PHYSOR 2004 -The Physics of Fuel Cycles and Advanced Nuclear Systems: Global Developments
Chicago, Illinois, April 25-29, 2004, on CD-ROM, American Nuclear Society, Lagrange Park, IL. (2004)

Irradiation Experiment Analysis for Cross Section Validation

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An analysis of the irradiation experiment TRAPU performed at the French fast reactor PHENIX is presented. The observed C/E's on the final densities of the measured isotopes for the different basic data files (JEF2.2, ENDF/B-V, and ENDF/B-VI) indicate some large discrepancies that a subsequent sensitivity analysis attributes to specific cross sections of actinides. Among them: ^{238}U σ(n,2n), and capture cross sections of higher plutonium isotopes, ^{241}Am, ^{243}Am, and ^{242}Cm. capture cross sections. Very useful information is gained by performing a simulated adjustment that uses the observed C/E's and the calculated sensitivity coefficients. In particular this adjustment shows that a good consistency can be reached on final adjusted cross sections, and associated new C/E's, starting from different data files. The same adjustment shows that we cannot reach definite conclusions on many fission cross sections (^{238}Pu, ^{241}Pu, ^{242}Am, and ^{243}Cm), because the experiments were not sensitive enough to these parameters.

1. Introduction

The fuel form to be used in advanced nuclear systems dedicated to transmutation will contain a high fraction of Minor Actinides (MA). Good quality cross section data are therefore required for these isotopes in order to provide a reliable neutronic design. Basic data are available for these isotopes but still a validation is needed in order to quantify their reliability. This is traditionally done through the use of integral experiments. Integral experiments in reactors play an essential role in nuclear data validation and improvements. The information that can be gathered on MA from experiments comes mostly from small sample irradiation, reactivity oscillation, and fission and capture rates measurements. Separate isotope sample and fuel pin irradiation in power reactors provides a unique source of high accuracy measurements.

In the framework of the CEA/DOE international collaboration on the AFCI (Advanced Fuel Cycle Initiative) program, several efforts are being made to provide a careful assessment on how we can exploit the CEA experimental data base on Minor Actinides to validate and improve the current set of cross sections (JEF and ENDF libraries) and decay constants.

The cleanest and most useful irradiation experiments available in the CEA data base are the PROFIL and TRAPU programs [1]

The analysis of the PROFIL-1 experiments has been the object of a previous paper [2]. In this paper, we will focus on the TRAPU experiment. After a brief description of the experimental information, the methodology for calculating the final densities and the related observed C/E's for different sets of basic data (JEF2.2, and ENDF/B-VI) will be shown. A subsequent sensitivity analysis is reported in order to attribute the discrepancies between calculational and experimental results to specific cross sections.

Finally a simulated adjustment will be shown where the observed C/E's and the calculated sensitivity coefficients are used to gather information on possible trends for improved MA cross sections.

2. The TRAPU Experiment

The TRAPU experiment consisted of a six-cycle irradiation(10^{th} to 15^{th}) of mixed-oxide pins that contained plutonium of different isotopic compositions but heavily charged in the higher isotopes (^{240}Pu, ^{241}Pu and ^{242}Pu) compared to typical PHENIX fuel. Standard pins were placed in regular PHENIX subassemblies and irradiated in an assembly located in the third row of the reactor (see Fig.1). Three types of plutonium containing pins were used. Table 1 summarizes the plutonium isotopic compositions of the three pins.

After irradiation, small samples (20 mm high) were cut from the experimental pins (both fuel and clad) and put into a solution in order to determine the fuel composition by nuclide. Neodymium-148 was used as burnup indicator since it is a stable fission product with a small capture cross section, and it enables determination of the number of fission reactions that have taken place in the sample. Mass spectrometry was then used, with simple or double isotopic dilution and well-characterized tracers.

