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NUCLEAR DATA IN ARGENTINA

(1992 - 1993)

Prepared by G H Ricabarra

Comisión Nacionál de Energía Atómica
Buenos Aires, Argentina

March 1993

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Abstract A progress report of nuclear data research in Argentina is given for the years 1992/1993, including the WIMS nuclear data library update project, and measurements and evaluations of selected neutron induced nuclear reactions

March 1993

1. Description of the WIMS Library Update Project.

A. M.Lerner (CAC-CNEA).

Different groups around the world, already users of the WIMS lattice code, were invited to participate in an international project coordinated by IAEA, called WIMS LIBRARY UPDATE PROJECT (WLUP). Its purpose was to acquire confidence in updating the code's cross section library by means of one of the best tools available at the moment at IAEA: the ENDF/B series of nuclear data libraries (particularly ENDF/B IV and VI).

The first stage proposed was the calculation of a set of well known benchmarks using both code and cross section library as originally provided by NEADB, that is to say the English version of WIMS-D/4. The main goals of the project at this stage were:

Identification of the differences between different versions of the WIMS-D/4 code and of the library stemming from computer adaptations or modifications by the users.

Optimal modeling of the selected benchmark problems.

evaluations of benchmark results obtained with the original WIMS library.

Stage 1 may be divided into two parts:

1a- Benchmark calculations without prescriptions of the input models.

1b- Benchmark calculations with the prescribed input, as provided by the coordinators of the project.

In the second stage, cross sections based on ENDF/B-IV evaluated nuclear data library should be processed. The data entered into the WIMS library after processing with different data processing codes were to be compared.

The third stage involves processing of the more recent evaluated nuclear data libraries and new WIMS library construction. The same set of benchmarks mentioned in the first stage are calculated with the new cross section data.

2. Summary of the Results Obtained in the First Stage.

Ana María Lerner (CAC-CNEA)

The following benchmarks have been analyzed for this stage:

a. TRX - 1
b. TRX - 2
c. BAPL - UO2 - 1
d. BAPL - UO2 - 2
e. BAPL - UO2 - 3

A heterogeneous lattice cell calculation followed by a homogenized-core leakage calculation was performed. No full core calculation is made so that only the lattice code is involved.

Integral parameters have been calculated using WIMS-D/4 and its associated library.

These benchmarks are H2O moderated lattices of slightly enriched uranium rods and only involve the following isotopes: U235, U238, H, O and Al.

The input data for WIMS were here chosen by the author. The coordinators prescriptions for these data were also run; the results obtained were identical to those reported by

them and thus are not shown in this summary.

Some results using the CNRL (Chalk River) 69 group WIMS library are also obtained. The MIT - 1 D2O lattice was also calculated, although it was not contained in the original IAEA's proposal.

The general agreement between calculated and measured values, with both the standard library and the Chalk River Library, is satisfactory. Although the last one seems to give better values for k-effective, both libraries predict integral parameters which agree with their measured values.

When dealing with D2O moderated lattices, the situation is somewhat different. Systematic underestimation of reactivity is observed with the standard library, while the Chalk River Library gives better agreement. This is mainly due to the evaluation of U238 and U235 as well as to the hardness of the fission spectrum.

The influence of the buckling measurement error on k-effective is bigger than all the other factors. The following table summarizes the results.

Standard Library

CASE:		TRX-1	TRX-2	BAPL-1	BAPL-2	BAPL-3
ρ^{28}	E	1.320±0.021	0.837±0.016	1.39±0.01	1.12±0.01	0.906±0.01
	C	1.28110	0.80510	1.36880	1.14220	0.89980
δ^{25}	E	.0987+.001	.0614+.0008	.084+.002	.068+.001	.0524+.001
	C	.09900	.06085	.08405	.06865	.05285
δ^{28}	E	.0946+.0041	.0693+.0035	.078+.004	.070+.004	.057+.003
	C	.09674	.06953	.07681	.06627	.05457
C^*	E	.797+.008	.647+.006			
	C	.78100	.63520	.80430	.73530	.65940
k-eff		1.002526	1.001372	1.00070	0.99963	0.99911

Chalk River Library

CASE:		TRX-1	BAPL-1	MIT - 1
ρ^{28}	E	1.320+0.021	1.39+0.01	0.498+0.008
	C	1.3227	1.3680	0.4357
δ^{25}	E	.0987+.001	.084+.002	.0447+.0019
	C	.0971	.0807	.0410
δ^{28}	E	.0946+.0041	.078+.004	.0597+.002
	C	.1008	.07591	.0529
C^*	E	.797+.008		1.017+.012
	C	.7897	.7992	.9329
k-eff		0.99888	0.99984	0.99908

For each parameter the first value corresponds to measurement (E) and the second to calculation (C).

