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Fission Evaluation on Th-232

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1. Introduction

In recent years, several studies of neutron induced reaction on thorium were carried out in the framework of an IAEA coordinate research project involving a US contribution. The importance of Th-232 is for an innovative fuel cycle concept based on thorium fuel. Thorium fuels are also considered in accelerator driven system (ADS) to produce the power and radioactive waste transmutation. Therefore, the accurate neutron cross section for fission is crucially important for the design of various reactor systems. On December 2006, the ENDF/B-VII involving the new evaluation of actinides for Th-U fuel cycle was released.

From the current environmental change, increasing oil price, air pollution by carbon dioxide, drain of oil resource, increasing demand of electricity, and energy independence, nuclear power is slowly to start to be re-considered recently and it might be an alternative proposal as a production facility of energy and a reuse of resources. Even though it produces the nuclear wastes, it has an advantage in the emission of greenhouse gases. Therefore, new concept of nuclear technology to be developed for power production is subject to the condition of increased safety, reduction of nuclear wastes, resistance to nuclear material proliferation, Thorium fuel cycle is the most feasible option to satisfy the condition. Specially, thorium reserves are much larger than those of uranium.

However, the quality of nuclear data for the thorium cycle fuels is less developed than the materials in the uranium or mixed oxide fuels cycle. The neutron absorption and production cross sections and the fission neutron spectrum are important for fission reactor.

For the first time, the neutron induced fission cross section was evaluated using the triple humped fission barrier from 1 keV to 20 MeV. The evaluation in this energy range was fully based on the nuclear model calculations using the EMPIRE-2.19 code[1]. A crucial starting point in an evaluation was the decision of the proper coupled channel optical model potential.

ECIS95-EMPIRE code[1] combination was adopted in the calculation for the total, elastic scattering and threshold reaction cross sections. The evaluation consists of an optical model calculation followed by a complete nuclear reaction model calculation. The energy dependent optical model potential was decided and applied for a calculation of the transmission coefficients. The calculated cross sections are graphically compared with the experimental data and the evaluated files. The results will be merged with the resonance results to make a full data file.

2. Optical Model

The complex potential was considered to describe the multi-humped fission barrier in optical model for the transmission mechanism.

$$V_f = V + iW \tag{1}$$

The real part of the barrier are parameterized as a function of the deformation using smoothly joined parabolas

$$V_i(\beta) = E_{fi} + (-1)^i \frac{1}{2}\mu\hbar^2\omega_i^2(\beta - \beta_i)^2 \tag{2}$$

where i=3 runs from 1 to 5 for a three humped barrier. The energies E_{fi} represent maxima of V_i in odd regions (humps) and minima in even regions (wells). The harmonic oscillator frequencies, ω_i define the curvature of each parabola and μ is the inertial mass parameter.

The negative imaginary potential, iW is introduced in the deformation range corresponding to the well to simulate the damping, absorption of the incoming flux in this well. The strength, W depends on the deformation,

$$W(\beta) = -\alpha(E)[E - V(\beta)]\,. \tag{3}$$

The input parameter, $\alpha(E)$, which controls the strength of the imaginary part of the fission potential, should be chosen to fit the width of the resonances in sub-barrier fission cross section and to be consistent with physical values for the transmission coefficients at higher energies.

For multi-humped barrier, the fission probability is derived in the optical model. The fraction absorbed in the isomeric well can decay by direct fission through the outer humps, by transition to the isomeric state, or by another change of shape. The fission cross section in the statistical model is

$$\sigma_{a,f}(E) = \sum_{J,\pi} \sigma_a(E,J,\pi) P_f(E,J,\pi). \tag{4}$$

where $\sigma_a(E,J,\pi)$ is the population of the fission nucleus in the state energy E, spin J and parity π.

3. Results and Discussions

Fig. 1 shows the comparison of the calculated total cross section with the experimental data and the evaluated files. The calculation from the determined potential parameters is in good agreement with the experimental

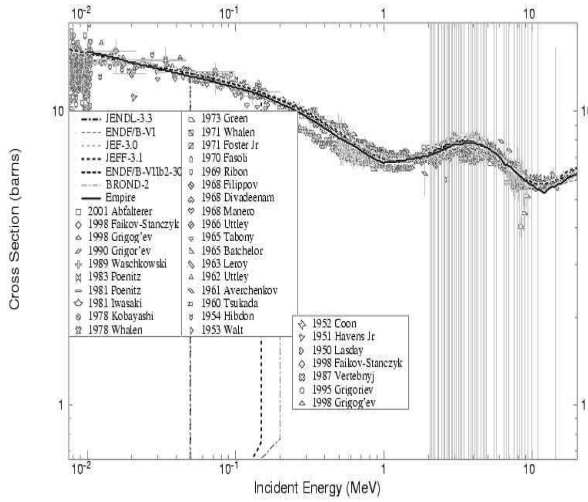

Figure 1. Total cross section of Th-232.

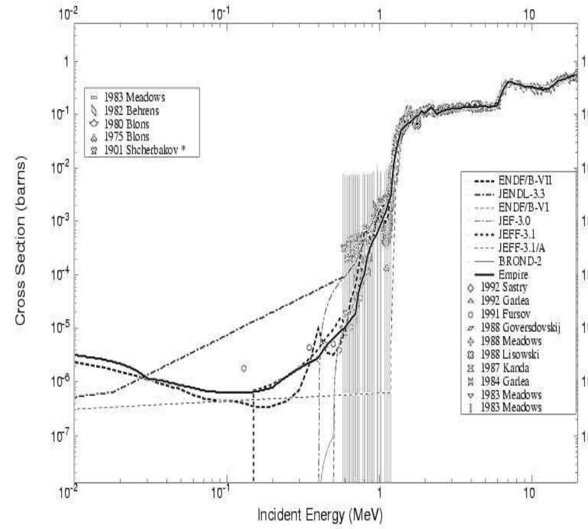

Figure 2. Fission cross section of Th-232.

data[2,3,4,5] in the whole evaluation energy range. The current evaluation is very consistent with the ENDF/B-VII and JENDL-3.3. However, above 10 MeV, there is a little difference, but, the evaluations are in good agreement with the experimental data. Fig. 2 shows a fission cross section. From 500 keV to 1 MeV, the measured data have a large fluctuation. The evaluation is based on a recent measurement data[6,7,8]. The current evaluation shows the structure well at 2 MeV energy. However, the ENDF/B-VII rather describes the structure well at 1.5 MeV than the current evaluation. The current evaluation shows the mean value in that energy. However, above 1 MeV, the current evaluation, ENDF/B-VII and JENDL-3.3 are in good agreement with the reference measured data.

4. Conclusion

The current evaluation on the Th-232 was the monumental result for the first time of the fission cross section generation. The fission cross section was successfully evaluated with the triple humped barrier in the fast energy region. The decided optical model potential parameter was proper for the coupled channel calculation. The calculation is in good agreement with the measured data. However, the current evaluation needs to improve the fission data at 1.5 MeV to depict the resonance structure well.

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