

# **LWR First Recycle of TRU with Thorium Oxide for Transmutation and Cross Sections**

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February 2013



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## ACRONYMS

<i>Th</i>	Thorium
<i>U</i>	Uranium
<i>Am</i>	Americium
<i>Bk</i>	Berkelium
<i>Cf</i>	Californium
<i>Cm</i>	Curium
<i>FP</i>	Fission Product
<i>GWd</i>	Gigawatt-days
<i>INL</i>	Idaho National Laboratory
<i>ItHM</i>	Initial tons of Heavy Metals
<i>LEU</i>	Low Enriched Uranium
<i>LWR</i>	Light Water Reactor
<i>MOX</i>	Mixed Oxide
<i>Np</i>	Neptunium
<i>Pa</i>	Protactinium
<i>Pu</i>	Plutonium
<i>TRU</i>	Transuranic
<i>UOX</i>	Uranium Oxide
<i>w/o</i>	weight percent

# LWR FIRST RECYCLE OF TRU WITH THORIUM OXIDE FOR TRANSMUTATION AND CROSS SECTIONS

## 1 INTRODUCTION

Thorium has been considered as an option to uranium-based fuel, based on considerations of resource utilization (thorium is approximately three times more plentiful than uranium) and as a result of concerns about proliferation and waste management (e.g. reduced production of plutonium, etc.). Since the average composition of natural Thorium is dominated (100%) by the fertile isotope Th-232, Thorium is only useful as a resource for breeding new fissile materials, in this case U-233. Consequently a certain amount of fissile material must be present at the start-up of the reactor in order to guarantee its operation. The thorium fuel can be used in both once-through and recycle options, and in both fast and thermal spectrum systems.

The present study has been aimed by the necessity of investigating the option of using reprocessed plutonium/TRU, from a once-through reference LEU scenario (50 GWd/tHM), mixed with natural thorium and the need of collect data (mass fractions, cross-sections etc.) for this particular fuel cycle scenario. As previously pointed out, the fissile plutonium is needed to guarantee the operation of the reactor.

Four different scenarios have been considered:

- Thorium – recycled Plutonium;
- Thorium – recycled Plutonium/Neptunium;
- Thorium – recycled Plutonium/Neptunium/Americium;
- Thorium – recycled Transuranic.

The calculations have been performed with SCALE6.1-TRITON.

The amount of transuranic present in the reference 50.0 GWd/tHM UOX SNF (4.2% U-235) after 5 years of cooling time is given in Table 1.1 below.

Isotope	kg/tIHM
Np237	6.497413E-01
Np238	1.550531E-10
Np239	1.691246E-07
Np240m	4.848635E-18
Pu236	2.000000E-97
Pu238	3.160877E-01
Pu239	6.175266E+00
Pu240	2.945851E+00
Pu241	1.406346E+00
Pu242	8.728926E-01

Pu243	3.494420E-16
Pu244	2.893894E-05
Pu246	1.799982E-21
Am241	4.443372E-01
Am242	9.896332E-09
Am242M	8.269964E-04
Am243	1.968006E-01
Am245	6.709985E-19
Am246	9.216389E-25
Cm242	1.308463E-05
Cm243	6.755201E-04
Cm244	6.995664E-02
Cm245	5.596512E-03
Cm246	7.152499E-04
Cm247	9.800633E-06
Cm248	7.574186E-07
Cm250	4.286988E-15
Bk249	1.728293E-10
Bk250	1.267657E-23
Cf249	1.039076E-08
Cf250	1.554787E-09
Cf251	9.700168E-10
Cf252	1.750708E-10
Total Pu	1.171647E+01
Total Np	6.497414E-01
Total Am	6.419649E-01
Total Cm	7.696756E-02
Total Bk	1.728293E-10
Total Cf	1.309063E-08
<b>Total TRU</b>	<b>1.308515E+01</b>

**Table 1.1** - TRU composition in the reference 50 GWd/tHM UOX SNF (5-year cooling time).



## 2 CALCULATION METHODOLOGY

As previously said, the calculations needed by this study have been performed through the code SCALE 6.1/TRITON.

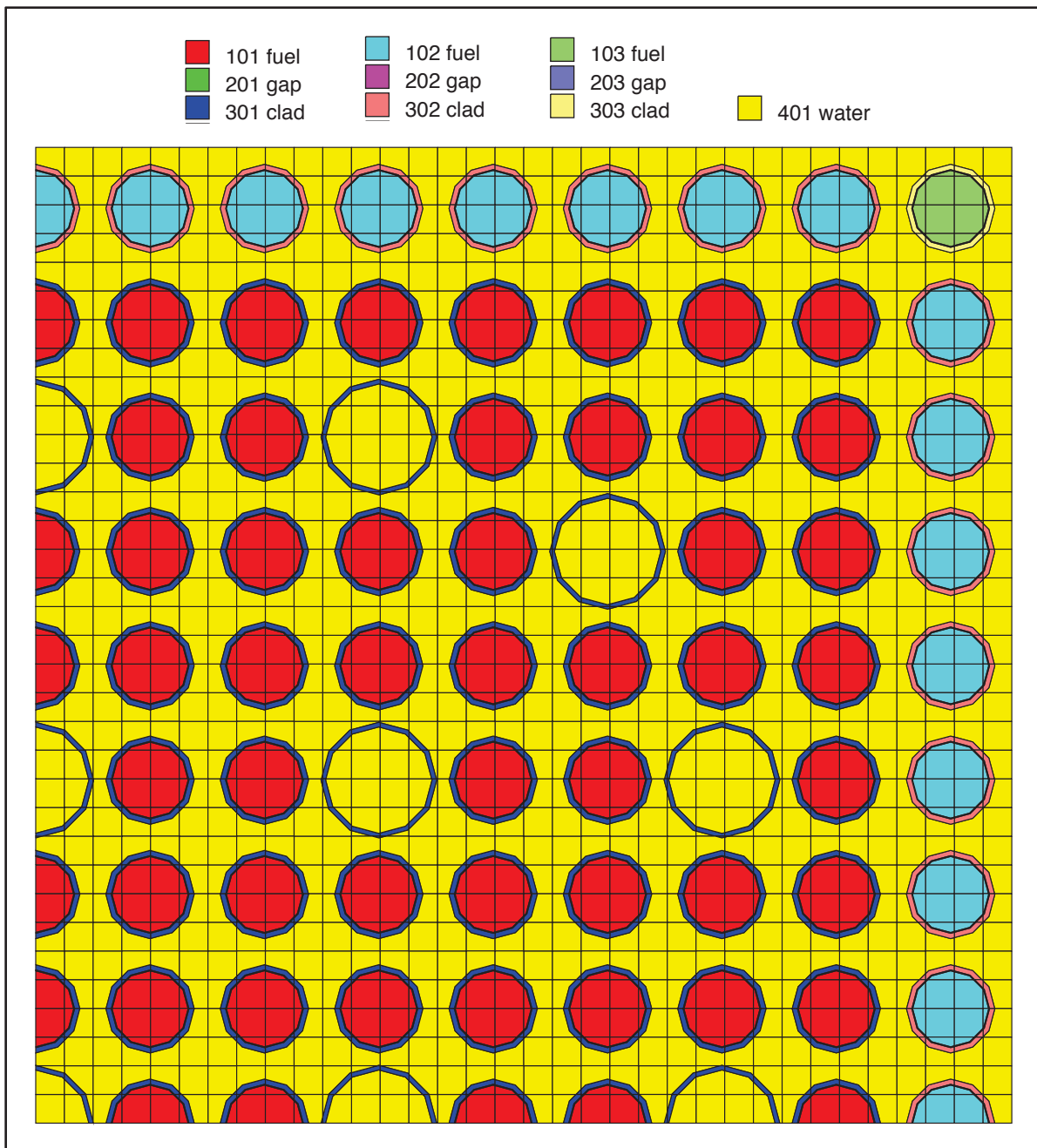
A small overview on the main capabilities and models used is reported in the following paragraphs.

### 2.1 SCALE 6.1 CODE SYSTEMS.

The reactor physics calculations have been performed by the lattice physics capabilities of the SCALE 6.1 code systems. The calculation flow consists of the use of several modules mutually coupled. The discrete-ordinates code NEWT (New ESC-based Weighting Transport code) coupled to the depletion code ORIGEN [8] via the TRITON control module [4]. Using the discrete-ordinates approximation to the transport equation on an arbitrary grid, together with a 238-group neutron cross-section library based on ENDF/B-VII, NEWT provides a robust and rigorous deterministic solution for non-orthogonal configurations. The differencing scheme employed by NEWT, the Extended Step Characteristic Approximation, allows a computational two-dimensional mesh based on arbitrary polygons. Such a mesh can be used to closely approximate curved or irregular surfaces to provide the capability to model problems that were formerly difficult or impractical to model directly with discrete-ordinates methods.

The TRITON control module performs the task of coordination of data transfer between various physics codes available within SCALE 6.1 and of invoking those codes in the proper sequence for a desired type of calculation. The high-fidelity nature of the NEWT solution in estimating angular flux distributions combined with the rigor of the ORIGEN depletion solver gives TRITON the capability to perform precise burnup-dependent physics calculations with few implicit approximations, and limited primarily by the accuracy of nuclide cross-sectional data. Such rigor may be necessary to capture the unique attributes of MOX/Th-TRU fuel behavior as well as that of advanced, highly heterogeneous fuel assembly designs being deployed in current-generation reactors. Cross-sectional self-shielding is carried out by BONAMI for unresolved-range resonance data; the resolved resonance processor module CENTRM performs a 1-D discrete-ordinates code that uses point-wise cross-section data to produce a set of continuous-energy fluxes at discrete spatial intervals for each unit cell. Following a CENTRM calculation, the code PMC uses the resulting flux to collapse the point-wise continuous-energy cross sections into multi-group cross sections for each nuclide in each material in a unit (e.g., pin cell). The result is a multi-group library in which point cross-sectional data are weighted using the explicit point-wise spectrum representative of the nuclides present in a pin cell. Effects from overlapping resonances, fissile material in the fuel and surrounding moderator, anisotropic scattering, and inelastic level scattering are explicitly handled by this approach.

For the physics calculations carried out during this study, a TRITON model of one fourth standard (17x17) fuel assembly has been used (Fig 2.1). All the Th-TRU rods have the same Th-232 enrichment and the same Plutonium content. The 0.5 mm water gap at the periphery is explicitly represented. The model uses three different burn-up zones to take into account the different local moderating ratios: 1 for the corner rods (green), 1 for the other rods located at the periphery (cyan) and 1 for the internal rods (red).

