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Total and Capture Cross Section for Pd-107, I-129 and Cs-135

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Abstract

The neutron induced nuclear data for Pd-107, I-129 and Cs-135 were calculated and evaluated from 10 keV to 20 MeV for nuclear waste transmutation, using a modular type Empire code package. The energy dependent optical model potential was investigated and applied up to 20 MeV. The optical model, the full feature Hauser-Feshbach model, the multistep direct and multistep compound model were used in the calculation. The direct and semi-direct (DSD) capture model was applied for fast neutron capture in the pre-equilibrium energy region. The theoretically calculated cross sections were compared with the experimental data and the evaluated files. With the experimental data, the calculated total and capture cross section was in good agreement.

1. Introduction

In addition to the fission products evaluation[1], that mainly influences fission reactor reactivity, Pd-107, I-129 and Cs-135 were considered and evaluated concerning toxicity for waste transmutation. I-129 has been of particular concern in nuclear reactors because of its 16 million year half-life and volatility in the elemental state. Pd-107 has a 6.5 million year half-life and exists as a fission product poison in a fission reactor. Cs-135 has 2.3 million year half-life. Pd-107, I-129 and Cs-135 nuclei have beta particle decay and transit to Ag-107, Xe-129 and Ba-135, respectively. In ENDF/B-VI, the evaluation was done in 1989, 1980 and 1974 for Pd-107, I-129 and Cs-135, respectively.

The neutron cross sections were calculated from 10 keV to 20 MeV. Scat2-Empire[2] code combination was adopted in the current cross section calculation, for total, elastic scattering and reaction cross sections. The energy dependent optical model potential was investigated for the full evaluation of the energy range. The individual nuclear

reaction cross sections were calculated by the recently released Empire code[2] using the Hauser-Feshbach model for the equilibrium energy region and the quantumn mechanical approach for the pre-equilibrium energy region. The calculated cross sections are graphically compared with the experimental data and the evaluated files (ENDF/B-VI, JENDL-3.2, JEF-2.2 and BROND-2).

2. Models

The code combination accounts for the major nuclear reaction mechanisms, such as the optical model, the Multistep Direct (MSD), the Multistep Compound (MSC) and the full featured Hauser-Feshbach model, including width fluctuation correction. The Multistep direct model takes care of the inelastic scattering to vibrational collective levels and decay information. The direct-semidirect (DSD) capture model was recently incorporated into the Empire to improve fast neutron capture in the pre-equilibrium energy region.

3. Calculation

The total experimental data for each nucleus do not exist. Therefore, the natural experimental data was referenced for the optical model potential parameter search. Unless natural experimental data exist as well, the default parameters already built into the code were used. Fig. 1 shows the calculated total cross section for Pd-107. There is no elemental experimental data. Therefore, the calculation is compared with the natural experimental data and evaluated files. The calculated total cross section shows little difference from the ENDF/B-VI data above 100 keV. The calculation is in good agreement with Poenitz natural data[3,4]. Fig. 2 is the capture cross section. The calculation was compared with the natural data. At the end of the resonance region, ~9 keV, Block data[5] was referenced. The ENDF/B-VI is different from the calculation in the fully evaluated energy region. The ENDF/B-VI shows a drastic decrease from 300 keV to 600 keV. The calculation agrees well with the natural experimental data[6], above 500 keV. Also, the direct capture contribution shows well around 14 MeV.

Fig. 3 is the total cross section for I-129. There are only evaluated files. Fig. 4 is the calculated capture cross section. The calculation is in very good agreement with Mackline experimental data[7]. ENDF/B-VI is lower than the calculation from 20 keV to 3 MeV. ENDF/B-VI has higher cross section data than the calculation in the pre-equilibrium energy range. The calculation shows a direct capture contribution around 14

MeV.

Fig. 5 is the total cross section for Cs-135. There is no experimental data. Fig. 6 is the calculated capture cross section. Unfortunately, there is no experimental data. The calculation shows the direct capture cross section at pre-equilibrium energy, however, at 5 MeV, it has a rather deep valley. The ENDF/B-VI is higher than the calculation in the equilibrium range.