Table 1 Plutonium Isotopic Compositions of the Three TRAPU Fuel Pins

Experiment	Isotope Composition [%]				
	Pu-238	Pu-239	Pu-240	Pu-241	Pu-242
TRAPU-I	0.1	73.3	21.9	4.0	0.7
TRAPU-II	0.8	71.4	18.5	7.4	1.9
TRAPU-III	0.2	34.0	49.4	10.0	6.4

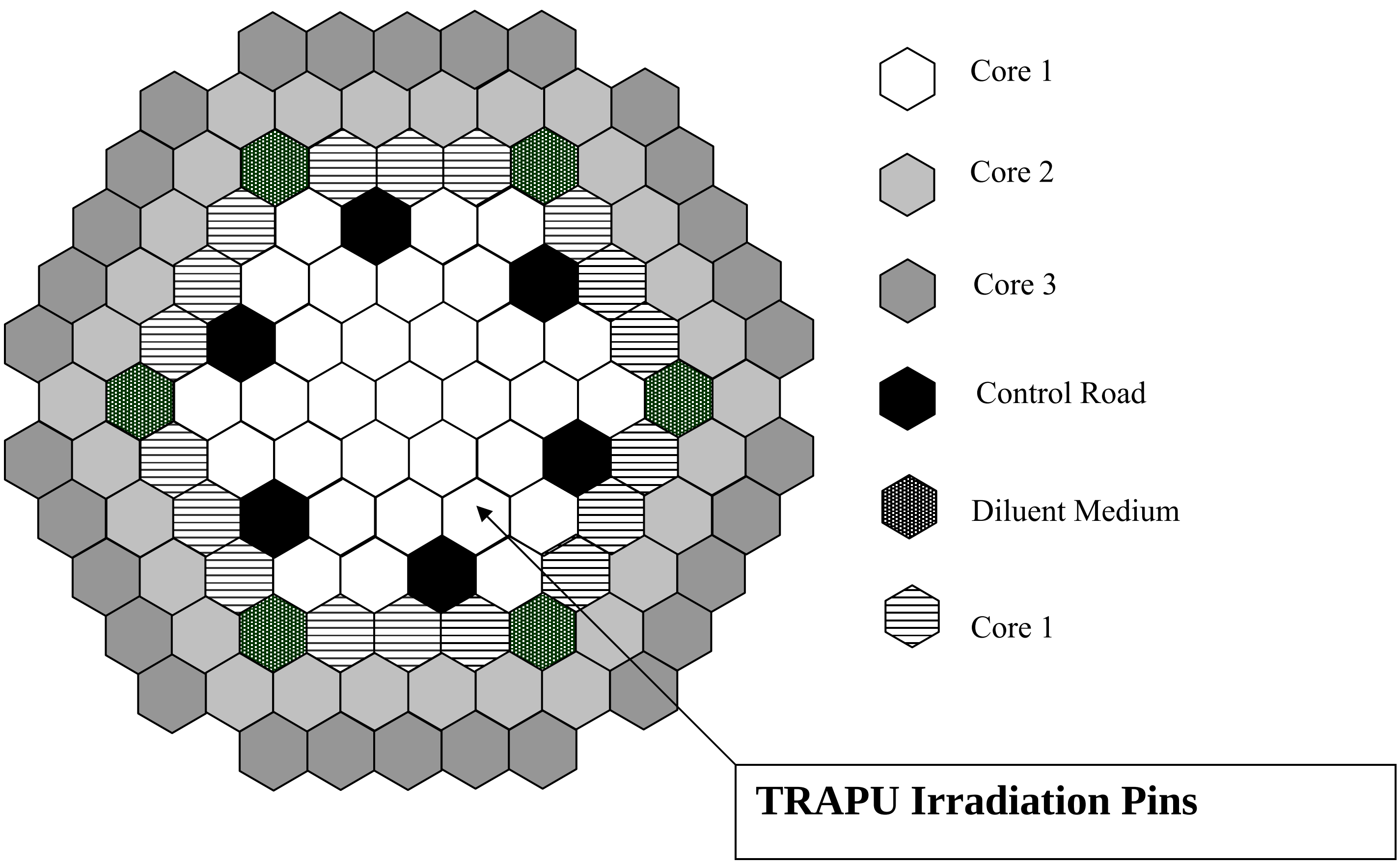

Figure 1. Position of the TRAPU Irradiation Pins in the PHENIX Fast Reactor Core

3. Analysis of Experimental Results

Cross sections in a 33-group energy structure have been generated using the ECCO and MC^2-2 cell codes (with JEF2.2 and ENDF/B-VI data respectively) using a RZ model of PHENIX. Geometric details as well as isotopic compositions by region of this reactor model are relative to the first cycle of the PHENIX reactor. This is the only information that were currently available; in the future more detailed geometry and composition information specific to the TRAPU irradiation period will be available. One-group cross sections have been obtained by condensing the 33-group structure cross sections coming from the cell calculation with the fluxes calculated at the position.

