Neutron Induced Capture Cross Sections for Ir-191 and Ir-193

YongDeok Lee and Young-Ouk Lee
Korea Atomic Energy Research Institute, P.O Box 105, Yusung, Daejon, Korea 305-600, ydlee@kaeri.re.kr

1. Introduction

The neutron induced cross sections are calculated on Ir-191 and Ir-193 from 10 keV up to 20 MeV, on (n, tot), (n, n), (n, n'), (n, γ), (n, p), (n, α), (n, 2n), (n, 3n), (n, np) and (n, nα) reactions. Iridium emits intense gamma rays. Specially, Ir-192 is the major gamma ray source material and widely used in the several areas: material assay, non-destructive testing and medical treatment. For the purpose of the above utilization, Ir-192 is mainly produced in the isotopic production nuclear reactor by the neutron capture process from Ir-191. Using threshold reaction with high energy of neutron, Ir-192 can be produced from Ir-194 by the process of the neutron capture and decay as well. Ir-191 and Ir-193 have 37.3 % and 62.7 % respectively in the natural abundance. Ir-191 and 193 are stable isotopes. Ir-192 has 73.8 days half-life at ground state and 1.45 months at 56.7 keV meta stable state. Ir-192 has the beta decay to produce Pt-192 and the electron capture to produce Os-192. The major emitted gamma rays are 604 keV, 316 keV and 468 keV from the ground state decay.

ENDF/B-VI has fairly recent evaluation on Ir-191 and Ir-193, evaluated in 1995 and distributed in 1997 (by R.Q.Wright, ORNL). From 2 to 20 MeV, the capture data was obtained by renormalizing the natural iridium capture to the Macklin data[1] of Ir-191 at 2 MeV energy. ENDF/B-VI[2] has the (n, 2n), (n, 3n), (n, p) and (n, a) cross section data unchanged from the BROND natural iridium evaluation.

The evaluations consisted of an optical model potential search followed by a complete nuclear reaction model calculation and a validation for the experimental data. Nuclear reaction cross sections were calculated using the recently released Empire-II code[3]. The direct capture model enhances the capture cross section in the pre-equilibrium energy region, and the width fluctuation correction influences on the capture and inelastic scattering cross sections in the equilibrium energy region. The calculated cross sections are graphically compared with the experimental data and the evaluated files (ENDF/B-VI and BROND-2). The evaluated results are compiled in an ENDF-6 format and finally, they will be merged with the resonance results to make the full data file.

2. Models

The optical model is used to provide the total, elastic scattering and reaction cross sections. The potential form in the optical model and the corresponding parameters, as a function of the incident neutron energy, were searched based on the reference experimental data. To the obtain proper potential parameters, the Woods-Saxon well is used for the real part potential in the optical model:

$$V(r) = -V/(1+\exp((r-R_v)/a_v)) \quad (1)$$

where V and a_v are the strength and diffuseness of the potential. The nuclear radius R_v, related to the mass number A, is given by

$$R_v = r_v A^{1/3}. \quad (2)$$

For the imaginary part potential, the derivative Woods-Saxon shape is used,

$$W(r) = -4W\exp((r-R_w)/a_w) / (1+ \exp((r-R_w)/a_w)^2 \quad (3)$$

where W, R_w and a_w are the potential strength, radius and diffuseness, respectively.

Empire is a modularized code system. The main utilities include the masses, level densities and the discrete levels, the decay schemes, deformation parameters, γ-ray strength functions, RIPL, ENDF-6 formatting and the plotting capabilities. The main modules are: the Optical model, Multi-step Direct and Compound, Pre-equilibrium exiton model (DEGAS) and Monte Carlo hybrid simulation (HMS) and a full featured Hauser-Feshbach including the width fluctuation correction.

3. Results and Discussions

I-191 and I-193 do not have the experimental data for their total cross section. Therefore, the natural element experimental data[4] was used instead in the fast energy region for the optical model potential parameter search. In ENDF/B-VI, the total cross section was modified from 10 to 130 keV and was 19% higher than the natural iridium at 10 keV. In this paper, the neutron capture cross section is just introduced.

