{237}Np and ^{241}Am, and the capture cross-section of ^{241}Am especially has considerable impact. The variance data, diagonal section of covariance matrix, of capture cross section of ^{241}Am is shown in Fig.3 with differences between the corresponding values based on JENDL-3.3. The variance data for the capture cross section of ^{241}Am are relatively large in the energy region from 100keV to 1MeV because there is less experimental data in this energy domain.

As simply indicated in previous section, neutron cross-sections for MA are needed with improved accuracy for the development of the future nuclear system. Of course, other nuclear data, such as data related to delayed neutron and decay heat, are also important. To give the feedback to the nuclear data from the integral experiments, the sensitivity and uncertainty analysis provide strong tools. For this purpose, estimation of the variance-covariance data should be enhanced.

4. Conclusions

The nuclear data still play an important role in the future nuclear power development. The neutron cross-sections of MA, especially, will become key issues. Current status of MA nuclear data is not so satisfactory. What must be done for the future nuclear data? To improve the nuclear data for MA, significant efforts are needed not only to measure nuclear data but also to evaluate the reliability of existing data by using integral measurements. For this purpose, well-organized framework program with coordinating role will be necessary.

References

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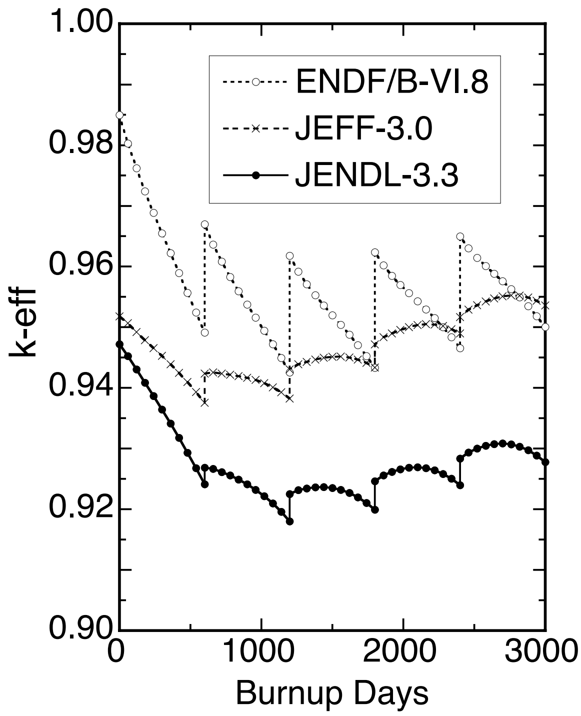
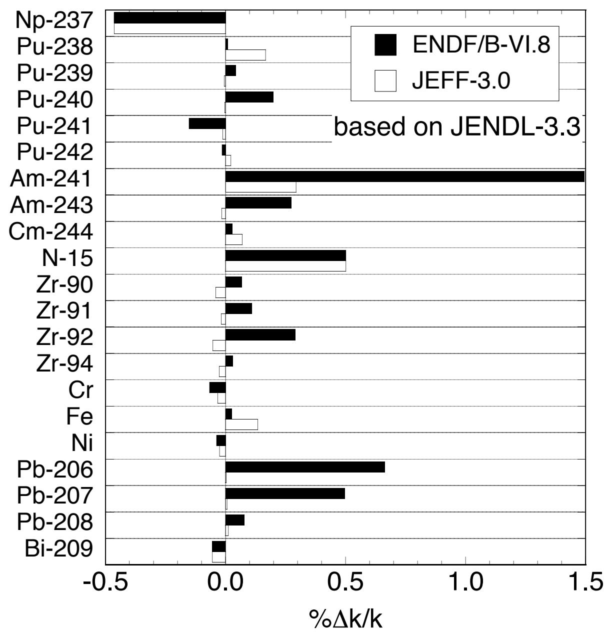


(a) Burnup calculation results with different nuclear data libraries



(b) Contribution of each nuclide to the difference of k-eff at initial state

Fig.1 Burnup calculation results with different nuclear data libraries and contribution of each nuclide to the difference of k-eff at initial state. The calculations were performed for ADS proposed by JAEA.

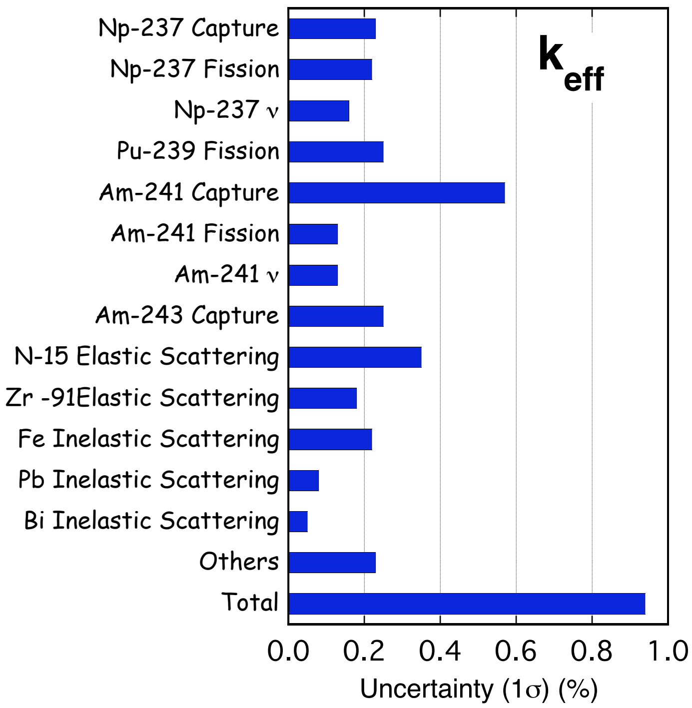


Fig.2 Uncertainty analysis results for k-eff at initial state of ADS

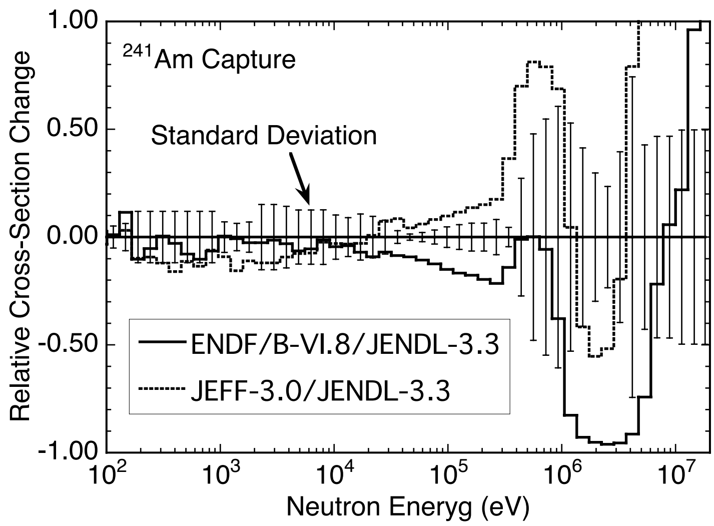


Fig.3 Variance data of capture cross section for ^{241}Am with difference between data in the nuclear data libraries. Variance data is diagonal data of covariance matrix proceeded by ERRORJ code[4)].