In order to correctly normalize the results to the actual value of the flux (and hence eliminate the uncertainty in the total burnup), the production of ^{148}Nd in the fuel pin has been calculated and compared with the correspondent experimental values (measured flux level were available for the TRAPU irradiation period). Correcting factors have been obtained and applied to the values of the fluxes used in the time-dependent calculations.

Time dependent calculations were subsequently performed with the NUTS code [3] in order to obtain isotope concentrations at the end of irradiation. Results for the different sets of basic data and the three TRAPU pins are reported in Tables 2 and 3. Uncertainties on the final concentrations of the measured isotopes have been obtained by statistically combining the provided experimental uncertainties on the final concentration with the variations on the final densities obtained by propagating the uncertainties on the initial concentrations through a depletion calculation.

The JEF2.2 C/E's are in a general agreement with the previous analyses [2, 3] performed by our French colleagues. ^{237}Np show a large discrepancy, an underestimation of the order of 30%, while ^{241}Am, ^{242}Am, ^{243}Am, and ^{244}Cm exhibit large overestimation (between 10 and 30%). This latter isotope has a clear inconsistency among the results of the three pins, and, likely, the TRAPU-I result should be discarded.

ENDF/B-VI results show, in general a better agreement than JEF2.2 with the experimental measurements, except for the case of ^{243}Cm where almost a 50% discrepancy is observed. ^{237}Np results are similar to JEF2.2, while ^{242}Am and ^{244}Cm have opposite sign discrepancies with respect to JEF2.2.

In general the observed C/E's seem to agree with the previous analysis performed for the PROFIL [2] irradiation experiments.

4. Sensitivity Analysis

In order to better understand the observed discrepancies on C/E ratio, and also in view of performing a simulated adjustment of cross sections that can provide further information on how to improve their data, a sensitivity analysis has been carried out on the three different pins of TRAPU for each individual measured isotope. Each experimental measure requires a NUTS calculation that provides the corresponding sensitivity coefficients. Results obtained using as starting data the JEF2.2 one group cross sections are shown in Tables 4 and 5 for the TRAPU-1 pin. Only calculations with JEF2.2 data have been performed because of the perturbation nature of the sensitivity calculation: using a different library will affect the final sensitivity coefficients with only second order type effects.

Table 2. C/E Values of Final Concentrations in the TRAPU Experiment Using JEF-2 Data.

Isotope	TRAPU-1	TRAPU-2	TRAPU-3
U-234	0.97± 3.9 %	1.00± 3.8 %	1.04± 4.6 %
U-235	0.99± 0.4%	1.00± 0.4 %	1.00± 0.4 %
U-236	0.98± 0.8 %	1.00± 1.0 %	1.00± 0.9 %
Np-237	0.70± 6.8 %	0.71± 3.3 %	0.69± 3.2 %
Pu-238	1.02± 1.5 %	1.03± 1.0 %	1.08± 1.6 %
Pu-239	1.02± 0.6 %	1.01± 0.5 %	1.01± 0.4 %
Pu-240	1.02± 0.6 %	1.00± 0.6 %	0.99± 0.6 %
Pu-241	1.09± 0.6 %	1.03± 0.6 %	1.06± 0.6 %
Pu-242	1.15± 0.8 %	1.07± 0.6 %	1.04± 0.6 %
Am-241	0.96± 3.2 %	0.96± 3.9 %	0.96± 2.6 %
Am242M	1.08± 3.8 %	1.11± 4.3 %	1.10± 3.1%
Am-243	1.18± 2.6 %	1.13± 3.1 %	1.15± 2.5 %
Cm-242	1.10± 3.9 %	1.07± 3.1 %	1.07± 2.7 %
Cm-243	-	0.88± 3.1 %	0.89± 3.2 %
Cm-244	1.20± 2.1 %	1.32± 2.3 %	1.33± 1.8 %

Table 3. C/E Values of Final Concentrations in the TRAPU Experiment Using ENDF/B-VI Data.