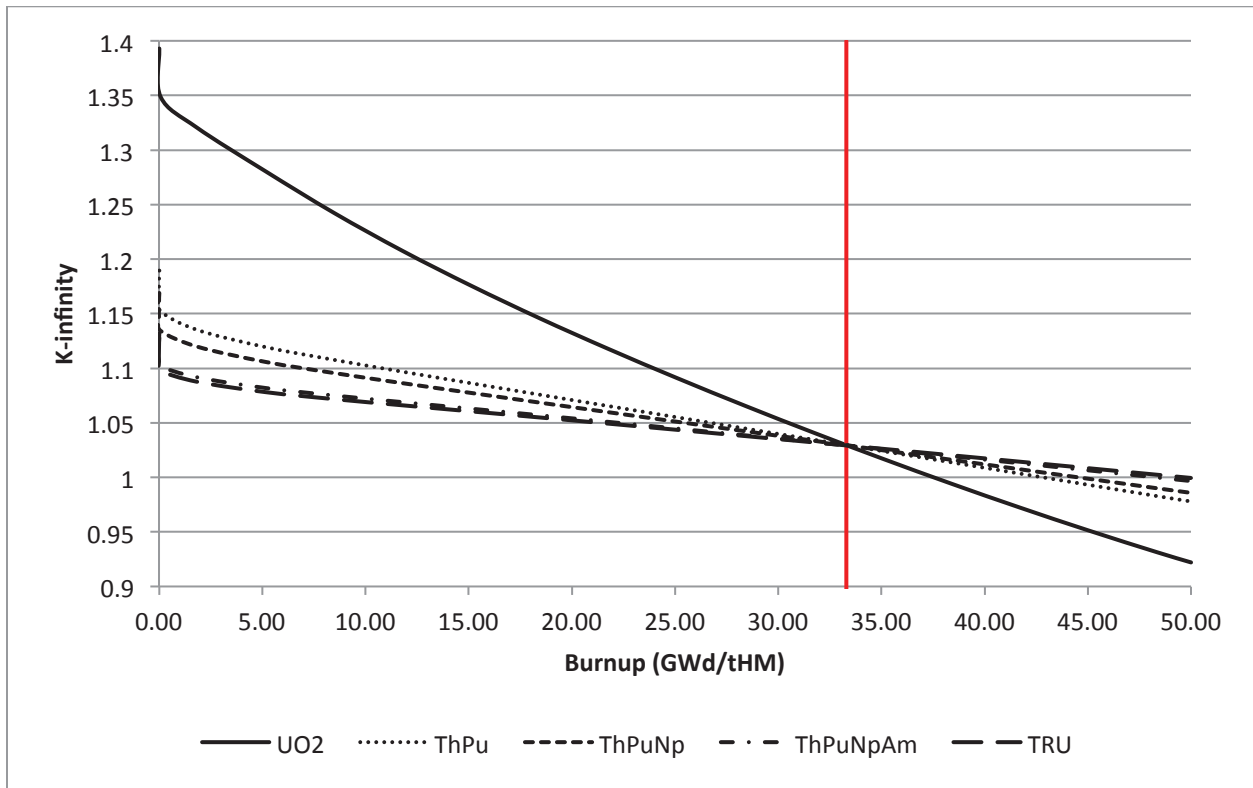


**Figure 2.1** - TRITON model (one fourth of a standard 17x17 fuel assembly)

The TRU content in the Th-TRU fuel assemblies has been tuned to maintain the same average discharge burn-up and a **constant cycle length**. The calculations have been run considering a 3-batch core with an average discharge burn-up of **50.0 GWd/tHM** and a fuel power density of **~39.2 MW/tHM**. The model takes in account 2 year fuel aging (time needed by the fabrication and transport operations) and 5 years of cooling time (time needed in order to reduce the decay heat generation to levels compatible with the separation operations). The burn-up level above

specified is reached after  $\sim 1275$  days of irradiation. **One cycle then corresponds to 2 years + 50 GWd/tHM (1275 days) + 5 years cooling time  $\cong 10.5$  years.**

The necessary  $TRU^1$  enrichments are determined with a methodology that is standard for this kind of application: the k-infinity of the assembly at the average end of cycle burn-up (33.33 GWd/tHM), without soluble boron, is equal to that of the reference 4.2% UOX assembly calculated using the same code (SCALE 6.1), methods (SN), nuclear data (238 group library based on ENDF/B - VII), etc., i.e.  **$k_{\text{inf}} = 1.029643$**  in our case. Figure 2-2, below, shows the k-infinity trends for all the cases considered in this study as a function of burnup in GWd/tHM. The red vertical line in Figure 2-2 corresponds to 33.33 GWd/tHM, where k-infinity for all the cases are equal to each other.



**Figure 2.2** – K-infinity trends vs. burnup showing the intersection point at 33.33 GWd/tHM.

The previous explained strategy ensures the different fuels will release the same amount of energy and thus allows relevant comparisons among them.

## 2.2 DENSITY CALCULATION.

The mixture densities have been calculated through the individual values of the single mixture ( $\rho_i$ ) and relative volume( $w_i$ ):

<sup>1</sup> Pu, PuNp, PuNpAm or TRU

$$\rho_{mixture} = \sum_{i=1}^{\# mixtures} \rho_i \times w_i$$

The computed value has been corrected considering the fabrication packing factor ( $f$ )[10]:

$$\rho_{mixture\_final} = \rho_{mixture} \times f$$

The following individual densities have been considered:

- ThOx: 10.0 g/cc;
- TRUOx: 11.5 g/cc.

Considering as an example the Th-PuOx case, the previous relations become:

$$\begin{aligned} \rho_{ThPuOx} &= (\rho_{ThOx} \times w_{ThOx} + \rho_{PuOx} \times w_{PuOx}) \times f \\ &= (10.0 \times 0.8488 + 11.5 \times 0.1512) \times 0.95 = \mathbf{9.715 \text{ g/cc}} \end{aligned}$$

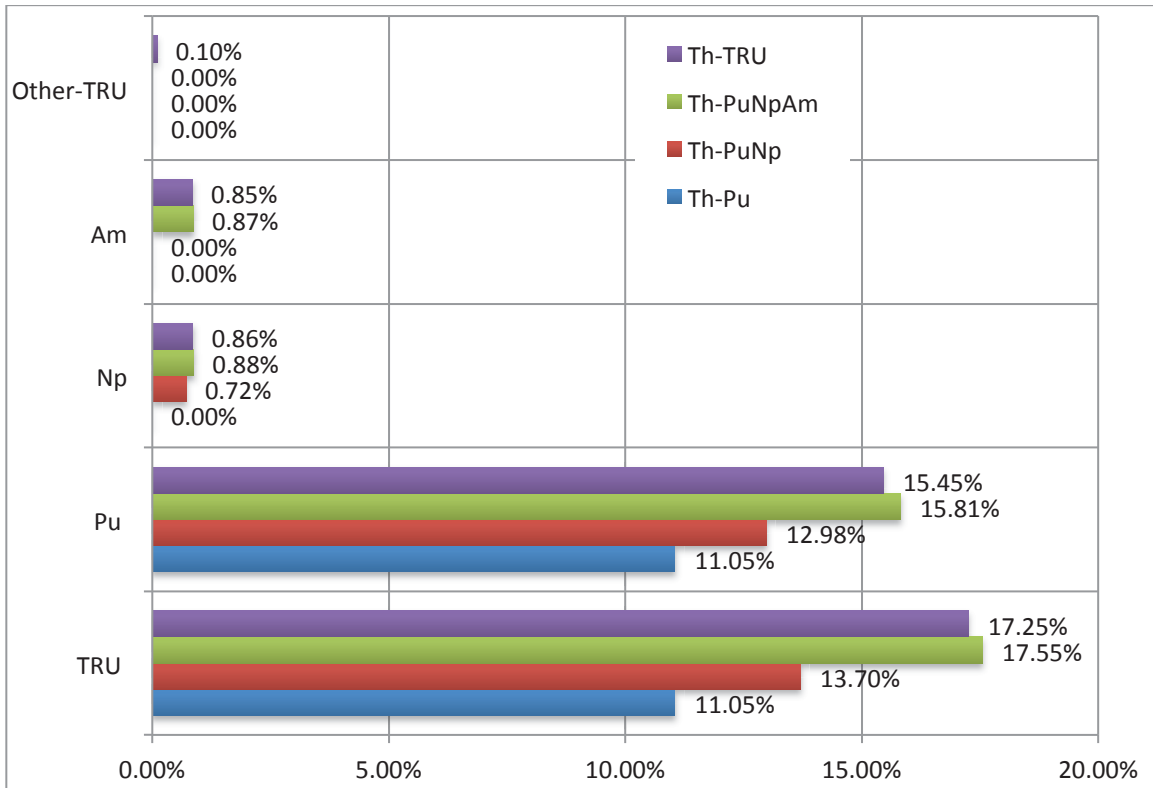
### 3 RESULTS

#### 3.1 SCALE6.1

The table and figure below show the calculated  $Pu/PuNp/PuNpAm/TRU$  enrichment and Pu, Np, Am, other-TRU contents in the fuel assemblies necessary to maintain the same average burn-up at discharge of 50 GWd/tHM.

Case	TRU enrichment (w/o%)	Pu content (w/o%)	Np content (w/o%)	Am content (w/o%)	Other-TRU content (w/o%)
<i>Th-Pu</i>	11.05%	11.05%	0.000%	0.000%	0.000%
<i>Th-PuNp</i>	13.70%	12.98%	0.72%	0.000%	0.000%
<i>Th-PuNpAm</i>	17.55%	15.81%	0.88%	0.87%	0.000%
<i>Th-TRU</i>	17.25%	15.45%	0.86%	0.85%	0.10%

**Table 3.1 - TRU enrichment and main actinide contents..**



**Figure 3.1 - TRU content in PWR Th-TRUOx fuel assemblies calculated with SCALE6.1.**

The figure below shows the  $k_{\infty}$  trend for each case and each cycle step (initial fuel aging, burning) against the 50 GWd/tHM UOX (4.2%) SNF reference case.

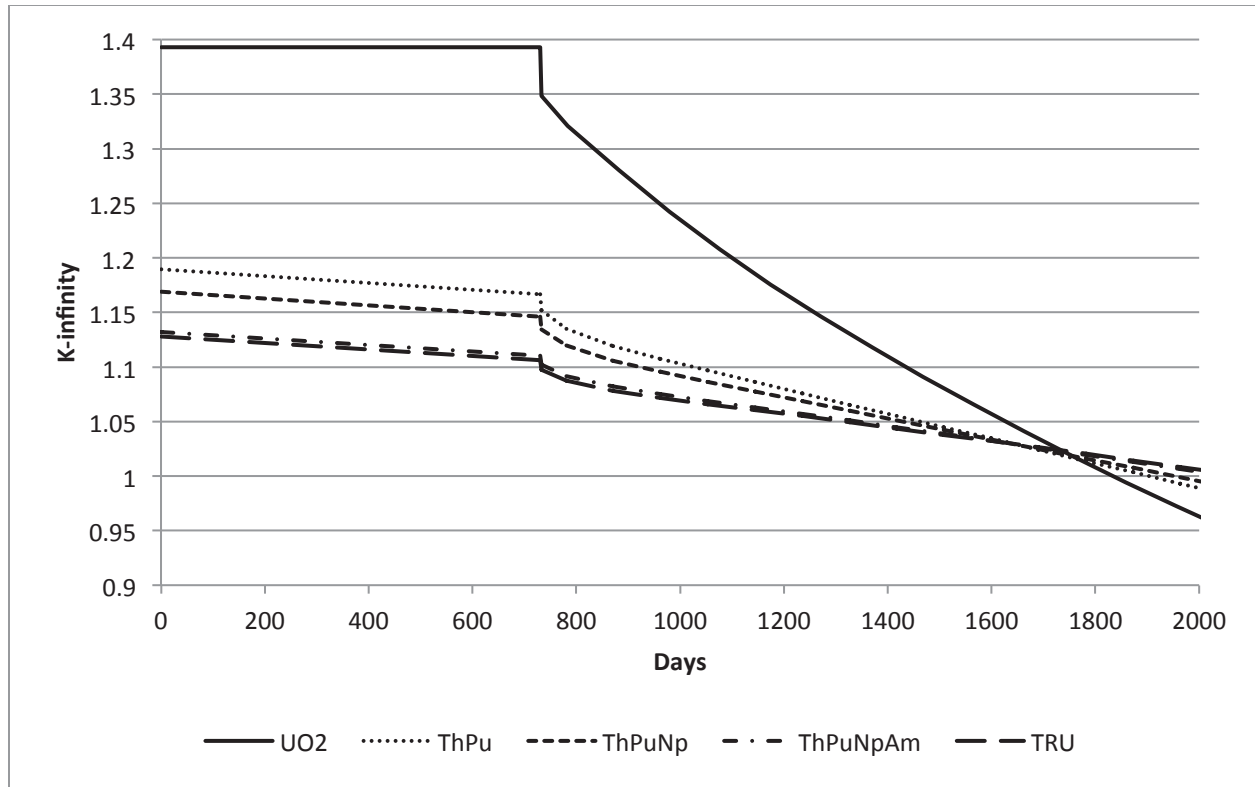


Figure 3.2 –  $k$ -infinite trends.

