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Progress Report

of the Nuclear Data and Related Nuclear Physics Activities

at the Energy Research Centre at Petten (The Netherlands)

1 January 1977 until 1 July 1978

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Progress Report for the Period 1 January 1977 until 1 July 1978 of the Nuclear Data and Related Nuclear Physics Activities at the Energy Research Centre at Petten (The Netherlands).

Petten, July 18, 1978.

Fission-Product Nuclear Data Project (compiled by H. Gruppelaar)

1. Introduction

The purpose of the Dutch Fission-Product Nuclear Data (FPND) project is to obtain neutron cross sections for the prediction of the effects of fission products in large fast power reactors. For this purpose neutron cross sections are evaluated from which 26-group constants are calculated and adjusted to fit integral measurements, performed at STEK (Petten) and CFRMF (Idaho). Recently, adjustment have been applied also to evaluated point cross sections. The project is performed in the framework of a cooperation between Germany, Belgium and The Netherlands on fast breeder reactor development. The progress of the project is reported in quarterly reports |1-3|.

In 1977 a great deal of effort has been devoted to prepare a contribution |4| and two reviews |5,6| for the Second I.A.E.A. Advisory Group Meeting on FPND which was held at Petten, September 5-9, 1977. It appeared that the contribution of integral measurements to the present status of fast fission-product capture cross sections was rather important. For most nuclides the requested accuracy could only be reached by using these data in an adjustment process. The contribution of STEK integral data was very significant: in most cases the requirements were met already without the use of other integral experiments.

2. Evaluation of neutron cross sections (microscopic point data)

In refs. |7,8| neutron cross sections are given for 34 fission products, evaluated in 1975 to 1977. The most recent evaluations, yet to be published, are those for the Nd isotopes and for ^{147}Pm. The complete list of nuclides for which the so-called RCN-2 evaluation has been completed is given below: ^{93}Nb, ^{92,94,95,96,97,98,100}Mo, ^{99}Tc, ^{101,102,104}Ru, ^{103}Rh, ^{102,104,105,106,107,108,110}Pd, ^{107,109}Ag, ^{127,129}I, ^{133}Cs, ^{139}La, ^{141}Pr, ^{142,143,144,145,146,147,148,150}Nd, ^{147}Pm, ^{147,148,149,150,151,152,154}Sm. New evaluations are in progress for the stable Eu isotopes. For the capture cross sections the un-

certainty margins and correlation coefficients have been evaluated as well. These results have not been published, but the uncertainty margins of the group constants are given in refs. |14,15|. The format of the evaluated microscopic data files is that of the KEDAK library. These files are available from the NEA Data Bank at Saclay.

Adjusted microscopic cross section evaluations based upon the RCN-2 evaluation and integral measurements in STEK and CFRMF have been obtained by utilizing adjusted statistical-model parameters for a recalculation of the capture cross sections above 1 keV. These data have been obtained so far for 13 nuclides: ^{99}Tc, ^{103}Rh, $^{107,109}Ag$, $^{127,129}I$, $^{147,148,149,150,151,152,154}Sm$.

Recently, a new evaluation of natural Mo cross sections has been completed, containing revised radiative capture data |9| which give about 16% lower average capture cross sections in a fast breeder reactor than the currently used ENDF/B-IV and KEDAK-3 cross sections. The new evaluation |10| is in very good agreement with STEK integral reactivity worths for natural Mo. The data file is available from the NEA Data Bank at Saclay.

Some work has been devoted to the theory of the width fluctuation correction factor used in the statisitcal model, in cooperation with CNEN, Bologna |11|. Other theoretical work has been performed on the pre-equilibrium model |12,13|.

3. Adjustment of 26-group constants and neutron spectra

Unadjusted and adjusted capture group constants (with uncertainties) based upon the RCN-2 evaluation |7,8| and integral STEK reactivity worths have been published in refs. |14,15|. For those nuclides, for which CFRMF activation measurements are also available, both STEK and CFRMF results have been used to obtain adjusted group constants |4|. An outline of some results is given in conference reports |16, 17| and in Table 1. Very recently also adjustment calculations have been performed for the capture cross sections of the stable Nd isotopes and for ^{147}Pm.