Isotope	TRAPU-1	TRAPU-2	TRAPU-3
U-234	0.96± 3.9 %	0.99± 3.8 %	1.03± 4.6 %
U-235	0.99± 0.4%	1.01± 0.4%	1.01± 0.4%
U-236	1.01± 0.8 %	1.03± 1.0 %	1.02± 0.9 %
Np-237	0.75± 6.8 %	0.75± 3.3 %	0.73± 3.2 %
Pu-238	0.96± 1.5 %	0.97± 1.0 %	0.99± 1.6 %
Pu-239	1.03± 0.6 %	1.02± 0.5 %	1.02± 0.4 %
Pu-240	1.02± 0.6 %	1.00± 0.6 %	1.00± 0.6 %
Pu-241	1.07± 0.6 %	1.03± 0.6 %	1.05± 0.6 %
Pu-242	1.08± 0.8 %	1.03± 0.6 %	1.02± 0.6 %
Am-241	0.99± 3.2 %	0.99± 3.9 %	1.00± 2.6 %
Am242M	0.91± 3.8 %	0.94± 3.1 %	0.93± 3.1 %
Am-243	1.05± 2.6 %	1.02± 3.9 %	1.06± 2.5 %
Cm-242	1.02± 3.9 %	1.00± 3.1 %	1.00± 2.7 %
Cm-243	-	0.51± 3.1 %	0.52± 3.2 %
Cm-244	0.66± 2.1 %	0.73± 2.3 %	0.75± 1.8 %

The sensitivity coefficients that are shown in the tables represent the variation induced on the final concentration of the measured isotope by a variation of 100% of the basic data. The high sensitivity to values of the ^{238}U $\sigma_{(n,2n)}$ are noted for the ^{237}Np build up, therefore the large discrepancies observed for this isotope final densities are to be attributed to the poor knowledge of this cross section. Large sensitivities are observed also for the ^{242}Pu σ_{cap} to ^{243}Am build up, the ^{241}Am σ_{cap} for ^{242}Am, ^{242}Cm, and ^{243}Cm builds up, and the ^{243}Am σ_{cap} for ^{244}Cm. When we compared the sensitivities of the other two pins with the ones relative to the TRAPU-1 experiment it is observed that only TRAPU-3 shows increased sensitivity for a few cases. Specifically: ^{238}Pu λ and ^{241}Am $σ_{cap}$ for the ^{234}U build up, ^{241}Am $σ_{cap}$ and ^{242}Cm λ for the ^{238}Pu build up. This implies that for a possible adjustment only the complete set of the TRAPU-1 experimental results can be used with those relative to the ^{234}U build up and ^{238}Pu build up replaced by the correspondent results of the TRAPU-3 pin. The other experimental results can be used for checking the consistency of the overall adjustment

Table 4 Sensitivity, expressed in percent of variation, of basic cross section to isotope builds up in the TRAPU-1 irradiation experiment.