The following table summarizes the isotopic input, after 2 years aging, and output compositions, at the average discharged burn-up of 50 GWd/tHM, for the four cases taken in exam.

Isotopic input (2 yrs aging) and output mass vectors								
Isotope	ThPu		ThPuNp		ThPuNpAm		ThTRU	
	<i>kg/tIHM</i>		<i>kg/tIHM</i>		<i>kg/tIHM</i>		<i>kg/tIHM</i>	
IDs	Input	Output	Input	Output	Input	Output	Input	Output
Th228	7.61E-09	5.17E-04	7.38E-09	4.58E-04	7.05E-09	3.94E-04	7.08E-09	4.02E-04
Th229	1.52E-14	1.96E-04	1.89E-11	1.77E-04	2.30E-11	1.58E-04	2.25E-11	1.60E-04
Th230	1.28E-07	1.56E-03	1.50E-07	1.58E-03	1.83E-07	1.62E-03	1.79E-07	1.63E-03
Th232	8.89E+02	8.65E+02	8.63E+02	8.40E+02	8.24E+02	8.03E+02	8.27E+02	8.06E+02
Pa231	1.05E-11	1.57E-01	1.10E-11	1.63E-01	1.17E-11	1.69E-01	1.17E-11	1.69E-01
U232	4.25E-10	6.49E-02	4.25E-10	5.68E-02	4.25E-10	4.79E-02	4.25E-10	4.89E-02
U233	1.98E-09	1.42E+01	4.57E-06	1.40E+01	5.58E-06	1.36E+01	5.45E-06	1.37E+01
U234	4.59E-02	1.31E+00	5.39E-02	1.22E+00	6.57E-02	1.11E+00	6.42E-02	1.13E+00
U235	3.29E-03	1.18E-01	3.86E-03	1.09E-01	4.71E-03	9.75E-02	4.60E-03	9.85E-02
U236	5.77E-03	1.98E-02	6.77E-03	2.15E-02	8.25E-03	2.45E-02	8.07E-03	2.41E-02

<i>U238</i>	2.99E-05	9.60E-05	3.51E-05	1.07E-04	4.28E-05	1.27E-04	4.18E-05	1.25E-04
<i>Np237</i>	1.99E-03	9.82E-03	7.20E+00	3.90E+00	8.79E+00	5.18E+00	8.58E+00	5.03E+00
<i>Pu238</i>	2.93E+00	2.92E+00	3.45E+00	6.10E+00	4.20E+00	8.98E+00	4.10E+00	8.82E+00
<b><i>Pu239</i></b>	5.82E+01	1.52E+01	6.84E+01	2.40E+01	8.33E+01	3.78E+01	8.14E+01	3.63E+01
<i>Pu240</i>	2.78E+01	2.14E+01	3.26E+01	2.71E+01	3.97E+01	3.53E+01	3.89E+01	3.44E+01
<b><i>Pu241</i></b>	1.20E+01	1.25E+01	1.41E+01	1.48E+01	1.72E+01	1.75E+01	1.68E+01	1.72E+01
<i>Pu242</i>	8.23E+00	9.37E+00	9.67E+00	1.05E+01	1.18E+01	1.27E+01	1.15E+01	1.24E+01
<i>Am241</i>	1.22E+00	1.57E+00	1.44E+00	2.06E+00	7.72E+00	5.25E+00	7.55E+00	5.07E+00
<b><i>Am242m</i></b>	2.61E-08	3.40E-02	2.67E-08	4.82E-02	1.10E-02	1.65E-01	1.08E-02	1.59E-01
<i>Am243</i>	1.44E-09	2.30E+00	1.45E-09	2.43E+00	2.65E+00	3.81E+00	2.59E+00	3.75E+00
<i>Cm242</i>	2.15E-11	2.87E-01	2.19E-11	3.00E-01	2.75E-05	6.35E-01	3.71E-05	6.27E-01
<b><i>Cm243</i></b>	4.51E-16	1.32E-02	4.51E-16	1.38E-02	4.56E-13	3.62E-02	8.46E-03	3.81E-02
<i>Cm244</i>	4.41E-16	1.19E+00	4.40E-16	1.13E+00	1.64E-09	2.15E+00	8.54E-01	2.65E+00
<b><i>Cm245</i></b>	4.07E-16	1.64E-01	5.96E-16	1.52E-01	6.25E-16	3.14E-01	7.38E-02	4.71E-01
<i>Cm246</i>	1.14E-09	1.06E-02	1.14E-09	7.90E-03	1.14E-09	1.61E-02	9.43E-03	4.07E-02
<b><i>Cm247</i></b>	1.70E-17	1.90E-04	1.62E-17	1.35E-04	1.53E-17	3.09E-04	1.14E-04	1.55E-03
<i>Cm248</i>	3.58E-25	9.21E-06	3.03E-25	5.65E-06	2.42E-25	1.25E-05	1.58E-09	1.77E-04
<i>Bk249</i>	3.88E-36	1.79E-07	3.13E-36	1.11E-07	2.38E-36	2.58E-07	4.91E-10	5.12E-06
<b><i>Cf249</i></b>	0.00E+00	5.14E-08	0.00E+00	3.34E-08	0.00E+00	9.11E-08	2.91E-09	2.99E-06
<b>Element input and output summary</b>								
<b><i>IDs</i></b>	<b>%</b>	<b>%</b>	<b>%</b>	<b>%</b>	<b>%</b>	<b>%</b>	<b>%</b>	<b>%</b>
<i>Th</i>	88.94%	86.52%	86.29%	84.03%	82.44%	80.34%	82.74%	80.62%
<i>Pa</i>	0.00%	0.02%	0.00%	0.02%	0.00%	0.02%	0.00%	0.02%
<i>U</i>	0.01%	1.57%	0.01%	1.54%	0.01%	1.49%	0.01%	1.50%
<i>Np</i>	0.00%	0.00%	0.72%	0.39%	0.88%	0.52%	0.86%	0.50%
<i>Pu</i>	10.92%	6.14%	12.83%	8.24%	15.62%	11.23%	15.27%	10.91%
<i>Am</i>	0.12%	0.39%	0.14%	0.45%	1.04%	0.92%	1.02%	0.90%
<i>Cm</i>	0.00%	0.17%	0.00%	0.16%	0.00%	0.31%	0.09%	0.38%
<i>Bk</i>	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
<i>Cf</i>	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
<i>FP</i>	0.00%	5.09%	0.00%	5.09%	0.00%	5.08%	0.00%	5.08%

**Table 3.2 – Mass Fraction input and output (summary).**

## 4 CONCLUSIONS.

This report presents the results of a neutronics analysis in which the option of a thorium-based fuel cycle has been shown.

The main objective of these calculations is quantify the TRU enrichment needed to operate a Thorium based reactor (PWR) in order to maintain the same average burnup at discharge (50 GWd/tHM) and, consequently, collect the data needed for further analysis.

It is important to recognize that these results are based on infinite lattice assembly calculations, assuming standard UOX fuel assembly parameters with homogeneously loaded fuel. While this approach increases the ability to retrofit thorium-based fuels into existing commercial PWRs with minimal or no changes required to reactor hardware, it **does not** represent the optimum performance achievable. Additionally more detailed studies (i.e. optimization of assembly and reactor parameters, calculation of void coefficients, etc.) would be required.



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## Appendix 1: Detailed isotopic mass fraction input (after 2-yrs fuel aging).

Isotopic input mass vector				
Isotope	ThPu	ThPuNp	ThPuNpAm	ThTRU
<i>IDs</i>	<i>kg/tIHM</i>	<i>kg/tIHM</i>	<i>kg/tIHM</i>	<i>kg/tIHM</i>
<i>He4</i>	9.73E-04	1.14E-03	1.72E-03	2.80E-03
<i>Ra228</i>	7.66E-08	7.43E-08	7.10E-08	7.13E-08
<i>Th228</i>	7.61E-09	7.38E-09	7.05E-09	7.08E-09
<i>Th229</i>	1.52E-14	1.89E-11	2.30E-11	2.25E-11
<i>Th230</i>	1.28E-07	1.50E-07	1.83E-07	1.79E-07
<i>Th231</i>	3.81E-08	3.77E-08	3.73E-08	3.75E-08
<i>Th232</i>	8.89E+02	8.63E+02	8.24E+02	8.27E+02
<i>Pa231</i>	1.05E-11	1.10E-11	1.17E-11	1.17E-11
<i>Pa233</i>	1.87E-08	2.62E-07	3.14E-07	3.08E-07
<i>Pa234</i>	4.87E-16	1.70E-14	1.90E-14	1.88E-14
<i>U232</i>	4.25E-10	4.25E-10	4.25E-10	4.25E-10
<i>U233</i>	1.98E-09	4.57E-06	5.58E-06	5.45E-06
<i>U234</i>	4.59E-02	5.40E-02	6.57E-02	6.42E-02
<i>U235</i>	3.29E-03	3.86E-03	4.71E-03	4.60E-03
<i>U236</i>	5.77E-03	6.77E-03	8.25E-03	8.07E-03
<i>U237</i>	3.76E-07	4.41E-07	5.38E-07	5.25E-07
<i>U238</i>	2.99E-05	3.51E-05	4.28E-05	4.18E-05
<i>Np236</i>	3.46E-15	1.28E-11	1.62E-11	1.59E-11
<i>Np237</i>	1.99E-03	7.20E+00	8.79E+00	8.59E+00
<i>Np238</i>	2.14E-10	6.78E-07	7.20E-07	7.14E-07
<i>Np239</i>	2.56E-13	3.20E-13	2.29E-06	2.23E-06
<i>Pu236</i>	7.01E-10	7.01E-10	7.01E-10	7.01E-10
<i>Pu237</i>	3.52E-11	4.22E-11	5.32E-11	5.22E-11
<i>Pu238</i>	2.93E+00	3.45E+00	4.20E+00	4.10E+00
<i>Pu239</i>	5.82E+01	6.84E+01	8.33E+01	8.14E+01
<i>Pu240</i>	2.78E+01	3.26E+01	3.97E+01	3.89E+01
<i>Pu241</i>	1.20E+01	1.41E+01	1.72E+01	1.68E+01
<i>Pu242</i>	8.23E+00	9.67E+00	1.18E+01	1.15E+01
<i>Pu243</i>	5.93E-07	6.12E-07	6.28E-07	6.27E-07
<i>Pu244</i>	2.27E-04	3.41E-04	3.41E-04	3.41E-04
<i>Am241</i>	1.22E+00	1.44E+00	7.72E+00	7.55E+00
<i>Am242</i>	2.16E-07	2.20E-07	1.07E-06	1.07E-06
<i>Am242M</i>	2.61E-08	2.67E-08	1.10E-02	1.08E-02
<i>Am243</i>	1.44E-09	1.45E-09	2.65E+00	2.59E+00
<i>Cm242</i>	2.15E-11	2.19E-11	2.75E-05	3.71E-05