The input data for these set of lattices chosen by the author (A.M.L.) have no essential differences with those obtained with the prescribed inputs as distributed by the coordinators of the project.

3. Summary of the Results Obtained at Centro Atómico Bariloche.

Francisco Lestczynski (CAB-CNEA).

3.1. The same set of benchmark lattices was calculated by the author with his own selection of input data (only for the BAPL series) and with the prescribed inputs for the whole set. The results are shown in the table below.

3.2. In what refers to stage 2, a WIMS library has been generated for the isotopes H, O, Al, U235 and U238 from the ENDF/B-IV nuclear data file.

A new computational system has been developed for updating and generating multigroup data libraries to be used with different computer programs, particularly WIMS.

The main elements of this System are: a basic data library in ENDF/B format, the NJOY system, the RMET21 code for generating resonant multigroup constants, and a new program called WILIMO, for construction of a new library or modification of data of an already existing one. These programs were already sent to NEADB.

The results obtained with the new WIMS Library thus generated are also shown in the table below.

WIMS Library (Standard and ENDF/B-IV)

CASE:		TRX-1	TRX-2	BAPL-1	BAPL-2	BAPL-3
ρ^{28}	E	1.320+0.021	0.837+0.016	1.39+0.01	1.12+0.01	0.906+0.01
	B	1.2630	0.7967	1.3454	1.1227	0.8849
	C			1.3456	1.1243	0.8858
	D	1.3295	0.8329	1.4136	1.1759	0.9235
δ^{25}	E	.0987+.001	.0614+.0008	.084+.002	.068+.001	.052+.001
	B	.09900	.0610	.0840	.0687	.0529
	C			.842	.0688	.0530
	D	.0990	.0607	.0839	.0684	.0526
δ^{28}	E	.0946+.0041	.0693+.0035	.0778+.004	.070+.004	.057+.003
	B	.0965	.0695	.0755	.0652	.0538
	C			.762	.0658	.0542
	D	.0964	.0685	.0749	.0644	.0527
C^*	E	.797+.008	.647+.006			
	B	.7745	.6321			
	D	.7815	.6318	.8028	.7315	.6537
k-eff	B	1.00231	0.99664	1.00108	0.99908	0.99740
k-eff	D	0.99204	0.99097	0.99361	0.99345	0.99367

The author shows that his results for these benchmarks

give integral parameters in close agreement with measurements.

Detailed comparisons, in what refers to microscopic parameters are still required, and will be performed as continuation of this work.

The preceding table shows measured values (E), calculated values with prescribed input data and standard library (B), calculated values (not all cases run) with author's input data and standard library (C), and calculated values with prescribed input data and WIMS library generated with the author's system from ENDF/B-IV data file (D), in this order. The values for k effective correspond to standard library with author's input (C) and ENDF/B-IV library with prescribed input data (D).

3.3. As Stage 3 of this project, a nuclear data library for WIMS was generated for the isotopes H, O, Al, U235 and U238 from the ENDF/B-VI evaluated nuclear data file.

The computational system used in this work was the same as that described in Stage 2.

The same set of benchmark lattices was calculated, using the standardized input data provided by the coordinators of the Project. The results (C), as compared with measured values (E), are shown in the table below.

WIMS Library (ENDF/B-VI)

CASE:		TRX-1	TRX-2	BAPL-1	BAPL-2	BAPL-3
ρ^{28}	E	1.320+0.021	.837+0.016	1.39+0.01	1.12+0.01	.906+0.01
	C	1.25710	.7919	1.3534	1.1285	.8836
δ^{25}	E	.0987+.001	.0614+.0008	.084+.002	.068+.001	.052+.001
	C	.0965	.0594	.0819	.0669	.0515
δ^{28}	E	.0946+.0041	.0693+.0035	.078+.004	.070+.004	.057+.003
	C	.0955	.0681	.0741	.0638	.0523
C^*	E	.797+.008	.647+.006			
	C	.7514	.6127	.7771	.7103	.6370
k-eff		1.00584	.99977	1.00500	1.00289	1.00094

The general agreement between calculated and measured values is satisfactory, particularly in what refers to integral parameters, when the standard library is used. The library generated from ENDF/B-IV, when using the same input data, produces good integral parameters, with a small underestimation of k effective. It should be emphasizes that the good results here obtained reflect that the resonance parameter calculation can be used with confidence.