4. Conclusion

The evaluation for waste transmutation faced the lack of experimental data in total and capture cross sections. The natural experimental data was used in the total and capture cross sections for Pd-107. The calculation shows good agreement with the data. The calculated capture cross sections of I-129 were in very good agreement with the reference measured data. In the pre-equilibrium energy region, the direct and semi-direct capture models show improved fast neutron capture. Without experimental data, evaluation was difficulty. The evaluated results will help improve the current ENDF/B-VI.

Acknowledgements

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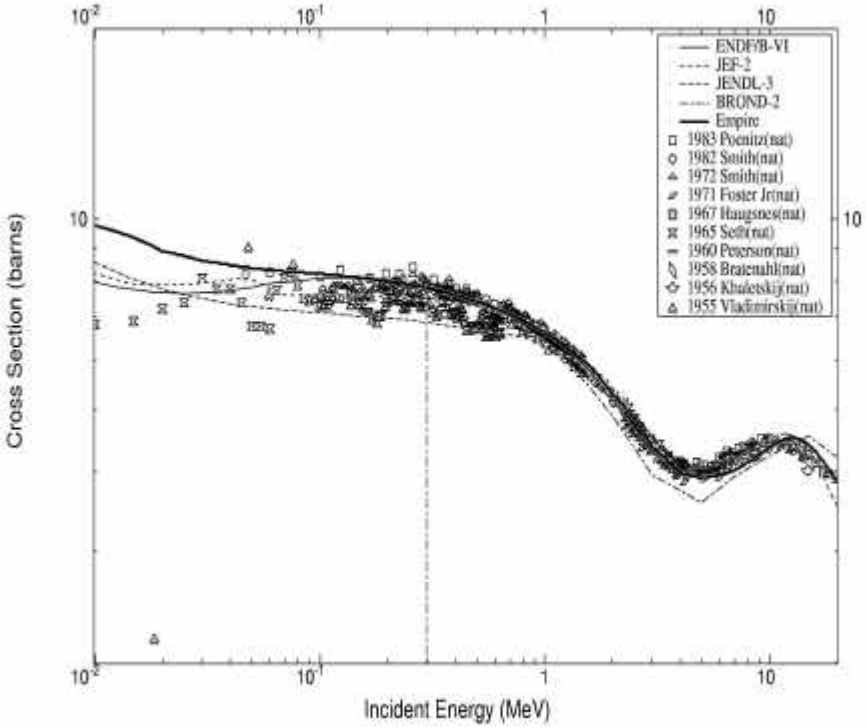

Fig. 1. Total cross section of Pd-107.