<i>Cm243</i>	4.51E-16	4.51E-16	4.56E-13	8.46E-03
<i>Cm244</i>	4.41E-16	4.40E-16	1.64E-09	8.54E-01
<i>Cm245</i>	4.07E-16	5.96E-16	6.25E-16	7.38E-02
<i>Cm246</i>	1.14E-09	1.14E-09	1.14E-09	9.43E-03
<i>Cm247</i>	1.70E-17	1.62E-17	1.53E-17	1.14E-04
<i>Cm248</i>	3.58E-25	3.03E-25	2.42E-25	1.58E-09
<i>Bk249</i>	3.88E-36	3.13E-36	2.38E-36	4.91E-10
<i>Cf249</i>	0.00E+00	0.00E+00	0.00E+00	2.91E-09
<i>Zn70</i>	8.36E-14	8.56E-14	8.72E-14	8.72E-14
<i>Ga71</i>	1.54E-14	1.58E-14	1.62E-14	1.62E-14
<i>Ge72</i>	8.32E-16	8.38E-16	8.46E-16	8.47E-16
<i>Ge73</i>	7.65E-15	7.60E-15	7.54E-15	7.55E-15
<i>Ge74</i>	4.17E-13	4.16E-13	4.15E-13	4.15E-13
<i>Ge76</i>	2.15E-11	2.15E-11	2.16E-11	2.16E-11
<i>As75</i>	1.13E-14	1.13E-14	1.12E-14	1.12E-14
<i>Se77</i>	2.52E-14	2.53E-14	2.54E-14	2.54E-14
<i>Se78</i>	3.56E-13	3.52E-13	3.46E-13	3.46E-13
<i>Se79</i>	4.87E-12	4.80E-12	4.70E-12	4.70E-12
<i>Se80</i>	4.14E-10	4.09E-10	4.03E-10	4.03E-10
<i>Se82</i>	3.43E-09	3.40E-09	3.36E-09	3.36E-09
<i>Br79</i>	4.25E-15	4.17E-15	4.07E-15	4.08E-15
<i>Br81</i>	9.28E-12	9.13E-12	8.89E-12	8.90E-12
<i>Kr82</i>	1.11E-13	1.09E-13	1.06E-13	1.06E-13
<i>Kr83</i>	3.92E-12	3.87E-12	3.78E-12	3.78E-12
<i>Kr84</i>	8.92E-11	8.79E-11	8.58E-11	8.58E-11
<i>Kr85</i>	2.62E-10	2.59E-10	2.56E-10	2.55E-10
<i>Kr86</i>	3.56E-09	3.54E-09	3.51E-09	3.51E-09
<i>Rb85</i>	2.84E-12	2.84E-12	2.83E-12	2.83E-12
<i>Rb87</i>	3.72E-10	3.66E-10	3.56E-10	3.56E-10
<i>Sr86</i>	2.44E-14	2.39E-14	2.32E-14	2.33E-14
<i>Sr87</i>	5.83E-13	5.73E-13	5.57E-13	5.57E-13
<i>Sr88</i>	3.11E-11	3.07E-11	3.01E-11	3.01E-11
<i>Sr89</i>	4.25E-10	4.17E-10	4.06E-10	4.06E-10
<i>Sr90</i>	3.27E-09	3.22E-09	3.15E-09	3.15E-09
<i>Y89</i>	6.64E-12	6.62E-12	6.57E-12	6.57E-12
<i>Y90</i>	2.38E-12	2.33E-12	2.28E-12	2.28E-12
<i>Y91</i>	3.28E-11	3.24E-11	3.18E-11	3.18E-11
<i>Zr90</i>	3.80E-13	3.79E-13	3.76E-13	3.76E-13
<i>Zr91</i>	9.56E-12	9.54E-12	9.48E-12	9.48E-12
<i>Zr92</i>	1.48E-11	1.47E-11	1.46E-11	1.46E-11

<i>Zr93</i>	5.89E-11	5.82E-11	5.71E-11	5.71E-11
<i>Zr94</i>	9.49E-10	9.34E-10	9.12E-10	9.12E-10
<i>Zr95</i>	4.13E-09	4.08E-09	4.01E-09	4.01E-09
<i>Zr96</i>	1.00E-07	1.00E-07	9.96E-08	9.95E-08
<i>Nb94</i>	2.50E-13	2.46E-13	2.42E-13	2.42E-13
<i>Nb95</i>	2.71E-11	2.67E-11	2.61E-11	2.74E-11
<i>Nb95M</i>	4.62E-12	4.54E-12	4.43E-12	4.44E-12
<i>Mo95</i>	1.89E-11	1.88E-11	1.87E-11	1.87E-11
<i>Mo96</i>	1.56E-13	1.54E-13	1.52E-13	1.52E-13
<i>Mo97</i>	2.83E-11	2.82E-11	2.79E-11	2.79E-11
<i>Mo98</i>	2.73E-08	2.73E-08	2.71E-08	2.71E-08
<i>Mo100</i>	1.47E-07	1.47E-07	1.46E-07	1.46E-07
<i>Tc98</i>	1.12E-14	1.10E-14	1.09E-14	1.10E-14
<i>Tc99</i>	2.95E-11	2.94E-11	2.93E-11	2.93E-11
<i>Ru99</i>	1.35E-15	1.35E-15	1.34E-15	1.34E-15
<i>Ru100</i>	2.82E-12	2.77E-12	2.74E-12	2.74E-12
<i>Ru101</i>	3.17E-11	3.16E-11	3.15E-11	3.15E-11
<i>Ru102</i>	1.57E-09	1.56E-09	1.54E-09	1.54E-09
<i>Ru103</i>	2.83E-09	2.81E-09	2.79E-09	2.79E-09
<i>Ru104</i>	9.25E-10	9.12E-10	8.95E-10	8.97E-10
<i>Ru106</i>	2.87E-08	2.86E-08	2.85E-08	2.86E-08
<i>Rh103</i>	3.17E-11	3.17E-11	3.15E-11	3.15E-11
<i>Rh103M</i>	9.62E-15	9.52E-15	9.49E-15	9.58E-15
<i>Rh106</i>	6.54E-12	6.69E-12	7.21E-12	7.38E-12
<i>Pd104</i>	8.13E-15	8.03E-15	7.99E-15	8.09E-15
<i>Pd105</i>	2.55E-11	2.55E-11	2.54E-11	2.54E-11
<i>Pd106</i>	1.76E-11	1.76E-11	1.78E-11	1.78E-11
<i>Pd107</i>	3.30E-11	3.27E-11	3.24E-11	3.24E-11
<i>Pd108</i>	6.25E-10	6.23E-10	6.26E-10	6.29E-10
<i>Pd110</i>	9.10E-09	9.14E-09	9.30E-09	9.38E-09
<i>Ag109</i>	8.14E-12	8.14E-12	8.18E-12	8.20E-12
<i>Ag110M</i>	1.67E-14	1.76E-14	3.93E-14	7.63E-14
<i>In115</i>	2.30E-13	2.32E-13	2.36E-13	2.40E-13
<i>Sn115</i>	1.16E-14	1.16E-14	1.19E-14	1.20E-14
<i>Sn116</i>	1.81E-15	1.93E-15	2.12E-15	2.10E-15
<i>Sn117</i>	2.27E-13	2.28E-13	2.30E-13	2.30E-13
<i>Sn118</i>	2.83E-12	2.89E-12	2.99E-12	2.98E-12
<i>Sn119</i>	2.46E-12	2.47E-12	2.51E-12	2.51E-12
<i>Sn120</i>	1.56E-10	1.57E-10	1.61E-10	1.61E-10
<i>Sn121</i>	1.69E-10	1.70E-10	1.72E-10	1.72E-10

<i>Sn121M</i>	3.20E-11	3.22E-11	3.28E-11	3.29E-11
<i>Sn122</i>	1.30E-09	1.31E-09	1.33E-09	1.33E-09
<i>Sn123</i>	4.81E-10	4.84E-10	4.91E-10	4.91E-10
<i>Sn124</i>	2.86E-09	2.86E-09	2.87E-09	2.87E-09
<i>Sn126</i>	8.09E-09	8.08E-09	8.08E-09	8.08E-09
<i>Sb121</i>	2.26E-13	2.30E-13	2.40E-13	2.41E-13
<i>Sb123</i>	1.83E-11	1.82E-11	1.82E-11	1.82E-11
<i>Sb124</i>	4.87E-12	4.88E-12	4.95E-12	4.96E-12
<i>Sb125</i>	3.94E-11	3.94E-11	3.97E-11	3.97E-11
<i>Sb126</i>	4.97E-11	4.96E-11	4.97E-11	4.97E-11
<i>Te122</i>	1.95E-15	2.00E-15	2.16E-15	2.23E-15
<i>Te124</i>	1.64E-13	1.64E-13	1.67E-13	1.67E-13
<i>Te125</i>	2.06E-13	2.06E-13	2.07E-13	2.07E-13
<i>Te125M</i>	7.01E-15	8.19E-15	1.02E-14	9.78E-15
<i>Te126</i>	4.72E-13	4.80E-13	4.93E-13	4.91E-13
<i>Te127</i>	6.52E-14	7.59E-14	8.72E-14	8.59E-14
<i>Te127M</i>	1.46E-13	1.97E-13	2.51E-13	2.45E-13
<i>Te128</i>	2.87E-11	2.87E-11	2.85E-11	2.85E-11
<i>Te129M</i>	2.05E-11	2.11E-11	2.19E-11	2.26E-11
<i>Te130</i>	7.93E-09	7.84E-09	7.70E-09	7.70E-09
<i>I127</i>	2.40E-12	2.39E-12	2.37E-12	2.37E-12
<i>I129</i>	6.89E-12	6.88E-12	6.85E-12	6.86E-12
<i>Xe128</i>	1.39E-14	1.36E-14	1.31E-14	1.31E-14
<i>Xe130</i>	2.47E-13	2.43E-13	2.37E-13	2.37E-13
<i>Xe131</i>	2.10E-11	2.10E-11	2.09E-11	2.08E-11
<i>Xe132</i>	9.07E-11	8.98E-11	8.86E-11	8.87E-11
<i>Xe134</i>	9.63E-09	9.52E-09	9.39E-09	9.39E-09
<i>Xe136</i>	1.62E-07	1.60E-07	1.58E-07	1.58E-07
<i>Cs133</i>	4.02E-11	4.02E-11	4.00E-11	4.00E-11
<i>Cs134</i>	1.27E-11	1.26E-11	1.25E-11	1.25E-11
<i>Cs135</i>	2.86E-10	2.83E-10	2.80E-10	2.81E-10
<i>Cs136</i>	1.94E-09	1.93E-09	1.93E-09	1.94E-09
<i>Cs137</i>	3.24E-08	3.22E-08	3.20E-08	3.21E-08
<i>Ba134</i>	9.70E-15	9.69E-15	9.88E-15	9.91E-15
<i>Ba135</i>	2.30E-13	2.27E-13	2.25E-13	2.26E-13
<i>Ba136</i>	5.82E-10	5.78E-10	5.79E-10	5.81E-10
<i>Ba137</i>	7.95E-11	7.83E-11	7.70E-11	7.72E-11
<i>Ba137M</i>	1.65E-10	1.63E-10	1.61E-10	1.61E-10
<i>Ba138</i>	2.32E-09	2.29E-09	2.27E-09	2.27E-09
<i>Ba140</i>	7.30E-08	7.22E-08	7.09E-08	7.10E-08

