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The Impact of ENDF/B-VI Rev. 3 Data on Thermal Reactor Lattices

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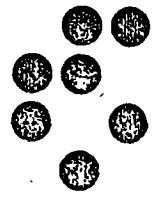

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Abstract

The ENDF/B-VI Revision 3 files have been released through the International Atomic Energy Agency. The data for hydrogen, aluminium and uranium-235 were processed to prepare an updated WIMS-D library. Thermal benchmark lattices TRX, BAPL and DIMPLE were analysed. The new data for the thermal scattering law of hydrogen bound in water had no significant influence on the integral parameters. The effect of the new uranium-235 data was to reduce the lattice multiplication factor by up to $0.3\,\%\Delta k/k$. The effect of the new aluminium data was also non-negligible. It was traced to the change in the interpolation law for the total and the capture cross sections, which seems incorrect.

1 Introduction

The ENDF/B-VI Revision 3 Tapes 132, 134 and 135 were retrieved from the International Atomic Energy Agency on-line data service at the end of August 1995. They contain new thermal scattering law data of hydrogen bound in water, neutron cross sections for aluminium and uranium-235, respectively. The impact of replacing the ENDF/B-VI Rev.2 data with the new evaluations on thermal reactor lattices was investigated.

2 Data analysis

The data for hydrogen bound in water, aluminium and uranium-235, were processed with NJOY91.118 [1] that included some additional updates [2] to generate updated WIMS-D [3] libraries. Two libraries were prepared, based on ENDF/B-VI Rev.2 and Rev.3 data, respectively.

Thermal benchmark lattices TRX, BAPL [4] and DIMPLE [5] were analysed. They are light water moderated, fuelled with slightly enriched uranium in metal form for TRX and oxide form for BAPL and DIMPLE. They are clad in aluminium except DIMPLE which is clad in stainless steel. DIMPLE is of interest because it contains fuel with a somewhat higher enrichment.

The details on the data processing with NJOY and modelling the lattices with WIMS-D/4 are described in ref. [6, 7]. In general, simple cell calculations using deterministic codes such as WIMS-D/4 are not sufficiently accurate for data validation in absolute terms, but they provide a cheap and convenient tool for analysing the relative changes in integral parameters due to changes in the data.

The integral lattice parameters, which were experimentally measured are defined in Table 1. The calculated results based entirely on ENDF/B-VI Rev.2 data are taken as reference and they are given in Table 2 for each lattice. The impact of replacing one material in the library in turn is also presented in Table 2. The absolute change in the rightmost digits of each parameter is given and the differences are discussed below.

Table 1: Definitions of thermal lattice integral parameters

k_{eff}	finite medium effective multiplication factor,
ρ^{28}	ratio of epithermal to thermal ^{238}U capture reaction rate,
δ^{25}	ratio of epithermal to thermal ^{235}U fission reaction rate,
δ^{28}	ratio of ^{238}U fission to ^{235}U fission reaction rate,
C^*	ratio of ^{238}U capture to ^{235}U fission reaction rate.

Hydrogen scattering law data: Compared to the results with ENDF/B-VI Rev.2, the new thermal scattering law data for hydrogen bound in water have a negligi-

ble influence on the lattice integral parameters. The detailed results are shown in Table 1, Case A.

Uranium-235 cross sections: A decrease in the multiplication factor of up to 0.3 $\%\Delta k/k$ is observed, as evident from Table 1, Case D. The effects due to uranium-235 are consistent with the evaluation description, which states that the capture widths in the resonances below 900 eV were increased. This was indeed observed when looking at the cross sections (not presented in this work) where an increase in the capture cross section in the resonance range of up to 8 % was noted, while other cross sections remained almost the same.

Aluminium cross sections: The effect of replacing the aluminium data was to decrease the multiplication factor by more than 0.2 $\%\Delta k/k$, as seen from Table 1 Case B. Such a decrease is in contradiction with the statement in the evaluation description, which says that the total cross section below 20 MeV and the radiative capture cross section below 100 keV remain the same. The aluminium data from ENDF/B-VI Rev.2 and Rev.3 were processed with the Pre-Processing codes [8] LINEAR-94/1, RECENT-94/1 and compared with COMPLOT-94/1. The results in Figure 1 show wiggles in the Rev.3 data which are typical of an inadequate interpolation, giving rise to differences in excess of 50 % in the cross sections. Indeed it was found that the request for a log-log interpolation in the first three data points of the total cross section and the first ten points of the radiative capture cross section in Rev.2 data have been changed to lin-lin interpolation in Rev.3, without changing the energy grid and the cross section values.