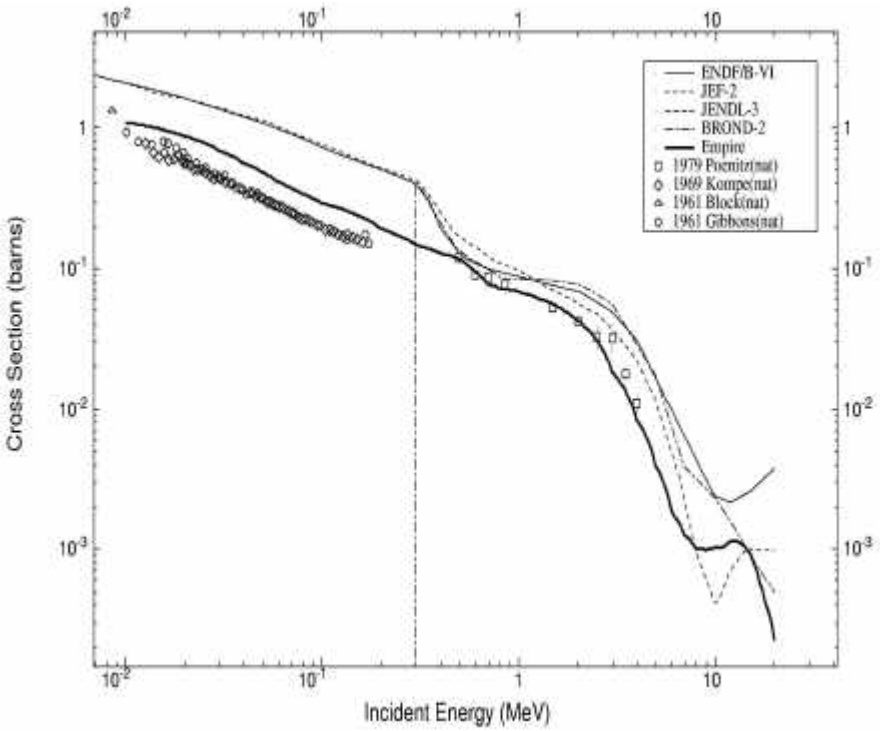

Fig. 2. Capture cross section of Pd-107.

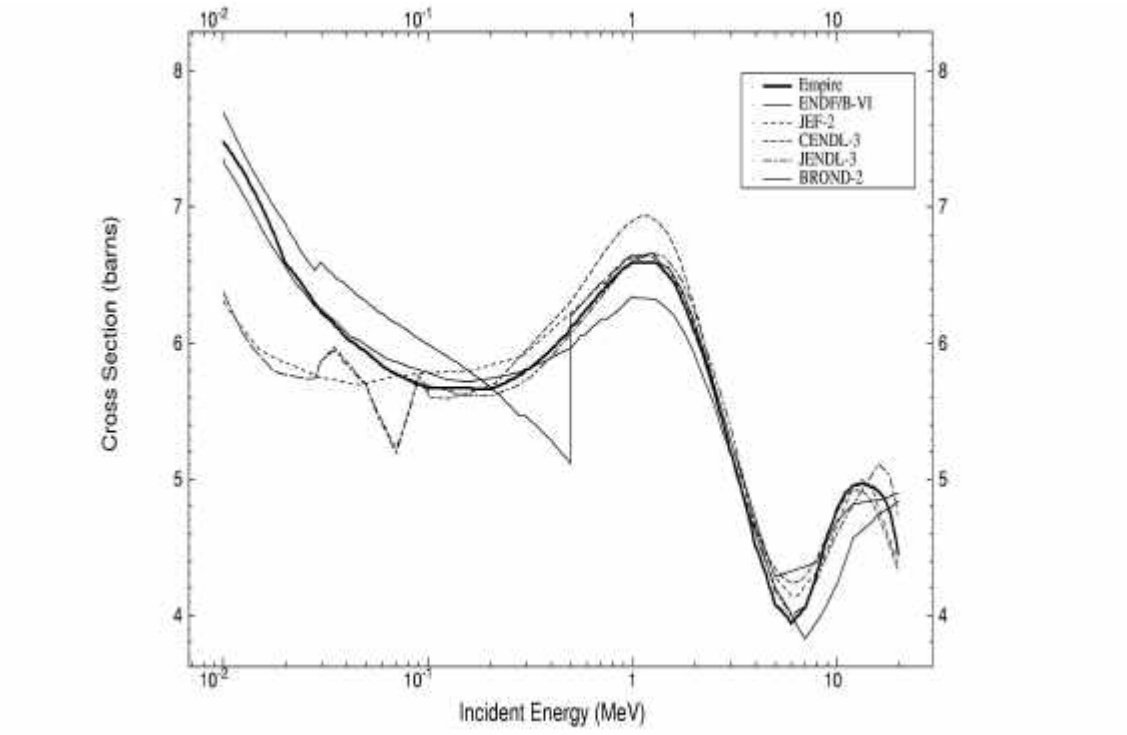

Fig. 3. Total cross section of I-129.