When ENDF/B-VI is used to generate WIMS library with the methodology already described, the results obtained for k effective are very near their experimental values, while the other integral parameters differ a little from their measurements. Further improvements may be achieved using more realistic condensation spectra for library generation.

NOTE: The three preceding abstracts have been prepared by Ana Maria Lerner, (Buenos Aires, February 1993), using the following documentation :

WIMS LIBRARY UPDATE PROJECT. First Stage - Preliminary results. - Ana Maria Lerner. I.T. 1006/91. (CNEA).

WIMS LIBRARY UPDATE PROJECT. First Stage. Second Version. Ana Maria Lerner. I. T. 1064/91. (CNEA).

WIMS LIBRARY UPDATE PROJECT - Stage One / Stage TWO / stage Three. Fracisco Lesczcynski. CNEA - CAB - NT. 1992.

4. INTEGRAL FISSION CROSS SECTION RATIOS OF TH232, U236 AND U238 RELATIVE TO U235 IN THE NEUTRON SPECTRUM PRODUCED BY 23.2 MeV DEUTERONS INCIDENT ON A THICK Be METAL TARGET.

M.D. Bovisio de Ricabarra, D. Waisman L. Cohen de Porto and G.H. Ricabarra

Integral neutron fission cross section ratios have been measured for Th232 /U238, U238/U235 and U236/U235 in the neutron field produced by bombardment of a thick Be metal target with 23.2 MeV deuterons. Validation of Th232, U236 , U238 fission cross sections in a high energy neutron continuum spectrum is the object of this work. The neutron spectrum in the irradiation site has been obtained by unfolding of the neutron induced activity of eleven selected reactions. The average standard deviation between calculated activities with SAND-II unfolding code and the experimental input activities was 2.5 %. Calculated values of the fission cross section ratios were obtained from the ENDF/B-V evaluated library of cross sections and the measured spectrum. These ratios were not sensitive (<0.7%) to quite different SAND-II input spectra assumed in in the low energy spectrum range (0.5-2 MeV). Analyses of error sources, errors propagation and their correlations was made and the correlation matrix of the experimental results was calculated. The experimental and calculated values obtained are consistent within the errors. Examination of the fissile ratios measured in other continuum neutron spectra shows a similar consistency in the spectrum produced by 7 MeV deuterons on Be. However in Cf252 and thermal U235 fission neutron spectra, a large discrepancy is found for Th232.

Experimental and Calculated Integral Fission Cross Section Ratio Results

		ENDF/B-V		ENDF/B-VI	
<σf> Ratio	Experimental	Calc.	C/E-1	Calc.	C/E-1
Th232/U238	0.3162±2.3%	0.3211	+1.5%	0.3225	+2.0%
U238/U235	0.4545±1.9%	0.4421	-2.8%	0.4444	-2.2%
U236/U235	0.7081±2.1%	0.6960	-1.7%		
Th232/U235	0.1437±2.9%	0.1420	-1.2%	0.1433	-0.3%

Fission Cross Section Ratios
in Different Neutron Spectra

<σf> Ratio	Spectrum	Exp	Calc*	C/E-1 %	Ref
	7MeV d,Be	0.2580	0.2608	1.1	4
Th232	7MeV d,Be		0.2640b	2.3	4
———	Ther Fiss	0.2640	0.2464	-7.1	3
U238	Ther Fiss	0.2665		-8.2	2
	Cf252	0.2740	0.2489	-10.1	1
	23MeV d,Be	0.3162	0.3211	1.5	c
U238	7MeV d,Be	0.3780	0.3850	1.9	4
———	Cf252	0.2681	0.2540	-5.6	1
U235	Cf252	0.2741		-7.9	1
	23MeV d,Be	0.4545	0.4421	-2.8	c
U236	7MeV d,Be	0.6235	0.6620	6.5	4
———	7MeV d,Be		0.6670b	7.0	4
U235	23MeV d,Be	0.7081	0.6960	-1.7	c
Th232	7MeV d,Be	0.0975	0.1003	2.9	4
———	Cf252	0.0735	0.0630	-16.6	1
U235	Cf252	0.0751		-19.2	1
	23MeV d,Be	0.1437	0.1420	1.2	c

* Most values calculated with ENDF/B-V
b Calculated with JENDL-2 c This paper

References :
1. W. Mannhart, "Handbook on Nuclear Activation Data", Tech. Rep. Series Nº273, IAEA (1987), (Part 2-4, pp 420,421,425,426)
2. A. Fabry et al., "Neutron Cross Sections for Reactor Dosimetry", V I (revew papers), IAEA-280, 233, Vienna (1978).
3. M. B. Ricabarra et al., "Nuclear Data for Science and Technology", 123-126, 1988, Mito, Japan. (Ed. Igarasi, JAE).
4. Y.Watanabe et al., Ann. Nucl. Energy, 14, 563 (1987).