The adopted method of adjustment has been described in ref. |18|. This method has also been used for the adjustment of STEK flux and

adjoint flux spectra. For this purpose rather complete 26x26 spectrum co-variance matrices have been calculated, based on assumed basic nuclear data uncertainties |19|. These adjusted STEK spectra have been used to calculate all published results of FPND adjustments |4,5,6,14,15|. Reports on experimentally determined STEK spectra have been given in refs. |20,21|.

4. References

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|2| Hoekstra, E.K. Fast reactor programme, Combined second and third quarter 1977 progress report. ECN-34 (1977)

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|6| Bustraan, M. et al. Integral determination of fission-product neutron capture cross sections for application in fast reactors. ECN-27 (1977).

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|8| Gruppelaar, H. Tables of RCN-2 fission-product cross section evaluation, vol. 2 (13 nuclides), ECN-33 (1977).

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|17| Gruppelaar, H. et al. Neutron capture cross section adjusment based upon integral measurements, Trans. Am. Nucl. Soc. 27 (1977), p. 876.

|18| Dragt, J.B. et al. Methods of adjustment and error evaluation of neutron capture cross sections; application to fission product nuclides. Nucl. Sci. and Eng. 62 (1977) 117.

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|20| Montizaan, J. and H. Ames. Fast neutron spectrum measurements with a proton recoil spectrometer in the fast-thermal coupled critical facility STEK. ECN-26 (1977).

|21| Oei, T.D. et al. Time-of-flight measurements in STEK. ECN-19 (1977)

Table 1

AVERAGE CAPTURE CROSS SECTIONS (IN b) AND THEIR STANDARD DEVIATIONS FOR SOME IMPORTANT F.P. NUCLIDES (SNR-300 FLUX SPECTRUM).

Nuclide	RCN-2 [7,8] (unadjusted)	RCN-2A [14,15] STEK	RCN-2A [4] CFRMF	RCN-2A [4] STEK+CFRMF	ENDF/B-IV
^{95}Mo	0.30 (18%)	0.28 (8%)	-	-	0.29
^{97}Mo	0.30 (17%)	0.30 (9%)	-	-	0.28
^{98}Mo	0.086 (9%)	0.084 (9%)	0.088 (6%)	0.087 (6%)	0.101
^{100}Mo	0.10 (27%)	0.080 (21%)	0.074 (9%)	0.074 (8%)	0.078
^{99}Tc[a]	0.54 (16%)	0.64 (7%)	0.49 (10%)	0.59 (6%)	0.49
^{101}Ru	0.69 (16%)	0.68 (8%)	-	-	0.53
^{102}Ru	0.20 (35%)	0.15 (18%)	0.15 (10%)	0.16 (8%)	0.19
^{104}Ru	0.17 (30%)	0.14 (10%)	0.14 (9%)	0.14 (7%)	0.14
^{103}Rh[a]	0.64 (9%)	0.64 (6%)	0.64 (9%)	0.64 (6%)	0.70
^{105}Pd	0.81 (16%)	0.88 (7%)	-	-	0.83
^{107}Pd	0.96 (55%)	0.93 (10%)	-	-	0.57
^{108}Pd	0.18 (85%)	0.17 (19%)	0.17 (30%)	0.17 (17%)	0.16
^{109}Ag	0.68 (12%)	0.71 (7%)	0.74 (8%)	0.73 (6%)	0.48
^{127}I [a]	0.52 (9%)	0.57 (7%)	0.50 (8%)	0.57 (7%)	0.54
^{129}I	0.34 (25%)	0.30 (12%)	0.30 (9%)	0.30 (8%)	0.38
^{133}Cs	0.51 (12%)	0.51 (7%)	0.46 (6%)	0.49 (6%)	0.48
^{139}La	0.031 (16%)	0.035 (12%)	0.030 (8%)	0.031 (7%)	0.038
^{141}Pr	0.13 (12%)	0.12 (8%)	0.12 (8%)	0.12 (7%)	0.16
^{143}Nd[b]	0.32 (8%)	0.30 (7%)	- -	-	0.30
^{145}Nd[b]	0.46 (9%)	0.48 (7%)	-	-	0.33
^{146}Nd[b]	0.093(15%)	0.090(15%)	0.092 (10%)	0.091 (9%)	0.13
^{148}Nd[b]	0.14 (11%)	0.13 (11%)	0.14 (8%)	0.14 (8%)	0.18
^{150}Nd[b]	0.18 (10%)	0.17 (10%)	0.17 (10%)	0.16 (9%)	0.22
^{147}Pm[b]	1.04 (19%)	1.30 (8%)	1.15 (12%)	1.28 (7%)	1.25
^{149}Sm	2.24 (15%)	2.21 (9%)	-	-	1.41
^{151}Sm	2.13 (9%)	1.80 (14%)	-	-	2.21
^{152}Sm	0.41 (12%)	0.47 (9%)	0.42 (6%)[b]	0.44 (5%)[b]	0.40