<i>La138</i>	2.36E-12	2.33E-12	2.33E-12	2.35E-12
<i>La139</i>	8.86E-11	8.79E-11	8.76E-11	8.78E-11
<i>La140</i>	4.01E-10	3.97E-10	4.00E-10	4.03E-10
<i>Ce140</i>	3.36E-11	3.36E-11	3.35E-11	3.35E-11
<i>Ce141</i>	1.07E-11	1.06E-11	1.05E-11	1.06E-11
<i>Ce142</i>	1.91E-10	1.89E-10	1.88E-10	1.89E-10
<i>Ce144</i>	2.07E-08	2.06E-08	2.06E-08	2.06E-08
<i>Pr141</i>	3.20E-11	3.20E-11	3.19E-11	3.19E-11
<i>Pr143</i>	1.44E-12	1.42E-12	1.43E-12	1.44E-12
<i>Pr144</i>	1.72E-12	1.71E-12	1.73E-12	1.74E-12
<i>Nd142</i>	5.61E-16	5.61E-16	5.61E-16	5.61E-16
<i>Nd143</i>	2.83E-11	2.83E-11	2.82E-11	2.82E-11
<i>Nd144</i>	2.02E-11	2.02E-11	2.02E-11	2.02E-11
<i>Nd145</i>	1.98E-11	1.98E-11	1.98E-11	1.98E-11
<i>Nd146</i>	2.56E-11	2.56E-11	2.57E-11	2.58E-11
<i>Nd147</i>	1.70E-10	1.69E-10	1.68E-10	1.68E-10
<i>Nd148</i>	2.17E-09	2.14E-09	2.11E-09	2.11E-09
<i>Nd150</i>	3.15E-08	3.15E-08	3.15E-08	3.15E-08
<i>Pm147</i>	7.91E-12	7.91E-12	7.90E-12	7.91E-12
<i>Pm148</i>	6.01E-14	6.13E-14	6.61E-14	6.77E-14
<i>Pm148M</i>	2.06E-13	2.09E-13	2.21E-13	2.24E-13
<i>Sm147</i>	5.33E-12	5.33E-12	5.33E-12	5.33E-12
<i>Sm148</i>	6.93E-16	6.94E-16	7.00E-16	7.02E-16
<i>Sm149</i>	8.22E-12	8.23E-12	8.24E-12	8.24E-12
<i>Sm150</i>	1.52E-13	1.51E-13	1.53E-13	1.54E-13
<i>Sm151</i>	6.71E-12	6.71E-12	6.73E-12	6.74E-12
<i>Sm152</i>	5.59E-11	5.55E-11	5.55E-11	5.57E-11
<i>Sm154</i>	7.23E-10	7.19E-10	7.19E-10	7.23E-10
<i>Eu151</i>	7.81E-14	7.82E-14	7.83E-14	7.84E-14
<i>Eu152</i>	2.33E-15	2.34E-15	2.45E-15	2.50E-15
<i>Eu153</i>	2.76E-12	2.77E-12	2.80E-12	2.81E-12
<i>Eu154</i>	6.29E-13	6.28E-13	6.43E-13	6.57E-13
<i>Eu155</i>	1.83E-11	1.83E-11	1.87E-11	1.89E-11
<i>Eu156</i>	5.42E-11	5.41E-11	5.49E-11	5.56E-11
<i>Gd152</i>	3.05E-16	3.05E-16	3.05E-16	3.05E-16
<i>Gd154</i>	8.31E-16	8.45E-16	8.92E-16	9.19E-16
<i>Gd155</i>	3.18E-13	3.20E-13	3.24E-13	3.25E-13
<i>Gd156</i>	1.08E-12	1.08E-12	1.09E-12	1.10E-12
<i>Gd157</i>	1.99E-12	2.00E-12	2.05E-12	2.10E-12
<i>Gd158</i>	8.41E-12	8.44E-12	8.67E-12	8.91E-12

<i>Gd160</i>	1.15E-10	1.16E-10	1.20E-10	1.23E-10
<i>Tb159</i>	2.58E-13	2.61E-13	2.71E-13	2.79E-13
<i>Tb160</i>	3.42E-13	3.50E-13	5.38E-13	5.72E-13
<i>Dy160</i>	9.27E-16	9.39E-16	1.03E-15	1.13E-15
<i>Dy161</i>	4.46E-14	4.52E-14	4.75E-14	4.94E-14
<i>Dy162</i>	9.75E-14	9.94E-14	1.07E-13	1.19E-13
<i>Dy163</i>	1.51E-13	1.56E-13	1.68E-13	1.97E-13
<i>Dy164</i>	5.08E-13	5.31E-13	5.79E-13	6.65E-13
<i>Ho165</i>	5.94E-15	6.42E-15	7.48E-15	9.40E-15
<i>Er166</i>	9.00E-16	9.40E-16	1.01E-15	1.08E-15
<i>Er167</i>	7.29E-16	7.96E-16	9.14E-16	1.06E-15
<i>Er168</i>	2.15E-15	2.57E-15	3.22E-15	4.35E-15

**Appendix 2: Detailed isotopic mass fraction output (discharged burn-up 50 GWd/ tHM).**

Isotopic output mass vector				
Isotope	ThPu	ThPuNp	ThPuNpAm	ThTRU
<i>IDs</i>	<i>kg/tIHM</i>	<i>kg/tIHM</i>	<i>kg/tIHM</i>	<i>kg/tIHM</i>
<i>He4</i>	2.86E-02	3.06E-02	6.99E-02	7.20E-02
<i>Ra228</i>	2.82E-07	2.77E-07	2.76E-07	2.78E-07
<i>Th228</i>	5.17E-04	4.58E-04	3.94E-04	4.02E-04
<i>Th229</i>	1.96E-04	1.77E-04	1.58E-04	1.60E-04
<i>Th230</i>	1.56E-03	1.58E-03	1.62E-03	1.63E-03
<i>Th231</i>	2.75E-04	2.68E-04	2.58E-04	2.61E-04
<i>Th232</i>	8.65E+02	8.40E+02	8.03E+02	8.06E+02
<i>Th233</i>	3.82E-04	3.49E-04	3.15E-04	3.19E-04
<i>Pa231</i>	1.57E-01	1.63E-01	1.69E-01	1.69E-01
<i>Pa233</i>	7.02E-01	6.43E-01	5.84E-01	5.90E-01
<i>Pa234</i>	6.74E-05	5.67E-05	4.57E-05	4.66E-05
<i>U232</i>	6.50E-02	5.68E-02	4.79E-02	4.89E-02
<i>U233</i>	1.42E+01	1.40E+01	1.36E+01	1.37E+01
<i>U234</i>	1.31E+00	1.22E+00	1.11E+00	1.13E+00
<i>U235</i>	1.18E-01	1.09E-01	9.75E-02	9.85E-02
<i>U236</i>	1.98E-02	2.15E-02	2.45E-02	2.41E-02
<i>U237</i>	3.83E-05	3.89E-05	4.05E-05	4.02E-05
<i>U238</i>	9.60E-05	1.07E-04	1.27E-04	1.25E-04
<i>Np236</i>	1.80E-08	1.21E-05	2.08E-05	1.99E-05
<i>Np236M</i>	4.09E-10	1.63E-07	2.19E-07	2.14E-07
<i>Np237</i>	9.82E-03	3.90E+00	5.18E+00	5.03E+00
<i>Np238</i>	1.65E-05	5.63E-03	6.34E-03	6.24E-03
<i>Np239</i>	2.05E-06	5.95E-06	6.54E-06	6.50E-06
<i>Pu236</i>	1.93E-06	4.53E-05	6.21E-05	6.06E-05
<i>Pu237</i>	8.44E-06	1.87E-05	2.88E-05	2.84E-05
<i>Pu238</i>	2.92E+00	6.10E+00	8.98E+00	8.82E+00
<i>Pu239</i>	1.52E+01	2.40E+01	3.78E+01	3.63E+01
<i>Pu240</i>	2.14E+01	2.71E+01	3.53E+01	3.44E+01
<i>Pu241</i>	1.25E+01	1.48E+01	1.75E+01	1.72E+01
<i>Pu242</i>	9.37E+00	1.05E+01	1.27E+01	1.24E+01
<i>Pu243</i>	9.11E-04	8.94E-04	8.91E-04	8.90E-04
<i>Pu244</i>	8.88E-04	9.46E-04	1.36E-03	1.35E-03
<i>Am240</i>	6.56E-08	8.66E-08	2.22E-07	2.17E-07
<i>Am241</i>	1.57E+00	2.06E+00	5.25E+00	5.07E+00



