IEC - 146

Status of Subgroup 10 (Fission Product Inelastic Scattering Cross Sections)

At the IAEA specialists meeting on fission product nuclear data held at JAERI in May of 1992, a status review of the evaluated cross sections and the integral test of JENDL-3 and JEF-1 were presented to clarify the problem concerning fission product nuclides[1]. Then, comprehensive report have been presented at 1994 Gatlinburg conference[2]. It contains the activities of subgroup 10 studying methodology of calculating inelastic scattering cross sections of fission product nuclides and integral test of FP cross sections of JENDL and JEF libraries emphasizing the effect of inelastic scattering cross sections. It was concluded that the DWBA method was generally applicable to evaluate direct component of inelastic scattering cross sections for levels of vibrational band, though some ambiguity was remained to apply the conclusion to nuclides around mass of 100, and that the coupled channel theory was needed for calculation of rotational spectrum.

At IRMM, the inelastic scattering cross sections were newly measured for Pd isotopes[3]. The results were well predicted with the coupled channel theory. Recently, we compared the experimental data of both ANL and IRMM for natural palladium with JENDL-3.2 which were evaluated with the ~~DWG~~ DWBA method. The evaluated data show a remarkable agreement with the ~~RIM~~ IRMM data up to 2.5 ~~me~~ MeV and the new ~~AL~~ ANL data (by China et al.) above 6 ~~me~~ MeV. Accordingly, we have reach a conclusion that the ~~DWG~~ DWBA is widely applicable to calculate the direct component of inelastic scattering cross sections by normalizing to the data measured or calculated with the coupled channel theory. It is also guessed that an anomalous behavior of the calculation with the ~~DWG~~ DWBA for nuclides around A=100 was of a special case due to some singularity in the optical potential specular to improper parameter. However, there is yet problem that disagreement is observed between the ~~RIM~~ IRMM and the old ~~AL~~ ANL data (by Smith et al.)[5] below 4 ~~me~~ MeV: reason of the disagreement is not clear to us. The details are given in Annex.

Finally, we wait for the results of JEF analysis on the STEK experiments to discuss the effect of the inelastic scattering cross setions to the reactivity worth for weakly absorbing nuclides. by comparing with the results of JENDL-3.2.

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Sum-up test of inelastic scattering cross sections of Pd

The inelastic scattering cross sections of Pd given in JENDL-3.2 in the region of Ex = 260 to 560 keV, corresponding to the 1st excited states of even-even isotopes of Pd, have been summed up and constracted the inelastic scattering cross section of natural Pd in the same excitation region. This excitation region was determined according to the energy resolution of the experiment at ANL (Chiba et al., Ann. Nucl. Energy, 16, 647(1989)). The following MT's and abundance ratios were adopted;

	MT	abundance ratio
Pd-102	51	1.02
Pd-104	51	11.14
Pd-105	51 - 57	22.33
Pd-106	51	27.33
Pd-108	51	26.46
Pd-110	51	11.72

The abundance ratio was normalized to sum up to unity. The same averaging procedure was applied to the inelastic scattering cross sections of the first 2^+ states in Pd-104, 106, 108 and 110 measured by Meister (ECN-C-94-084). The abundance ratio was also normalized to sum up to unity.

The comparison of the averaged data from JENDl-3.2, Meister's experiment, and measured data by Smith et al. and Chiba et al. for natural Pd is given in Fig. 1. Agreement of the JENDL-3.2 data with the data measured by Meister and Chiba et al. is excellent, therefore confirming the method adopted in the evaluation of the JENDL-3.2 data. Reason of the disagreement with the old data by Smith et al. is not clear to us. Anyway, this figure shows that in the energy region where the direct reaction dominates the JENDL-3.2 gives reasonable excitation function curve.

The JENDL-3.2 was evaluated based on the statistical model and the DWBA, with the optical model parameters of

V = 50.01 - 0.5528E	R = 5.972	a = 0.56
Ws= 8.165	Rs= 6.594	as= 0.44
Vso=5.261	Rso=5.97	aso=0.267

Comparison of JENDL-3.2 data for the inelastic scattering c.s. of ^{92}Zr

Another comparison was made in Fig. 2 for the inelastic scattering cross sections to some low-lying states of ^{92}Zr which include contribution of the direct reaction. The thick solid line denoted as Present correspond to the JENDL-3.2 data which was obtained with the statistical model + DWBA calculations. The parameter of OMP was taken from the default values of SINCROS-2(JAERI-M 90-006(1990)). This figure again confirms the methods adopted for evaluation of JENDL-3.2 data.