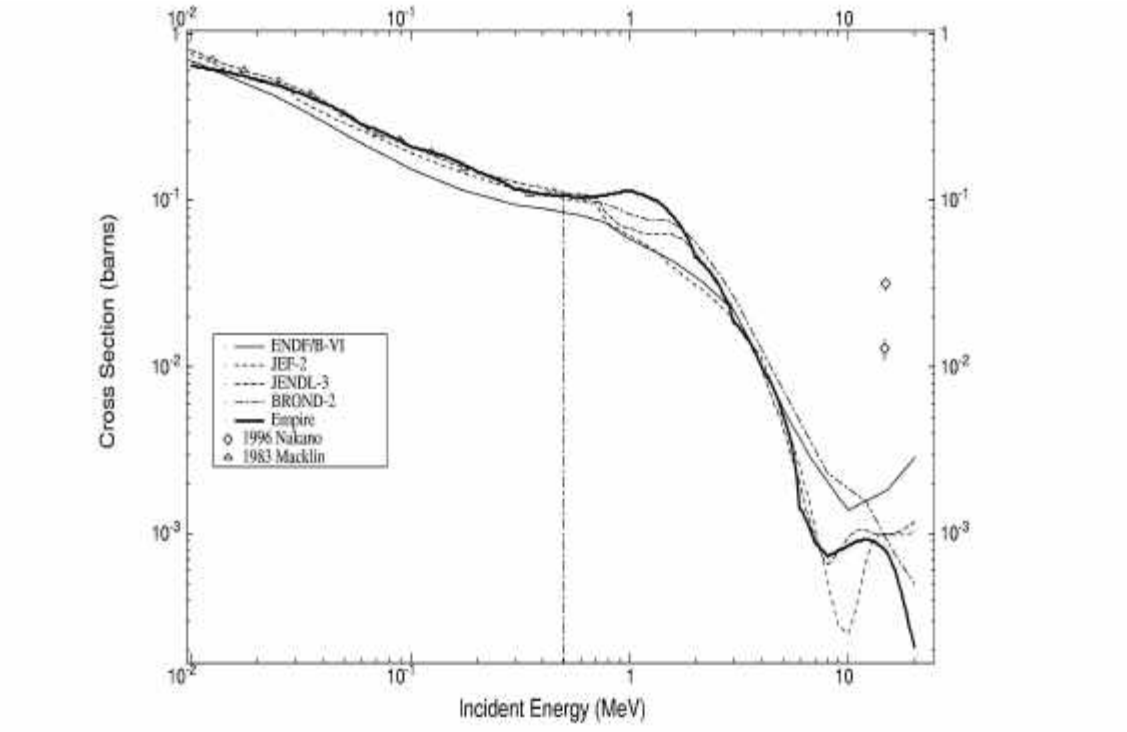

Fig. 4. Capture cross section of I-129.