<i>Am242</i>	1.56E-03	1.63E-03	3.15E-03	3.10E-03
<i>Am242M</i>	3.40E-02	4.82E-02	1.65E-01	1.59E-01
<i>Am243</i>	2.30E+00	2.43E+00	3.81E+00	3.75E+00
<i>Am244</i>	7.38E-05	6.91E-05	8.96E-05	8.94E-05
<i>Am244M</i>	4.51E-05	4.23E-05	5.48E-05	5.47E-05
<i>Cm242</i>	2.87E-01	3.00E-01	6.35E-01	6.27E-01
<i>Cm243</i>	1.32E-02	1.38E-02	3.62E-02	3.81E-02
<i>Cm244</i>	1.19E+00	1.14E+00	2.15E+00	2.65E+00
<i>Cm245</i>	1.64E-01	1.52E-01	3.14E-01	4.71E-01
<i>Cm246</i>	1.07E-02	7.90E-03	1.61E-02	4.07E-02
<i>Cm247</i>	1.90E-04	1.35E-04	3.09E-04	1.55E-03
<i>Cm248</i>	9.21E-06	5.65E-06	1.25E-05	1.77E-04
<i>Bk249</i>	1.79E-07	1.11E-07	2.58E-07	5.12E-06
<i>Cf249</i>	5.14E-08	3.34E-08	9.11E-08	2.99E-06
<i>Zn70</i>	5.15E-06	5.09E-06	5.08E-06	5.10E-06
<i>Zn72</i>	7.10E-08	6.71E-08	6.43E-08	6.48E-08
<i>Ga71</i>	1.25E-05	1.21E-05	1.19E-05	1.20E-05
<i>Ge72</i>	2.76E-05	2.70E-05	2.69E-05	2.70E-05
<i>Ge73</i>	6.01E-05	5.80E-05	5.65E-05	5.68E-05
<i>Ge74</i>	1.46E-04	1.41E-04	1.37E-04	1.37E-04
<i>Ge76</i>	7.00E-04	6.73E-04	6.48E-04	6.51E-04
<i>Ge77</i>	8.88E-07	8.38E-07	7.95E-07	7.99E-07
<i>Ge78</i>	2.77E-07	2.63E-07	2.50E-07	2.51E-07
<i>Ge80</i>	3.76E-10	3.55E-10	3.35E-10	3.36E-10
<i>As75</i>	3.41E-04	3.23E-04	3.07E-04	3.09E-04
<i>As77</i>	3.18E-06	3.00E-06	2.85E-06	2.86E-06
<i>As78</i>	2.99E-07	2.84E-07	2.71E-07	2.72E-07
<i>As79</i>	6.27E-08	5.91E-08	5.57E-08	5.59E-08
<i>As80</i>	3.88E-10	3.66E-10	3.45E-10	3.47E-10
<i>As81</i>	1.40E-09	1.37E-09	1.32E-09	1.32E-09
<i>As82</i>	1.08E-10	1.03E-10	9.82E-11	9.87E-11
<i>As82M</i>	7.88E-12	7.48E-12	7.08E-12	7.11E-12
<i>As83</i>	2.26E-11	2.11E-11	1.97E-11	1.99E-11
<i>Se77</i>	1.45E-03	1.41E-03	1.38E-03	1.38E-03
<i>Se78</i>	3.80E-03	3.70E-03	3.60E-03	3.60E-03
<i>Se79</i>	8.48E-03	8.22E-03	7.95E-03	7.97E-03
<i>Se79M</i>	2.81E-08	2.65E-08	2.49E-08	2.50E-08
<i>Se80</i>	1.69E-02	1.65E-02	1.60E-02	1.60E-02
<i>Se81</i>	4.45E-07	4.33E-07	4.18E-07	4.19E-07
<i>Se81M</i>	1.12E-07	1.13E-07	1.14E-07	1.13E-07

<i>Se82</i>	4.67E-02	4.55E-02	4.41E-02	4.42E-02
<i>Se83</i>	1.18E-06	1.11E-06	1.03E-06	1.04E-06
<i>Se83M</i>	2.27E-09	2.16E-09	2.05E-09	2.05E-09
<i>Se84</i>	1.98E-07	1.85E-07	1.73E-07	1.74E-07
<i>Se85</i>	4.05E-09	3.84E-09	3.62E-09	3.63E-09
<i>Se86</i>	1.15E-10	1.10E-10	1.04E-10	1.04E-10
<i>Se87</i>	9.80E-14	9.42E-14	9.01E-14	9.05E-14
<i>Br79</i>	4.28E-06	4.16E-06	4.03E-06	4.03E-06
<i>Br81</i>	3.03E-02	2.98E-02	2.92E-02	2.92E-02
<i>Br82</i>	3.00E-06	2.86E-06	2.69E-06	2.70E-06
<i>Br83</i>	9.19E-06	8.63E-06	8.08E-06	8.12E-06
<i>Br84</i>	3.17E-06	2.97E-06	2.78E-06	2.79E-06
<i>Br84M</i>	3.90E-08	3.68E-08	3.45E-08	3.47E-08
<i>Br85</i>	2.77E-07	2.59E-07	2.41E-07	2.43E-07
<i>Br86</i>	4.06E-08	3.83E-08	3.60E-08	3.62E-08
<i>Br87</i>	3.70E-08	3.51E-08	3.33E-08	3.35E-08
<i>Br88</i>	2.70E-10	2.58E-10	2.46E-10	2.47E-10
<i>Br89</i>	1.48E-13	1.44E-13	1.39E-13	1.40E-13
<i>Kr82</i>	9.53E-04	9.24E-04	8.84E-04	8.89E-04
<i>Kr83</i>	6.30E-02	6.16E-02	6.00E-02	6.01E-02
<i>Kr84</i>	1.29E-01	1.24E-01	1.18E-01	1.18E-01
<i>Kr85</i>	3.51E-02	3.35E-02	3.18E-02	3.20E-02
<i>Kr85M</i>	3.44E-05	3.21E-05	2.98E-05	3.00E-05
<i>Kr86</i>	2.01E-01	1.93E-01	1.85E-01	1.86E-01
<i>Kr87</i>	1.86E-05	1.73E-05	1.60E-05	1.61E-05
<i>Kr88</i>	5.37E-05	4.99E-05	4.61E-05	4.64E-05
<i>Kr89</i>	7.23E-07	6.77E-07	6.31E-07	6.35E-07
<i>Kr90</i>	1.48E-08	1.39E-08	1.31E-08	1.31E-08
<i>Kr91</i>	3.64E-12	3.47E-12	3.30E-12	3.31E-12
<i>Kr92</i>	7.44E-14	7.13E-14	6.82E-14	6.84E-14
<i>Rb85</i>	1.13E-01	1.09E-01	1.04E-01	1.04E-01
<i>Rb87</i>	2.69E-01	2.58E-01	2.46E-01	2.47E-01
<i>Rb88</i>	5.92E-06	5.49E-06	5.06E-06	5.10E-06
<i>Rb89</i>	5.89E-06	5.50E-06	5.12E-06	5.15E-06
<i>Rb90</i>	6.42E-07	6.04E-07	5.67E-07	5.70E-07
<i>Rb90M</i>	3.66E-07	3.43E-07	3.21E-07	3.23E-07
<i>Rb91</i>	1.17E-07	1.12E-07	1.06E-07	1.06E-07
<i>Rb92</i>	7.39E-13	7.16E-13	6.92E-13	6.93E-13
<i>Rb93</i>	7.26E-13	7.14E-13	7.00E-13	7.00E-13
<i>Rb94</i>	1.66E-13	1.64E-13	1.63E-13	1.63E-13

<i>Sr86</i>	6.00E-04	5.74E-04	5.47E-04	5.51E-04
<i>Sr87</i>	6.02E-06	5.92E-06	5.80E-06	5.82E-06
<i>Sr88</i>	3.56E-01	3.41E-01	3.24E-01	3.25E-01
<i>Sr89</i>	2.87E-02	2.69E-02	2.51E-02	2.52E-02
<i>Sr90</i>	4.94E-01	4.77E-01	4.58E-01	4.59E-01
<i>Sr91</i>	2.82E-04	2.68E-04	2.55E-04	2.56E-04
<i>Sr92</i>	8.50E-05	8.20E-05	7.88E-05	7.90E-05
<i>Sr93</i>	3.84E-06	3.74E-06	3.64E-06	3.65E-06
<i>Sr94</i>	2.64E-07	2.60E-07	2.55E-07	2.55E-07
<i>Sr95</i>	7.51E-09	7.45E-09	7.37E-09	7.36E-09
<i>Sr96</i>	1.59E-13	1.58E-13	1.56E-13	1.56E-13
<i>Y89</i>	4.10E-01	3.95E-01	3.78E-01	3.80E-01
<i>Y90</i>	1.27E-04	1.22E-04	1.17E-04	1.18E-04
<i>Y91</i>	4.03E-02	3.86E-02	3.67E-02	3.68E-02
<i>Y91M</i>	1.39E-05	1.32E-05	1.26E-05	1.26E-05
<i>Y92</i>	1.16E-04	1.12E-04	1.07E-04	1.07E-04
<i>Y93</i>	3.91E-04	3.81E-04	3.69E-04	3.69E-04
<i>Y94</i>	1.24E-05	1.21E-05	1.19E-05	1.19E-05
<i>Y95</i>	6.61E-06	6.55E-06	6.47E-06	6.46E-06
<i>Y96</i>	8.92E-13	8.87E-13	8.78E-13	8.78E-13
<i>Y96M</i>	1.62E-11	1.63E-11	1.62E-11	1.62E-11
<i>Y97</i>	6.29E-13	6.29E-13	6.27E-13	6.26E-13
<i>Y97M</i>	1.11E-13	1.12E-13	1.13E-13	1.13E-13
<i>Y98</i>	6.66E-14	6.73E-14	6.76E-14	6.75E-14
<i>Y98M</i>	1.56E-13	1.58E-13	1.60E-13	1.59E-13
<i>Y99</i>	1.67E-13	1.68E-13	1.68E-13	1.68E-13
<i>Zr90</i>	2.11E-02	2.05E-02	1.99E-02	2.00E-02
<i>Zr91</i>	5.30E-01	5.17E-01	5.02E-01	5.03E-01
<i>Zr92</i>	6.64E-01	6.51E-01	6.35E-01	6.36E-01
<i>Zr93</i>	7.96E-01	7.85E-01	7.71E-01	7.71E-01
<i>Zr94</i>	8.97E-01	8.88E-01	8.75E-01	8.75E-01
<i>Zr95</i>	6.72E-02	6.66E-02	6.57E-02	6.56E-02
<i>Zr96</i>	9.95E-01	9.92E-01	9.86E-01	9.85E-01
<i>Zr97</i>	7.92E-04	7.93E-04	7.92E-04	7.91E-04
<i>Zr98</i>	3.29E-08	3.33E-08	3.35E-08	3.35E-08
<i>Zr99</i>	7.46E-13	7.51E-13	7.54E-13	7.53E-13
<i>Zr100</i>	3.91E-12	3.96E-12	4.00E-12	3.99E-12
<i>Zr101</i>	4.48E-13	4.50E-13	4.50E-13	4.50E-13
<i>Zr102</i>	3.22E-13	3.21E-13	3.19E-13	3.19E-13
<i>Zr103</i>	4.61E-14	4.48E-14	4.34E-14	4.35E-14