5. INTEGRAL ACTIVATION CROSS SECTION RATIOS OF Ti(n,x)Sc46, Ti(n,x)Sc47, Ti48(n,p)Sc48, Ti50(n,α)Ca47 RELATIVE TO Al27(n,α)Na24 IN THE NEUTRON SPECTRUM PRODUCED BY 23.2 MeV DEUTERONS INCIDENT ON A THICK Be METAL TARGET.

M.D. Bovisio de Ricabarra, D. Waisman and G.H. Ricabarra

Integral activation cross section ratios have been measured for Ti(n,x)Sc46, Ti(n,x)Sc47, Ti48(n,p)Sc48 and Ti50(n,α) Ca47 relative to Al27(n,α)Na24 in the neutron spectrum produced by 23.2 MeV deuterons incident on a thick metal Be target. Validation of these cross sections in a high energy neutron continuum spectrum is the object of this work. The neutron spectrum in the irradiation site has been obtained in a previous work and tested by the excellent agreement (1-3%) between experimental and ENDF-B/V or VI, calculated fission ratios to U235. Evaluated activation cross section libraries have been used to calculate the titanium integral activation cross sections in the irradiation spectrum. In addition a new group of experimental differential data, non evaluated, pub-

lished from 1990 to 1992 (Jülich, Geel, ANL) was also used to calculate the integral cross sections. A comparison of the Ti isotopes experimental integral cross section with the calculated values shows an excellent agreement with the new set of non evaluated data and poor agreement with the evaluated libraries. Cf252 spectrum averaged cross section shows similar behavior.

Experimental Integral Cross Sections and Calculated with Jülich-Geel-ANL Data

Reaction	Experimental <σ> (mbarn)	Calculated* <σ> (mbarn)	(C/E-1) %
Ti(n,x)Sc46	149.5±3.3%	149.0	-0.3
Ti(n,x)Sc47[c]	14.15±5.2%	14.98[a]	+5.9
Ti48(n,p)Sc48	19.90±3.4%	19.80	-0.5
Ti50(n,α)Ca47	2.584±5.2%	2.572	-0.5

* <σ> averaged on unfolded neutron spectrum ITER1.
[c] Ti(n,x)Sc47 per atom of Ti47+Ti48(81.2%).
[a] σ(E) for 3MeV<E<5.37MeV from ANL.

Experimental and Calculated Integral Cross Sections with Evaluated Libraries

Reaction	Experimental <σ> (mbarn)	Calculated <σ> (mbarn)*			
		IRDF90	Manokhin	ENDF/B-VI	Chinese
Ti46(n,p)Sc46		119.0	129.9	124.3	
Ti47(n,np)Sc46		16.81		16.69	
Ti(n,x)Sc46	149.5±3.3%	135.8-9.2%		139.4-7%	138.9-7%
Ti47(n,p)Sc47		66.59	70.74	73.18	
Ti48(n,np)Sc47		4.018	3.904	3.968	
Ti(n,x)Sc47[c]	14.15±5.2%	9.72-33%	9.99-29%	10.3-27%	
Ti48(n,p)Sc48	19.90±3.4%	18.13-8.9%	18.04-9%	18.85-5%	18.04-9%

* <σ> averaged on unfolded neutron spectrum ITER1. The value of (C/E-1) in % is quoted with each calculated value.
[c] Ti(n,x)Sc47 per atom of Ti47+Ti48(81.2%).

Cf252 Spectrum Averaged Neutron Cross Sections

Reaction	Jülich-Geel-ANL		ENDF/B-VI		Mannhart*
	<σ> mbarn	C/E-1 %	<σ> mbarn	C/E-1 %	<σ> mbarn
Ti46(n,p)Sc46	13.88	-2.2	13.47	-5.1	14.20±0.24
Ti47(n,p)Sc47	19.63	-1.0	24.07	+24	19.43±0.31
Ti48(n,p)Sc48	0.4364	+1.4	0.4092	-4.2	0.4275±0.0078

* Recommended exp. values from W.Mannhart, Handbook Nucl. Act. Data, Tech. Rep. Ser. №273, IAEA (1987), (Part 2-4, p. 416).