	Isotope build-up						
Basic Data	^{234}U	^{235}U	^{236}U	^{237}Np	^{238}Pu	^{239}Pu	^{240}Pu
^{234}U $σ_{cap}$	-11.7	0.1					
^{234}U $σ_{fis}$	-6						
^{235}U $σ_{cap}$		-10.8	91	12.8	0.7		
^{235}U $σ_{fis}$	0.4	-37.8	-17.1	-1.6			
^{235}U $σ_{(n,2n)}$	2.1						
^{236}U $σ_{cap}$			-6	13.6	0.8		
^{236}U $σ_{fis}$			-1.1	-0.1			
^{238}U $σ_{cap}$				-2.5	0.2	26.8	3.8
^{238}U $σ_{fis}$				-0.4		-0.1	
^{238}U $σ_{(n,2n)}$	0.3			84.4			
^{237}Np $σ_{cap}$	0.3			-14.5	7.2		
^{237}Np $σ_{fis}$				-2.8	-0.2		
^{238}Pu $σ_{cap}$	-0.4				-7.3		
^{238}Pu $σ_{fis}$	-0.8				-13.9		
^{238}Pu λ	9.9				-1.2		
^{239}Pu $σ_{cap}$						-8.9	25.2
^{239}Pu σfis					-0.4	-30	-4.2
^{239}Pu $σ_{(n,2n)}$	0.1				2.2		
^{240}Pu $σ_{cap}$					2.3		-10.2
^{240}Pu $σ_{fis}$			-0.1				-6.4
^{240}Pu λ			2.2				
^{241}Pu $σ_{cap}$					-0.4		
^{241}Pu $σ_{fis}$					-1.7		
^{241}Pu λ	0.7			0.6	19.6		
^{241}Am $σ_{cap}$	1.5			0.2	35.3		
^{241}Am $σ_{fis}$					-0.8		
^{241}Am λ			1.4	0.3			
^{242}Cm $σ_{cap}$					-1		
^{242}Cm $σ_{fis}$					-1		
^{242}Cm λ	0.9				-17.8		

Table 5 Sensitivity, expressed in percent of variation, of basic cross section to isotope builds up in the TRAPU-1 irradiation experiment..

Basic data	Isotope build-up							
	^{241}Pu	^{242}Pu	^{241}Am	^{242}Am	^{243}Am	^{242}Cm	^{243}Cm	^{244}Cm
$^{238}U\ \sigma_{cap}$	0.8		0.2					
$^{239}Pu\ \sigma_{cap}$	7.9	1.2	2	0.5	0.4	0.7	0.3	0.2
$^{239}Pu\ \sigma_{fis}$	-0.9	0.1	-0.2					
$^{240}Pu\ \sigma_{cap}$	47.7	10.6	16.5	6.9	4.8	8.6		2.6
$^{240}Pu\ \sigma_{fis}$	-1.9	-0.3	-0.5	-0.1	-0.1	-0.2		
$^{241}Pu\ \sigma_{cap}$	-7.7	36.4	-2.7	-1.1	23	-1.4	-0.8	16.6
$^{241}Pu\ \sigma_{fis}$	-35.6	-7.9	-12.3	-5.1	-3.6	-6.4	-3.9	-2
$^{241}Pu\ \lambda$	-7.8	-0.9	63.8	50.6		54.5	47.5	0.2
$^{242}Pu\ \sigma_{cap}$		-7.6			94.5		-0.2	96
$^{242}Pu\ \sigma_{fis}$		-6			-2.4			-1.6
$^{241}Am\ \sigma_{cap}$		1.8	-26.4	82.4	2.2	78.8	85.5	1.9
$^{241}Am\ \sigma_{fis}$			-3.5	-2.4		-2.8	-1.9	
$^{241}Am\ \lambda$			-0.2	-0.2		-0.2	-0.2	
$^{242}Am\ \sigma_{cap}$				-4	1.1			0.8
$^{242}Am\ \sigma_{fis}$				-26.3	-0.2			-0.1
$^{242}Am\ \lambda$				-0.4		0.1	1.8	
$^{243}Am\ \sigma_{cap}$					-14.8			89.3
$^{243}Am\ \sigma_{fis}$					-1.7			-1.2
$^{242}Cm\ \sigma_{cap}$						-3.2	97.5	-0.3
$^{242}Cm\ \sigma_{fis}$						-3.2	-2.4	
$^{242}Cm\ \lambda$						-103.4	-52.2	0.2
$^{243}Cm\ \sigma_{cap}$							-1.5	0.4
$^{243}Cm\ \sigma_{fis}$							-20.1	
$^{243}Cm\ \lambda$							-1.6	
$^{244}Cm\ \sigma_{cap}$								-3.8
$^{244}Cm\ \sigma_{fis}$								-2.6
$^{244}Cm\ \sigma_{(n,2n)}$							-0.2	
$^{244}Cm\ \lambda$								-2.7

5. Simulated Adjustment

A simulated adjustment on JEF2.2 and ENDF/B-VI data was carried out using the experimental results of the TRAPU irradiation program. The C/E of Tables 2 and 3 were used in conjunction with the previously calculated sensitivity coefficients. The goal of this adjustment is to gain information on cross sections in order to provide trends and indications that cross section evaluators can exploit, and not directly generate an adjusted dataset.