<i>Nb94</i>	3.04E-06	3.11E-06	3.22E-06	3.21E-06
<i>Nb95</i>	3.66E-02	3.62E-02	3.58E-02	3.57E-02
<i>Nb95M</i>	4.10E-05	4.06E-05	4.01E-05	4.01E-05
<i>Nb96</i>	3.55E-06	3.34E-06	3.12E-06	3.13E-06
<i>Nb97</i>	5.75E-05	5.76E-05	5.75E-05	5.74E-05
<i>Nb98</i>	3.38E-09	3.42E-09	3.44E-09	3.44E-09
<i>Nb98M</i>	2.54E-07	2.57E-07	2.61E-07	2.60E-07
<i>Nb99</i>	1.89E-09	1.93E-09	1.97E-09	1.96E-09
<i>Nb99M</i>	1.44E-07	1.49E-07	1.53E-07	1.52E-07
<i>Nb100</i>	9.73E-13	9.88E-13	9.99E-13	9.97E-13
<i>Nb100M</i>	1.18E-13	1.22E-13	1.27E-13	1.27E-13
<i>Nb101</i>	4.74E-12	4.84E-12	4.93E-12	4.92E-12
<i>Nb102</i>	2.69E-13	2.72E-13	2.76E-13	2.75E-13
<i>Nb103</i>	3.34E-13	3.39E-13	3.44E-13	3.43E-13
<i>Nb104</i>	3.24E-13	3.23E-13	3.21E-13	3.21E-13
<i>Nb105</i>	1.47E-13	1.46E-13	1.45E-13	1.45E-13
<i>Mo95</i>	8.22E-01	8.20E-01	8.15E-01	8.14E-01
<i>Mo96</i>	4.71E-02	4.43E-02	4.10E-02	4.14E-02
<i>Mo97</i>	1.09E+00	1.09E+00	1.08E+00	1.08E+00
<i>Mo98</i>	1.15E+00	1.15E+00	1.15E+00	1.15E+00
<i>Mo99</i>	3.51E-03	3.54E-03	3.57E-03	3.56E-03
<i>Mo100</i>	1.33E+00	1.34E+00	1.34E+00	1.34E+00
<i>Mo101</i>	1.12E-05	1.15E-05	1.18E-05	1.18E-05
<i>Mo102</i>	8.35E-06	8.61E-06	8.86E-06	8.83E-06
<i>Mo103</i>	3.03E-07	3.16E-07	3.29E-07	3.28E-07
<i>Mo104</i>	2.13E-07	2.21E-07	2.29E-07	2.29E-07
<i>Mo105</i>	3.88E-08	4.02E-08	4.16E-08	4.14E-08
<i>Mo106</i>	6.83E-12	6.93E-12	7.00E-12	6.99E-12
<i>Mo107</i>	2.63E-13	2.59E-13	2.55E-13	2.55E-13
<i>Tc98</i>	1.19E-05	1.22E-05	1.27E-05	1.27E-05
<i>Tc99</i>	1.10E+00	1.11E+00	1.13E+00	1.12E+00
<i>Tc99M</i>	2.83E-04	2.86E-04	2.88E-04	2.87E-04
<i>Tc101</i>	1.18E-05	1.21E-05	1.24E-05	1.23E-05
<i>Tc102</i>	6.56E-08	6.76E-08	6.95E-08	6.93E-08
<i>Tc102M</i>	6.96E-09	7.89E-09	8.76E-09	8.67E-09
<i>Tc103</i>	4.88E-07	5.10E-07	5.31E-07	5.29E-07
<i>Tc104</i>	1.43E-05	1.49E-05	1.54E-05	1.54E-05
<i>Tc105</i>	4.78E-06	5.01E-06	5.23E-06	5.22E-06
<i>Tc106</i>	4.85E-08	4.99E-08	5.13E-08	5.11E-08
<i>Tc107</i>	4.06E-09	4.15E-09	4.28E-09	4.28E-09

<i>Tc108</i>	5.46E-13	5.39E-13	5.36E-13	5.39E-13
<i>Tc109</i>	4.08E-14	4.03E-14	3.99E-14	4.00E-14
<i>Ru99</i>	4.60E-05	4.64E-05	4.66E-05	4.65E-05
<i>Ru100</i>	1.72E-01	1.61E-01	1.48E-01	1.49E-01
<i>Ru101</i>	1.15E+00	1.17E+00	1.18E+00	1.18E+00
<i>Ru102</i>	1.31E+00	1.32E+00	1.34E+00	1.33E+00
<i>Ru103</i>	4.94E-02	5.14E-02	5.33E-02	5.31E-02
<i>Ru104</i>	1.25E+00	1.27E+00	1.29E+00	1.29E+00
<i>Ru105</i>	1.91E-04	2.00E-04	2.09E-04	2.08E-04
<i>Ru106</i>	3.33E-01	3.40E-01	3.48E-01	3.47E-01
<i>Ru107</i>	1.42E-06	1.46E-06	1.52E-06	1.52E-06
<i>Ru108</i>	1.24E-06	1.27E-06	1.32E-06	1.32E-06
<i>Ru109</i>	1.47E-08	1.51E-08	1.55E-08	1.55E-08
<i>Ru110</i>	3.03E-11	3.06E-11	3.14E-11	3.17E-11
<i>Ru111</i>	5.08E-14	5.11E-14	5.23E-14	5.30E-14
<i>Rh103</i>	1.01E+00	1.07E+00	1.14E+00	1.13E+00
<i>Rh103M</i>	4.86E-05	5.05E-05	5.23E-05	5.21E-05
<i>Rh105</i>	1.47E-03	1.55E-03	1.63E-03	1.62E-03
<i>Rh105M</i>	1.44E-07	1.51E-07	1.58E-07	1.58E-07
<i>Rh106</i>	3.08E-07	3.15E-07	3.22E-07	3.21E-07
<i>Rh106M</i>	2.89E-07	2.51E-07	2.14E-07	2.16E-07
<i>Rh107</i>	1.06E-05	1.10E-05	1.14E-05	1.14E-05
<i>Rh108</i>	8.10E-08	8.30E-08	8.61E-08	8.62E-08
<i>Rh108M</i>	8.32E-09	9.19E-09	1.07E-08	1.08E-08
<i>Rh109</i>	1.93E-07	1.97E-07	2.04E-07	2.05E-07
<i>Rh110</i>	1.15E-11	1.16E-11	1.19E-11	1.20E-11
<i>Rh111</i>	1.16E-11	1.17E-11	1.26E-11	1.29E-11
<i>Rh112</i>	4.04E-14	4.09E-14	4.41E-14	4.57E-14
<i>Pd104</i>	2.80E-01	2.44E-01	1.94E-01	1.98E-01
<i>Pd105</i>	1.04E+00	1.06E+00	1.09E+00	1.09E+00
<i>Pd106</i>	7.17E-01	7.17E-01	7.18E-01	7.18E-01
<i>Pd107</i>	7.11E-01	7.22E-01	7.38E-01	7.37E-01
<i>Pd108</i>	5.16E-01	5.22E-01	5.32E-01	5.33E-01
<i>Pd109</i>	2.84E-04	2.85E-04	2.89E-04	2.90E-04
<i>Pd110</i>	1.80E-01	1.81E-01	1.87E-01	1.89E-01
<i>Pd111</i>	1.36E-06	1.37E-06	1.46E-06	1.50E-06
<i>Pd111M</i>	1.05E-07	9.13E-08	1.36E-07	1.74E-07
<i>Pd112</i>	3.35E-05	3.36E-05	3.69E-05	3.89E-05
<i>Pd113</i>	1.26E-08	1.27E-08	1.37E-08	1.44E-08
<i>Pd114</i>	1.56E-08	1.59E-08	1.73E-08	1.81E-08

<i>Pd115</i>	1.39E-10	1.43E-10	1.55E-10	1.60E-10
<i>Pd116</i>	1.75E-12	1.83E-12	1.95E-12	1.97E-12
<i>Ag109</i>	2.65E-01	2.74E-01	2.88E-01	2.88E-01
<i>Ag110M</i>	1.96E-03	1.93E-03	1.88E-03	1.89E-03
<i>Ag111</i>	6.88E-04	6.87E-04	7.25E-04	7.47E-04
<i>Ag111M</i>	6.33E-08	6.36E-08	6.77E-08	6.97E-08
<i>Ag112</i>	5.01E-06	5.03E-06	5.54E-06	5.85E-06
<i>Ag113</i>	3.85E-06	3.83E-06	4.12E-06	4.36E-06
<i>Ag113M</i>	1.52E-08	1.52E-08	1.64E-08	1.73E-08
<i>Ag115</i>	1.42E-07	1.46E-07	1.58E-07	1.63E-07
<i>Ag116</i>	1.17E-08	1.23E-08	1.32E-08	1.33E-08
<i>Ag117</i>	2.34E-09	2.49E-09	2.66E-09	2.68E-09
<i>Cd110</i>	1.64E-01	1.56E-01	1.47E-01	1.48E-01
<i>Cd111</i>	8.66E-02	8.65E-02	8.97E-02	9.18E-02
<i>Cd112</i>	3.87E-02	3.89E-02	4.14E-02	4.32E-02
<i>Cd113</i>	8.04E-04	1.16E-03	1.93E-03	1.98E-03
<i>Cd113M</i>	1.18E-05	1.66E-05	2.71E-05	2.77E-05
<i>Cd114</i>	3.95E-02	3.94E-02	4.06E-02	4.24E-02
<i>Cd115</i>	2.40E-05	2.46E-05	2.65E-05	2.75E-05
<i>Cd115M</i>	3.09E-05	3.15E-05	3.37E-05	3.50E-05
<i>Cd116</i>	1.09E-02	1.12E-02	1.16E-02	1.17E-02
<i>Cd117</i>	9.33E-07	9.86E-07	1.05E-06	1.06E-06
<i>Cd117M</i>	3.98E-08	4.38E-08	4.73E-08	4.70E-08
<i>Cd118</i>	2.71E-07	2.83E-07	2.99E-07	2.99E-07
<i>Cd119</i>	7.55E-09	7.83E-09	8.17E-09	8.18E-09
<i>Cd119M</i>	1.26E-09	1.33E-09	1.41E-09	1.40E-09
<i>Cd120</i>	1.00E-09	1.03E-09	1.06E-09	1.06E-09
<i>In115</i>	4.38E-03	4.95E-03	5.88E-03	6.01E-03
<i>In117</i>	1.68E-07	1.78E-07	1.90E-07	1.91E-07
<i>In117M</i>	5.67E-07	5.99E-07	6.39E-07	6.43E-07
<i>In119</i>	6.17E-09	6.45E-09	6.76E-09	6.76E-09
<i>In119M</i>	5.20E-08	5.38E-08	5.60E-08	5.61E-08
<i>In121</i>	1.06E-10	1.10E-10	1.15E-10	1.14E-10
<i>In121M</i>	5.12E-09	5.28E-09	5.46E-09	5.45E-09
<i>Sn115</i>	5.10E-04	5.22E-04	5.49E-04	5.64E-04
<i>Sn116</i>	3.53E-03	3.32E-03	3.08E-03	3.19E-03
<i>Sn117</i>	9.98E-03	1.03E-02	1.06E-02	1.07E-02
<i>Sn118</i>	8.30E-03	8.51E-03	8.80E-03	8.82E-03
<i>Sn119</i>	8.23E-03	8.43E-03	8.67E-03	8.68E-03
<i>Sn120</i>	8.38E-03	8.55E-03	8.78E-03	8.78E-03