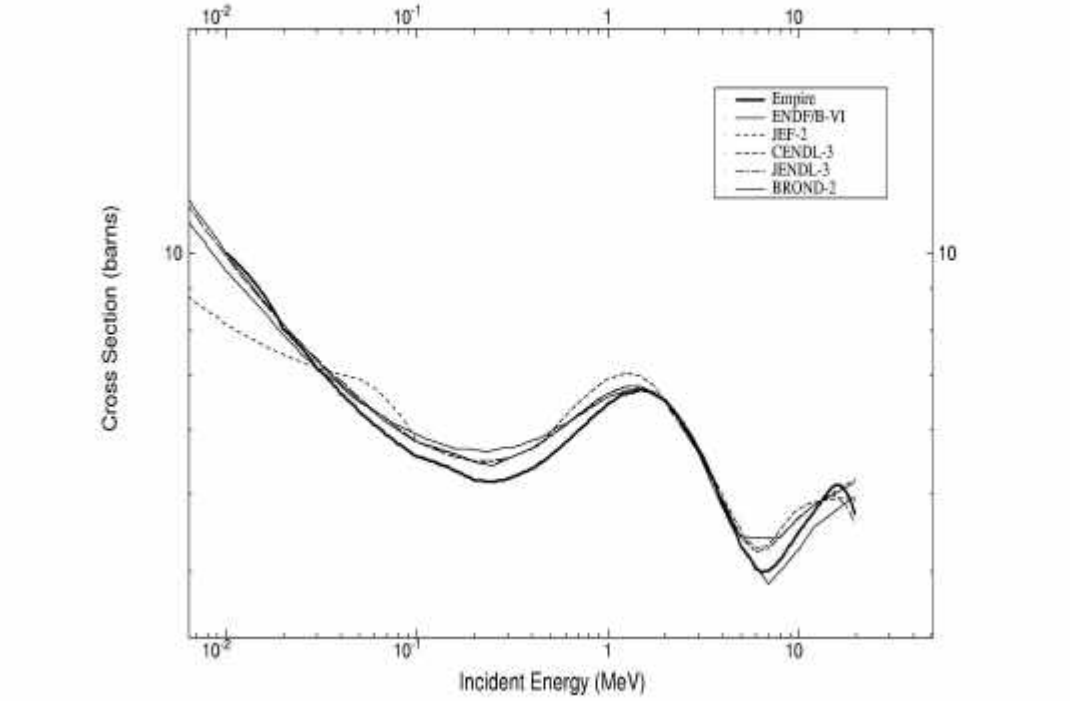

Fig. 5. Total cross section of Cs-135.

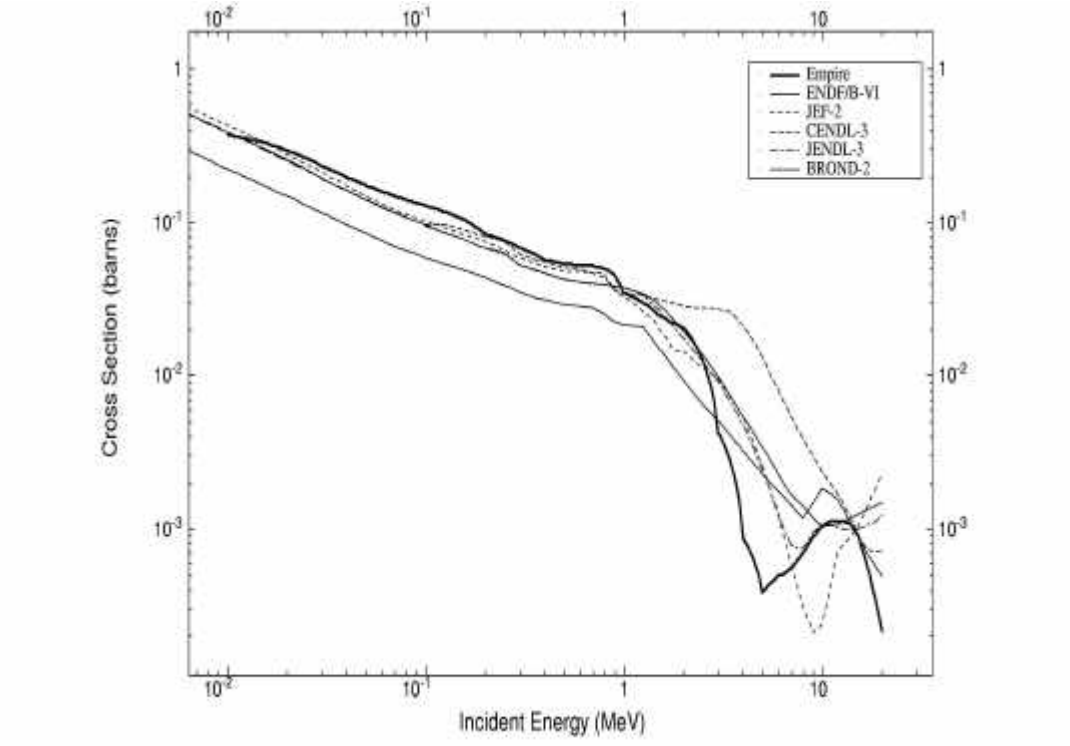

Fig. 6. Capture cross section of Cs-135.