We included a constraint to conserve the critical mass of the reference configuration of the MUSE-4 [5] experimental program (appropriate sensitivity coefficients related to this parameter were calculated). This constraint is intended to assure consistency, and avoid perturbations in the K_{eff} calculation. In a real adjustment many other parameters would be considered, for instance structural materials cross sections that would intervene on the K_{eff} sensitivity.

The other major assumptions and constraints are summarized below:

- Only one experiment for each final density of actinide isotope was used for a total of fifteen experiments. In general, because of their larger sensitivity TRAPU-1 results were used. For ^{234}U, ^{238}Pu, ^{243}Am, and ^{244}Cm, TRAPU-3 data were used because of the large spread of the C/E's with TRAPU-3 results being in the middle. For ^{243}Cm TRAPU-2 data were used because no experimental results are available for TRAPU-1. Finally, for ^{244}Cm, as previously indicated, there is a clear indication, looking at the C/E's, that the TRAPU-1 result has to be discarded because of inconsistency with the other two ones. Therefore the TRAPU-2 data were used for this isotope final density calculation.
- A statistical adjustment (more data to be adjusted than experimental data) based on the Lagrange multiplier method [6] that minimizes the variation of nuclear data to be adjusted has been used.
- Twenty two nuclear data were selected for adjustments based on their contribution in term of sensitivity to the final concentration of the build up isotopes. The criterion for selection has been that the change of 100% of the nuclear data should induce at least 10% of change on the final concentration of the measured isotope.
- The uncertainties on the calculated C/E have been derived by slightly increasing the experimental uncertainties in order to take into account the fact that the calculational conditions used for TRAPU are those of the first cycle of PHENIX different from the real ones.
- The dispersion matrix (variances on cross sections) normally associated with the JEF2.2 data has been used. ENDF/B-VI data at present do not provide this kind of information.

The new C/E's obtained performing the adjustment are shown in Tables 6 and 7. In Table 8 the new recalculated values of the nuclear data are compared against the initial ones (i. e. the ones that give the C/E's of Tables 6 and 7). First we have to point out that the residuals from the adjustments (χ^2 test) are quite reasonable, in general less or equal to the number of experiments used, even if the ones relative to ENDF/B-VI are larger than the ones of JEF2.2. This effect is probably due to the fact that we are using the sensitivity coefficient set calculated with the JEF2.2 data.

The new C/E's show a remarkable consistency. Of course, the ^{244}Cm TRAPU-1 result is still not acceptable, but as we have already pointed out the experimental value of this case should be discarded. The apparent inconsistency of the ^{237}Np TRAPU-3 result is explained by the high experimental uncertainty of the TRAPU-1 value that has been used for the adjustment. We will notice the almost 2% adjustment on the ^{241}Pu decay constant. In principle this type of quantity should be very well known.

Looking at Table 8 one can observe the remarkable agreement that some cross sections show between the two data sets, JEF2.2 and ENDF/B-VI, after the adjustments, in some cases starting from opposite sides and converging to almost a common value. Among them we can mention in particular the captures of the higher plutonium isotopes, the capture of ^{241}Am and ^{243}Am, and the capture of ^{242}Cm.

In some cases the discrepancy can be increased (as in the case of the fission cross section of the ^{243}Cm), indicating the need for more information on these data. This is confirmed by Table 9 where the initial uncertainties on nuclear data are compared against the uncertainty to be associated after the adjustment. If there is a small reduction in this uncertainty, this will indicate that the sensitivity of the data in the experiment was low and there is a need for more information. This is the case of the fission cross section of ^{243}Cm; therefore in this case the adjustment is inconclusive.