6. ALPHA AND DEUTERON INDUCED REACTIONS ON VANADIUM

A.A. Sonzogni, A.S.M.A. Romo, H.O. Mosca and S.J. Nassiff (CONICET, CNEA)

The stacked foil technique was used in combination with gamma ray spectroscopy to obtain excitation functions for the production of different nuclei using natural vanadium as target and 85 MeV alpha particles and 46.5 MeV deuterons as projectiles. The data are compared with theoretical predictions provided by an equilibrium and pre-equilibrium reaction model. In most cases the theoretical predictions seriously underestimated the measured cross sections.

CONICET : Consejo Nacional de Investigaciones Cientificas y Técnicas. Argentina.

7. A CODE TO DETERMINE THE ENERGY DISTRIBUTION, THE INCIDENT ENERGY AND THE FLUX OF A BEAM OF LIGHT IONS INTO A STACK OF FOILS

A.A. Sonzogni, A.S.M.A. Romo#, W.R. Frosch and S.J. Nassiff (CNEA)

The stacked-foil technique is one of the most used methods to obtain excitation functions of nuclear reactions using light ions as projectiles. The purpose of this program is the calculation of the energy of the beam in the stack, as well as the obtainment of the incident energy and the flux of the beam by using monitor excitation functions.

8. 184(m,g)Re CROSS SECTIONS AND ISOMERIC RATIOS IN 181Ta(α,n) AND W(α,pxn) REACTIONS

Ozafran M.J., Mosca H.O., Vazquez M.E., Frosch W.R., Nassiff S.J. (CNEA)

Excitation functions and isomeric ratios for 184Re from α-induced reactions on 181Ta and natural W have been measured using the "stacked-foil" method. The data are compared with the theoretical results provided by equilibrium and pre-equilibrium reaction model, for this purpose we used the code INDEX of Ernst.

This work has been sponsored by the CONICET.

9. EXCITATION FUNCTIONS FOR NUCLEAR REACTIONS INDUCED BY ALPHA PARTICLES ON NATURAL YTTERBIUM

A.S.M.A. Romo, A.A. Sonzogni, D.A. Rodriguez Sierra and S.J. Nassiff (CNEA)

The Cumulative Cross Sections for the production of different nuclei using natural ytterbium as target and 84.38 Mev alpha particles as projectiles, were determined using the stacked foil technique in combination with gamma ray spectroscopy. The data are compared with theoretical predictions provided by an

equilibrium and pre-equilibrium reaction model.

10. (α,pxn) REACTIONS ON NATURAL SAMARIUM
OZAFRAN M.J., ARCHENTI A., VAZQUEZ M.E., NASSIFF S.J. (CNEA)

A stack of natural Samarium was bombarded with 87 MeV alpha particles. Cumulative cross sections for the production of 145Eu, 146Eu, 147Eu, 148Eu, 150Eu, 152Eu,154Eu have been studied using gamma ray spectroscopy. The data are compared with the theoretical results provided by equilibrium and pre-equilibrium reaction models, for this purpose we used the code ALICE of Blann.

11. STUDY PRE-EQUILIBRIUM EFFECTS ON α-INDUCED REACTIONS ON COPPER
O.BONESSO, M.J.OZAFRAN, H.O.MOSCA, M.E.VAZQUEZ, O.A.CAPURRO, S.J. NASSIFF (CNEA)

A stack of natural copper was bombarded with α-particles. Cumulative cross-sections for 65Ga, 66Ga and 65Zn productions, and the excitation functions for 68Ga and 67Ga production, were measured using high resolution gamma ray spectroscopy.The data are compared with the theoretical result provided by equilibrium and pre-equilibrium reaction model, for this purpose we used the code ALICE of Blann.The overall agreement with theory is good. Besides, we present the experimental data obtained by other authors.

12. CROSS SECTIONS AND THICK TARGET YIELDS OF (α,pxn) REACTIONS ON NATURAL PLATINUM
O.A.CAPURRO, O.BONESSO, S.J.NASSIFF (CNEA)

Excitation functions for production of 194Au, 195(m+g) Au, 196(m+g)Au, 198mAu, 198gAu, 199Au were determined experimentally. In addition, the yields of thick targets of these products were calculated and a comparison between the cross sections obtained using the hybrid model of pre-equilibrium reactions in combination with the statistical model of compound nucleus is present. The method of activation of metallic foils was employed . The irradiations were performed in the internal beam of the isochronous cyclotron at Karlsruhe (FRG) with α-particles at 90 MeV. Gamma Spectrometry by means of an intrinsic Ge detector was used to determine the nuclides produced.