In conclusion, we see no specific problems by using DWBA to calculate the direct component of inelastic scattering cross sections of mass aroud 100 except for such obvious cases where a nucleus under interest has a clear rotational spectrum, such as ^{150}Nd for which we have used really a complicated coupling scheme (0^+ - 2^+ - 4^+ - 6^+ - 8^+ - 10^+ - 1^- - 3^- - 5^-), i.e., g.s. rotational band + octupole vibrational band. Still, we feel DWBA could give a reasonable excitation curve if it is normalized properly to the coupled-channel result at a certain energy.

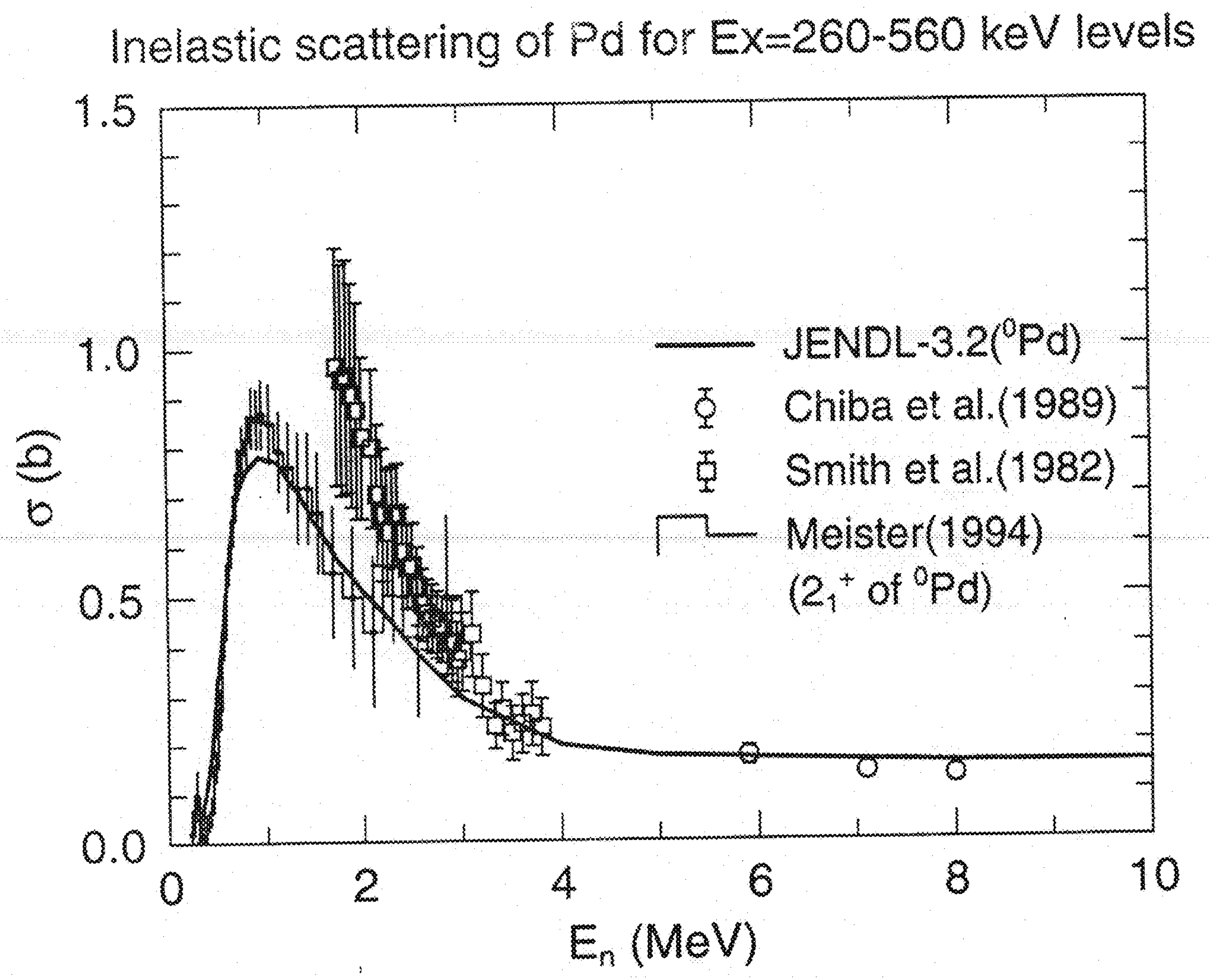
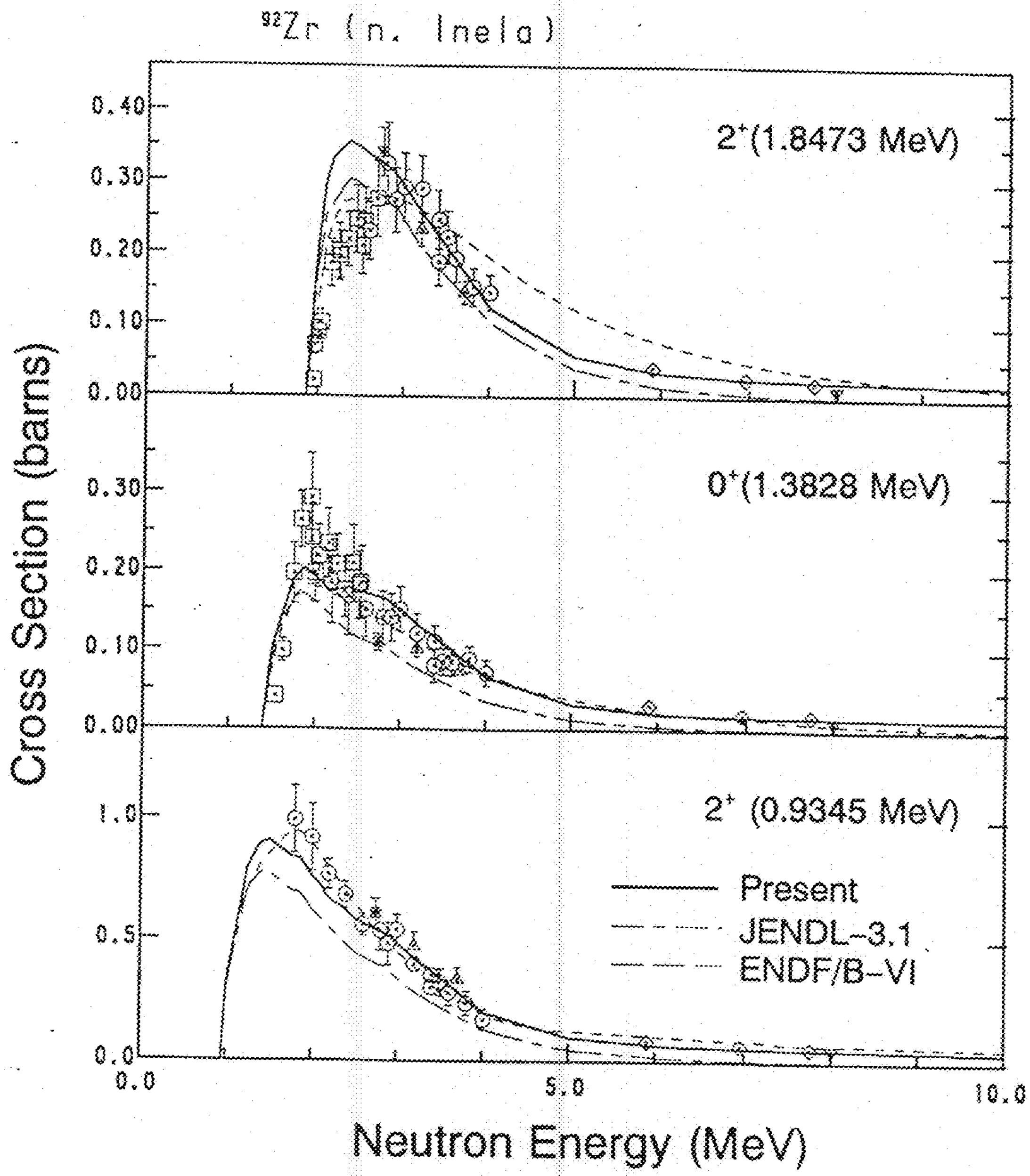

Inelastic scattering of Pd for Ex=260-560 keV levels
σ (b)
1.5
1.0
0.5
0.0
0
2
4
6
8
10
E_n (MeV)
JENDL-3.2(^{0}Pd)
Chiba et al.(1989)
Smith et al.(1982)
Meister(1994)
(2_1^+ of ^{0}Pd)

Fig. 1



^{92}Zr (n, Inela)
2⁺(1.8473 MeV)
0⁺(1.3828 MeV)
2⁺ (0.9345 MeV)
Present
JENDL-3.1
ENDF/B-VI
Cross Section (barns)
Neutron Energy (MeV)
0.00
0.10
0.20
0.30
0.40
0.0
0.5
1.0
5.0
10.0

Fig 2