Table 6. C/E Values of Final Concentrations in the TRAPU Experiment Using JEF-2 Data from Adjustment

Isotope	TRAPU-1	TRAPU-2	TRAPU-3
U-234	0.97	0.99	1.03
U-235	0.98	1.00	1.00
U-236	0.99	1.01	1.01
Np-237	0.98	0.97	0.91
Pu-238	1.00	1.00	1.00
Pu-239	1.02	1.00	1.00
Pu-240	1.02	1.00	1.00
Pu-241	1.02	0.99	1.00
Pu-242	1.05	1.02	1.01
Am-241	0.98	0.99	1.00
Am242M	0.98	1.01	1.00
Am-243	1.00	0.98	1.02
Cm-242	0.98	0.96	0.96
Cm-243		0.98	0.98
Cm-244	0.91	1.02	1.04

Table 7. C/E Values of Final Concentrations in the TRAPU Experiment Using ENDFB-VI Data from Adjustment

Isotope	TRAPU-1	TRAPU-2	TRAPU-3
U-234	0.96	0.99	1.03
U-235	0.99	1.01	1.01
U-236	0.99	1.01	1.01
Np-237	0.97	0.96	0.90
Pu-238	1.01	1.00	1.03
Pu-239	1.02	1.00	1.00
Pu-240	1.01	1.00	1.00
Pu-241	1.02	0.99	1.01
Pu-242	1.04	1.01	1.01
Am-241	0.97	0.97	0.98
Am242M	0.97	1.00	0.98
Am-243	1.02	1.00	1.04
Cm-242	1.02	1.00	1.00
Cm-243		1.02	1.02
Cm-244	0.89	0.99	1.01

Table 8. Values of nuclear data before and after adjustment

Basic Data	Starting Values		Adjusted Values	
	JEF2.2	ENDF/B-VI	JEF2.2	ENDF/B-VI
$^{234}U\ \sigma_{cap}$	6.533E-01	6.255E-01	6.514E-01	6.199E-01
$^{235}U\ \sigma_{cap}$	5.691E-01	5.815E-01	5.788E-01	5.755E-01
$^{235}U\ \sigma_{fis}$	1.988E+00	1.940E+00	1.979E+00	1.934E+00
$^{236}U\ \sigma_{cap}$	5.873E-01	5.791E-01	5.998E-01	5.941E-01
$^{238}U\ \sigma_{cap}$	2.933E-01	2.965E-01	2.802E-01	2.787E-01
$^{238}U\ \sigma_{(n,2n)}$	1.310E-03	1.420E-03	1.912E-03	1.926E-03
$^{237}Np\ \sigma_{cap}$	1.665E+00	1.726E+00	1.599E+00	1.693E+00
$^{238}Pu\ \sigma_{fis}$	1.128E+00	1.174E+00	1.147E+00	1.128E+00
$^{238}Pu\ \lambda$	2.510E-10	2.510E-10	2.512E-10	2.513E-10
$^{239}Pu\ \sigma_{cap}$	5.497E-01	5.289E-01	5.272E-01	5.140E-01
$^{239}Pu\ \sigma_{fis}$	1.845E+00	1.845E+00	1.808E+00	1.815E+00
$^{240}Pu\ \sigma_{cap}$	6.200E-01	5.746E-01	5.416E-01	5.261E-01
$^{241}Pu\ \sigma_{cap}$	5.681E-01	4.768E-01	4.496E-01	4.441E-01
$^{241}Pu\ \sigma_{fis}$	2.622E+00	2.550E+00	2.697E+00	2.605E+00
$^{241}Pu\ \lambda$	1.495E-09	1.495E-09	1.523E-09	1.523E-09
$^{241}Am\ \sigma_{cap}$	2.028E+00	1.785E+00	1.805E+00	1.896E+00
$^{242}Cm\ \sigma_{cap}$	5.683E-01	3.473E-01	6.979E-01	6.641E-01
$^{242}Cm\ \lambda$	4.924E-08	4.924E-08	4.915E-08	5.002E-08
$^{242}Pu\ \sigma_{cap}$	5.057E-01	4.461E-01	4.444E-01	4.581E-01
$^{242}Am\ \sigma_{fis}$	3.289E+00	4.118E+00	3.301E+00	3.946E+00
$^{243}Am\ \sigma_{cap}$	1.781E+00	1.116E+00	1.580E+00	1.522E+00
$^{243}Cm\ \sigma_{fis}$	3.339E+00	2.715E+00	3.297E+00	2.587E+00