a) Revised RCN-2 evaluation.

b) Recent results, not yet published.

The Study of the (n,γ) Reaction (compiled by K. Abrahams)

A. New instrumentation

1. Filtered neutron beam at H.F.R.

For one of the large channels at the research reactor H.F.R. a filter of natural iron with some sulfur and aluminium has been set-up to obtain a 24 keV neutron beam. Measurements have been performed on the reactions Mn(n,γ) and Ni(n,γ).
The filtered beam has an intensity of about 10^6 neutrons/second and an energy spread of 5 keV.

2. Nuclear orientation facilities

a) A design is being made for a new nuclear orientation facility in which, by use of the method of nuclear demagnetisation and application of a superconducting magnet a magnetic field of 10 T and temperatures of 10 mK will be reached. In this way it will be possible to polarise by brute force most odd A nuclides, which are in a metallic lattice.

b) In the existing facility the formerly used neutron monochromator CoFe crystal is exchanged for a Heusler crystal for which the neutron polarisation P_n is 95% and the intensity has risen from 6.10^5 to 4.10^6 neutrons per second.
It has been verified by measurements on the V(n,γ) reaction that the figure of merit $P_n^2 I$ has been increased accordingly.

B. Measurements

1. Measurements on light nuclei (sd shell)

The reactions $^{23}Na(n,\gamma)$, $^{27}Al(n,\gamma)$, $^{31}P(n,\gamma)$ and $^{35}Cl(n,\gamma)$ have been studied on direct and semi-direct components by measurements with polarised neutrons and by measuring the angular correlation of the capture γ's. New measurements have been performed on the mixing of spins in the capture state.
In Al(n,γ) and E1(M2) mixing of the order of one percent has been observed, and in $^{23}Na(n,\gamma)$ an M1(E2) mixing of the order of 10 percent.

2. Measurements on medium weight nuclei (fp shell)

Measurements have been finished on ^{43}Ca, ^{45}Ca, ^{46}Sc, ^{47}Ti, ^{52}V, ^{56}Mn, ^{59}Fe, ^{65}Ni, ^{65}Zn, ^{67}Zn, ^{69}Zn and ^{71}Zn.
On most of these isotopes shell model calculations (surface delta interaction method) are being performed in cooperation with the R. v.d. Graaff Laboratory of the State University of Utrecht.
Also in the analysis of some Zn isotopes excitation energies have been established with an accuracy of 100 eV.

3. Study of some nuclides with about 82 neutrons

Measurements on ^{137}Ba, ^{139}Ba, ^{141}Ce, ^{143}Ce, ^{143}Nd and ^{145}Nd have been finished. Nuclear orientation and γ-polarisation measurements were performed on ^{141}Pr for which a preliminary analysis has been made.

C. Publications

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Nucl. Phys. A299 (1978) 429.

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