A patch was made in the Rev.3 data for aluminium to re-introduce the log-log interpolation over the first ten points for the radiative capture cross section by modifying the TAB1 record as follows:

```
 7.725200+6 7.725200+6          0          0          2        1391325 3102 3066
         10          5        139          2                     1325 3102 3067
```

From Figure 1 it can be seen that the log-log interpolation would be appropriate over the first four energy points (rather than three, as defined in the Rev.2 data). The log-log interpolation was specified for the first four points in the total cross section data. As a consequence, comparing the total cross section on the file and that reconstructed from the partial cross sections, the mismatch in the interval between the third and the fourth point was reduced from 15 down to 4 %. The corresponding changes in the TAB1 record are:

```
 0.000000+0 0.000000+0          0          0          2       19881325 3   1  575
          4          5       1988          2                     1325 3   1  576
```

The non-elastic cross section is redundant and does not appear in the Rev.2 data. For consistency with the partial cross sections, the non-elastic cross section on the Rev.3 file also requires log-log interpolation over the first ten points. The TAB1 record was changed as follows:

```
 0.000000+0 0.000000+0          0          0          2        2241325 3   3 1909
         10          5        224          2                     1325 3   3 1910
```

After the above patch, the Rev.2 and Rev.3 data from ENDF/B-VI for aluminium agreed to within 0.1 % below 100 keV, except between points three and four of the total cross section table, as discussed above.

Table 2: Thermal lattice integral parameters based ENDF/B-VI Rev.2 data and the differences in the last digits due to the use of Rev.3 data for hydrogen bound in water, aluminium an uranium-235.

Lattice	Case	k_{eff}	ρ^{28}	δ^{25}	δ^{28}	C^*
TRX-1	Ref.	0.98999	1.369	0.0984	0.0966	0.804
	A	14	-1	-1	0	0
	B	-112	1	1	-1	1
	C	7	-1	0	-2	0
	D	-110	1	-6	1	0
TRX-2	Ref.	0.99112	0.859	0.0605	0.0685	0.649
	A	12	0	-1	0	9
	B	-100	1	1	0	0
	C	8	0	0	-1	0
	D	-49	0	-4	0	0
BAPL-1	Ref.	0.99824	1.401	0.0828	0.0742	0.809
	A	11	-1	-1	0	0
	B	-221	3	2	-1	1
	C	8	0	0	-3	0
	D	-91	0	-5	1	0
BAPL-2	Ref.	0.99747	1.167	0.0676	0.0638	0.738
	A	12	0	-1	0	0
	B	-208	3	2	-1	1
	C	12	0	0	-2	0
	D	-65	1	-4	0	0
BAPL-3	Ref.	0.99728	0.919	0.0520	0.0523	0.661
	A	10	0	-1	0	0
	B	-197	2	1	0	1
	C	11	0	0	-2	0
	D	-38	0	-3	0	0
DIMP1A	Ref.	0.99997	3.959	0.2349	0.0847	0.646
	A	15	-2	-3	0	0
	B	-6	0	0	0	0
	C	1	0	0	0	0
	D	-321	6	-11	3	1

Ref. : Reference results based on ENDF/B-VI Rev.2 data.
Case A : Rev.3 scattering law data for hydrogen bound in water.
Case B : Rev.3 cross section data for aluminium before the correction.
Case C : Rev.3 cross section data for aluminium after the correction.
Case D : Rev.3 cross section data for uranium-235.