Fig. 1 shows the comparison of the calculated total cross section with the experimental data and the evaluated file on Ir-191 and Ir-193. The calculation is in good agreement with the experimental data[4] and the ENDF/B-VI. However, from 100 keV to 500 keV, the calculation is ~5% higher than the natural measured data[5].

Fig. 2 shows the capture cross section on Ir-191. The evaluation is based on the Macklin experimental data[1]. The evaluated data shows the good agreement with the experimental data and the current ENDF/B-VI. However, at higher energy region, the calculation shows the direct capture feature. Fig. 3 shows the capture cross section on

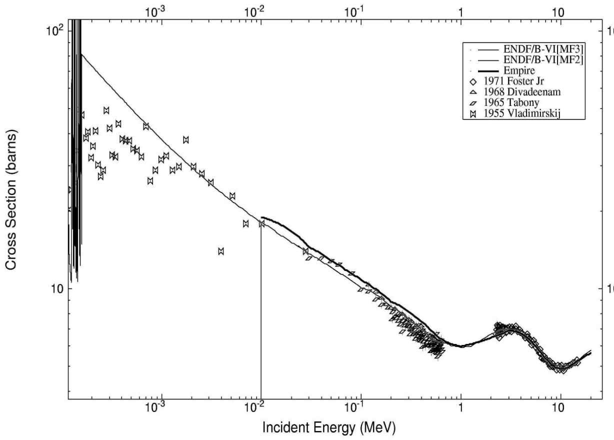

Figure 1. (n, tot) cross section of Ir-191 and Ir-193 (The experimental data shown in the figure are from the natural iridium element).

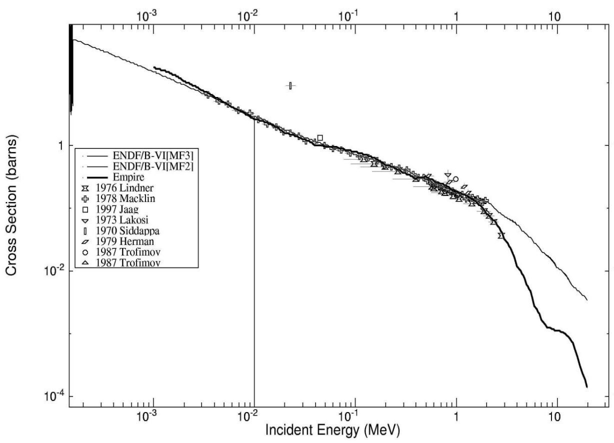

Figure 2. (n, γ) cross section of Ir-191.

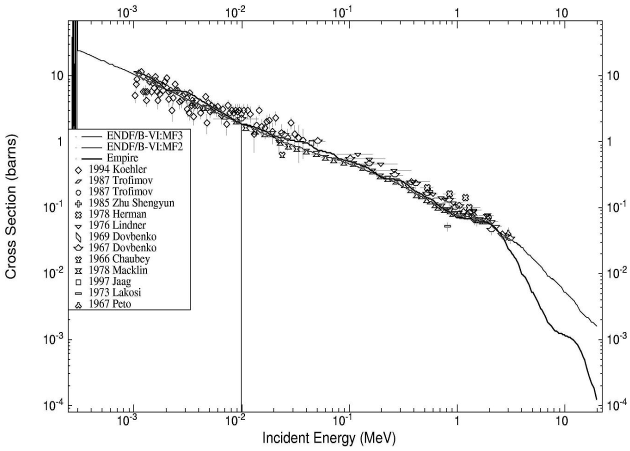

Figure 3. (n, γ) cross section of I-193.

Ir-193. The calculation and ENDF/B-VI agree well with the experimental data[6] in the measured energy region.

4. Conclusion

The selected energy dependent optical model potential, based on the experimental data of the natural iridium element, was properly used in the Empire code for producing the model calculated cross sections in the evaluation energy range. The capture cross sections were in good agreement with the reference experimental data and the ENDF/B-VI file. Specially, in the evaluation, the calculation shows the improvement on the fast neutron direct capture phenomena in the pre-equilibrium energy region. The fast energy evaluation will be merged with the resonance part at the unresolved energy and the smoothness and continuity checking will be followed.

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