Table 9. Uncertainty on nuclear data before and after adjustment

Basic Data	Starting Values	Adjusted Values
$^{234}U\ \sigma_{cap}$	2.00E-01	1.84E-01
$^{235}U\ \sigma_{cap}$	8.00E-02	3.19E-02
$^{235}U\ \sigma_{fis}$	2.00E-02	1.86E-02
$^{236}U\ \sigma_{cap}$	2.00E-01	1.96E-01
$^{238}U\ \sigma_{cap}$	8.00E-02	5.70E-02
$^{238}U\ \sigma_{(n,2n)}$	3.00E-01	9.12E-02
$^{237}Np\ \sigma_{cap}$	2.00E-01	1.98E-01
$^{238}Pu\ \sigma_{fis}$	1.50E-01	1.20E-01
$^{238}Pu\ \lambda$	5.00E-02	4.87E-02
$^{239}Pu\ \sigma_{cap}$	8.00E-02	5.37E-02
$^{239}Pu\ \sigma_{fis}$	3.00E-02	1.29E-02
$^{240}Pu\ \sigma_{cap}$	1.50E-01	5.85E-02
$^{241}Pu\ \sigma_{cap}$	1.50E-01	6.83E-02
$^{241}Pu\ \sigma_{fis}$	5.00E-02	4.75E-02
$^{241}Pu\ \lambda$	5.00E-02	3.97E-02
$^{241}Am\ \sigma_{cap}$	2.00E-01	5.27E-02
$^{242}Cm\ \sigma_{cap}$	4.00E-01	7.48E-02
$^{242}Cm\ \lambda$	5.00E-02	4.18E-02
$^{242}Pu\ \sigma_{cap}$	1.50E-01	4.23E-02
$^{242}Am\ \sigma_{fis}$	1.50E-01	1.30E-01
$^{243}Am\ \sigma_{cap}$	2.00E-01	6.34E-02
$^{243}Cm\ \sigma_{fis}$	2.00E-01	1.99E-01

6. Conclusions

In this paper we have presented an analysis of the irradiation experiment TRAPU performed at the French fast reactor PHENIX. The observed C/E's on the final densities of the measured isotopes for the different basic data files have indicated some large discrepancies that a subsequent sensitivity analysis has attributed to specific cross sections of actinides. Among them: ^{238}U $\sigma_{(n,2n)}$, and capture cross sections of higher plutonium isotopes, ^{241}Am, ^{243}Am, and ^{242}Cm. capture cross sections.

Very useful information has been gained by performing a simulated adjustment that uses the observed C/E's and the calculated sensitivity coefficients. In particular this adjustment has shown that good consistency can be reached on final adjusted cross sections, and associated new C/E's, starting from different data files. The same adjustment has shown that we cannot reach definite conclusions on many fission cross sections (^{238}Pu, ^{241}Pu, ^{242}Am, and ^{243}Cm), because the experiments were not sensitive enough to these parameters.

More investigations need to be done. First it is noted that this analysis suffers from the fact that the calculational details were incomplete because PHENIX loading data relative to the irradiation cycles were not available. In addition, we have also to mention the fact that the sensitivity analysis and the simulated adjustment were done at the one group level. In the future, a multigroup analysis will provide information by energy range. Also, the adjustment needs to include the PROFIL results, and more critical mass and spectral indices experiment sensitivity, coefficients in order to insure a larger consistency among all the data.

Finally, the information from the PROFIL and TRAPU irradiation experiments are relevant to fast energy spectrum reactor types. It would be very useful to add experiments that provide information in the thermal energy range.

Acknowledgements

This work was supported by the U.S. Department of Energy under Contract number W-31-109-Eng-38.

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