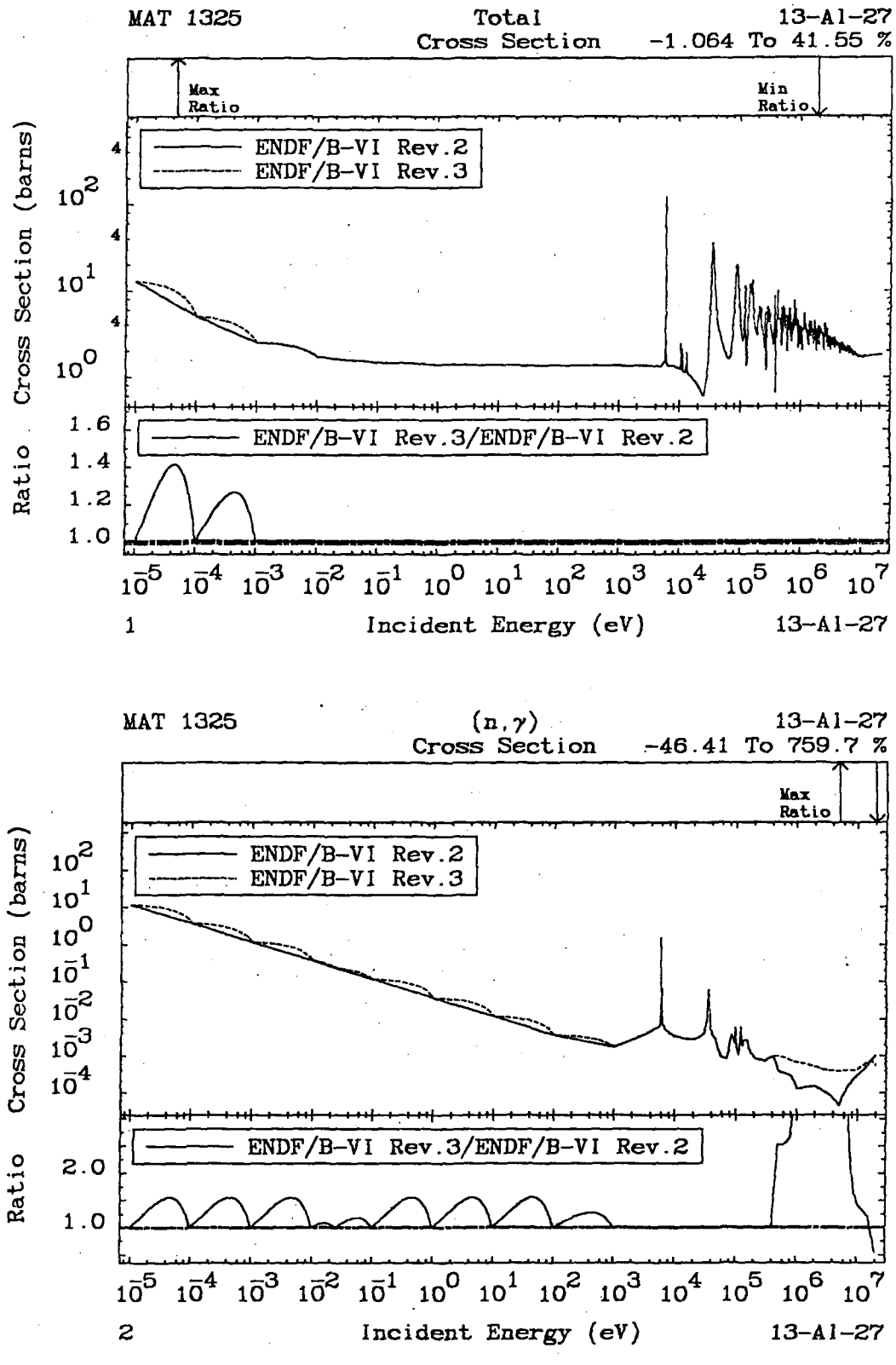

Figure 1: Comparison of ENDF/B-VI Rev.2 and Rev.3 data for aluminium.

The corrected data for aluminium were processed again and the effects of replacing the Rev.2 with the corrected Rev.3 data in the WIMS-D library were found have a negligible effect on the integral parameters, as seen from Table 1, Case C.

3 Conclusions

Considering the newly released ENDF/B-VI Rev.3 data files, the influence of the new thermal scattering law data for hydrogen bound in water on the integal parameters of thermal lattices is small. The main differences originate from the changes in the uranium-235 data. Originally, the influence of the new aluminium data was also significant, even though aluminium is only present in the cladding of the lattices considered. The evidence presented herein indicates that the interpolation law for the total, the non-elastic and the radiative capture cross sections for aluminium was incorrect. After some changes to the interpolation law flags, the overall effects on the thermal lattice integral parameters due to the replacement of the aluminium data were also small. Considering the magnitude of the influence of the incorrect interpolation law, the data for aluminium should be corrected before general distribution and application.

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Note added by IAEA Nuclear Data Section:

A corrected ENDF/B-6 data file for aluminium is expected within the 1996 update of the ENDF/B-6 database.

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