<i>Sn121</i>	9.80E-06	1.02E-05	1.06E-05	1.06E-05
<i>Sn121M</i>	5.65E-04	5.83E-04	6.04E-04	6.03E-04
<i>Sn122</i>	1.11E-02	1.13E-02	1.16E-02	1.16E-02
<i>Sn123</i>	6.81E-04	6.91E-04	7.06E-04	7.07E-04
<i>Sn123M</i>	2.01E-07	2.02E-07	2.04E-07	2.04E-07
<i>Sn124</i>	1.80E-02	1.83E-02	1.87E-02	1.86E-02
<i>Sn125M</i>	4.93E-08	5.01E-08	5.11E-08	5.11E-08
<i>Sn126</i>	4.66E-02	4.69E-02	4.74E-02	4.74E-02
<i>Sn127</i>	7.49E-06	7.53E-06	7.57E-06	7.57E-06
<i>Sn127M</i>	6.19E-08	6.23E-08	6.26E-08	6.26E-08
<i>Sn128</i>	6.36E-06	6.42E-06	6.47E-06	6.47E-06
<i>Sn129</i>	1.67E-07	1.67E-07	1.67E-07	1.67E-07
<i>Sn129M</i>	2.98E-07	2.99E-07	3.01E-07	3.00E-07
<i>Sn130</i>	2.81E-07	2.82E-07	2.82E-07	2.82E-07
<i>Sn131</i>	1.90E-08	1.89E-08	1.87E-08	1.87E-08
<i>Sn132</i>	7.88E-09	8.14E-09	8.31E-09	8.27E-09
<i>Sb121</i>	8.10E-03	8.33E-03	8.61E-03	8.58E-03
<i>Sb122</i>	4.65E-06	4.47E-06	4.23E-06	4.25E-06
<i>Sb123</i>	1.07E-02	1.09E-02	1.11E-02	1.11E-02
<i>Sb124</i>	6.26E-05	6.01E-05	5.75E-05	5.79E-05
<i>Sb125</i>	1.63E-02	1.65E-02	1.68E-02	1.68E-02
<i>Sb126</i>	7.46E-06	7.57E-06	7.70E-06	7.70E-06
<i>Sb127</i>	4.63E-04	4.66E-04	4.70E-04	4.70E-04
<i>Sb128</i>	6.45E-05	6.51E-05	6.56E-05	6.55E-05
<i>Sb128M</i>	8.06E-08	8.12E-08	8.21E-08	8.20E-08
<i>Sb129</i>	6.47E-05	6.50E-05	6.53E-05	6.53E-05
<i>Sb130</i>	7.41E-06	7.52E-06	7.63E-06	7.61E-06
<i>Sb130M</i>	1.14E-06	1.14E-06	1.15E-06	1.15E-06
<i>Sb131</i>	1.12E-05	1.12E-05	1.13E-05	1.13E-05
<i>Sb132</i>	6.74E-07	6.99E-07	7.17E-07	7.14E-07
<i>Sb132M</i>	4.40E-07	4.39E-07	4.38E-07	4.38E-07
<i>Sb133</i>	5.06E-07	5.01E-07	4.94E-07	4.94E-07
<i>Sb134M</i>	4.96E-12	4.89E-12	4.79E-12	4.79E-12
<i>Tel22</i>	7.79E-04	7.51E-04	7.15E-04	7.20E-04
<i>Tel24</i>	4.84E-04	4.68E-04	4.52E-04	4.55E-04
<i>Tel25</i>	8.70E-03	8.79E-03	8.90E-03	8.90E-03
<i>Tel25M</i>	2.10E-04	2.13E-04	2.17E-04	2.17E-04
<i>Tel26</i>	9.58E-04	9.69E-04	9.85E-04	9.85E-04
<i>Tel27</i>	4.63E-05	4.68E-05	4.72E-05	4.72E-05
<i>Tel27M</i>	5.02E-04	5.35E-04	5.67E-04	5.65E-04

<i>Te128</i>	1.79E-01	1.80E-01	1.80E-01	1.80E-01
<i>Te129M</i>	6.03E-05	5.27E-05	4.55E-05	4.63E-05
<i>Te130</i>	5.99E-01	6.02E-01	6.03E-01	6.02E-01
<i>Te131</i>	1.50E-05	1.51E-05	1.53E-05	1.52E-05
<i>Te131M</i>	2.46E-04	2.47E-04	2.48E-04	2.48E-04
<i>Te132</i>	4.54E-03	4.57E-03	4.59E-03	4.58E-03
<i>Te133</i>	8.69E-06	8.71E-06	8.70E-06	8.68E-06
<i>Te133M</i>	3.25E-05	3.25E-05	3.24E-05	3.23E-05
<i>Te134</i>	4.40E-05	4.39E-05	4.37E-05	4.36E-05
<i>Te135</i>	3.07E-09	3.05E-09	3.01E-09	3.01E-09
<i>Te136</i>	7.93E-10	7.66E-10	7.37E-10	7.38E-10
<i>Te137</i>	6.35E-14	6.16E-14	5.93E-14	5.93E-14
<i>I127</i>	1.08E-01	1.08E-01	1.09E-01	1.09E-01
<i>I128</i>	3.61E-07	3.47E-07	3.29E-07	3.32E-07
<i>I129</i>	3.33E-01	3.34E-01	3.35E-01	3.35E-01
<i>I130</i>	8.61E-06	7.57E-06	6.63E-06	6.71E-06
<i>I130M</i>	5.62E-08	4.92E-08	4.29E-08	4.34E-08
<i>I132</i>	1.40E-04	1.41E-04	1.42E-04	1.42E-04
<i>I133</i>	1.69E-03	1.70E-03	1.71E-03	1.71E-03
<i>I133M</i>	2.01E-12	2.13E-12	2.27E-12	2.26E-12
<i>I134</i>	7.82E-05	7.86E-05	7.89E-05	7.88E-05
<i>I134M</i>	4.44E-07	4.57E-07	4.71E-07	4.70E-07
<i>I135</i>	5.16E-04	5.21E-04	5.23E-04	5.23E-04
<i>I136</i>	3.23E-07	3.17E-07	3.11E-07	3.11E-07
<i>I136M</i>	5.12E-08	5.16E-08	5.20E-08	5.19E-08
<i>I137</i>	1.02E-08	1.01E-08	1.01E-08	1.01E-08
<i>I138</i>	1.03E-12	1.03E-12	1.02E-12	1.02E-12
<i>I139</i>	1.19E-13	1.16E-13	1.13E-13	1.13E-13
<i>Xe128</i>	9.46E-03	9.14E-03	8.73E-03	8.79E-03
<i>Xe130</i>	8.49E-03	7.70E-03	6.94E-03	7.00E-03
<i>Xe131</i>	7.25E-01	7.48E-01	7.74E-01	7.70E-01
<i>Xe132</i>	1.70E+00	1.69E+00	1.66E+00	1.66E+00
<i>Xe133</i>	9.89E-03	9.95E-03	9.99E-03	9.97E-03
<i>Xe133M</i>	6.32E-05	6.36E-05	6.39E-05	6.38E-05
<i>Xe134</i>	2.16E+00	2.16E+00	2.16E+00	2.16E+00
<i>Xe135</i>	4.89E-04	5.64E-04	6.41E-04	6.35E-04
<i>Xe135M</i>	3.62E-06	3.67E-06	3.71E-06	3.71E-06
<i>Xe136</i>	2.72E+00	2.59E+00	2.44E+00	2.45E+00
<i>Xe137</i>	3.75E-06	3.74E-06	3.72E-06	3.72E-06
<i>Xe138</i>	1.52E-05	1.52E-05	1.51E-05	1.51E-05



<i>Xe139</i>	7.75E-08	7.66E-08	7.56E-08	7.57E-08
<i>Xe140</i>	3.78E-10	3.70E-10	3.62E-10	3.62E-10
<i>Xe141</i>	1.49E-13	1.45E-13	1.41E-13	1.41E-13
<i>Cs133</i>	1.61E+00	1.64E+00	1.66E+00	1.66E+00
<i>Cs134</i>	1.95E-01	1.82E-01	1.69E-01	1.70E-01
<i>Cs134M</i>	6.97E-06	6.46E-06	5.92E-06	5.96E-06
<i>Cs135</i>	1.39E+00	1.53E+00	1.67E+00	1.66E+00
<i>Cs135M</i>	2.44E-07	2.64E-07	2.85E-07	2.84E-07
<i>Cs136</i>	1.30E-03	1.33E-03	1.35E-03	1.35E-03
<i>Cs137</i>	1.86E+00	1.86E+00	1.85E+00	1.85E+00
<i>Cs138</i>	4.39E-05	4.39E-05	4.38E-05	4.38E-05
<i>Cs138M</i>	1.96E-07	1.97E-07	2.00E-07	2.00E-07
<i>Cs139</i>	1.06E-05	1.05E-05	1.04E-05	1.04E-05
<i>Cs140</i>	3.65E-07	3.60E-07	3.55E-07	3.55E-07
<i>Cs141</i>	1.55E-08	1.53E-08	1.52E-08	1.52E-08
<i>Cs142</i>	3.66E-13	3.60E-13	3.52E-13	3.53E-13
<i>Cs143</i>	1.89E-13	1.86E-13	1.82E-13	1.82E-13
<i>Ba134</i>	9.28E-02	8.65E-02	8.02E-02	8.07E-02
<i>Ba135</i>	7.33E-04	6.59E-04	5.87E-04	5.95E-04
<i>Ba136</i>	6.40E-02	6.51E-02	6.60E-02	6.62E-02
<i>Ba137</i>	8.28E-02	8.27E-02	8.25E-02	8.25E-02
<i>Ba137M</i>	2.85E-07	2.84E-07	2.84E-07	2.84E-07
<i>Ba138</i>	1.85E+00	1.84E+00	1.84E+00	1.84E+00
<i>Ba139</i>	1.09E-04	1.08E-04	1.07E-04	1.07E-04
<i>Ba140</i>	2.34E-02	2.31E-02	2.29E-02	2.29E-02
<i>Ba141</i>	2.07E-05	2.05E-05	2.03E-05	2.03E-05
<i>Ba142</i>	1.07E-05	1.05E-05	1.04E-05	1.04E-05
<i>Ba143</i>	1.07E-09	1.06E-09	1.05E-09	1.05E-09
<i>Ba144</i>	1.61E-10	1.57E-10	1.53E-10	1.53E-10
<i>Ba145</i>	6.15E-13	5.95E-13	5.73E-13	5.75E-13
<i>Ba146</i>	1.27E-13	1.22E-13	1.16E-13	1.16E-13
<i>La138</i>	3.03E-05	3.11E-05	3.28E-05	3.29E-05
<i>La139</i>	1.75E+00	1.74E+00	1.74E+00	1.74E+00
<i>La140</i>	3.27E-03	3.23E-03	3.19E-03	3.19E-03
<i>La141</i>	2.85E-04	2.82E-04	2.79E-04	2.80E-04
<i>La142</i>	1.08E-04	1.07E-04	1.05E-04	1.05E-04
<i>La143</i>	1.44E-05	1.42E-05	1.40E-05	1.40E-05
<i>La144</i>	1.23E-07	1.21E-07	1.19E-07	1.19E-07
<i>La145</i>	1.30E-08	1.29E-08	1.29E-08	1.29E-08
<i>La146</i>	9.28E-13	9.07E-13	8.85E-13	8.87E-13

<i>Lal47</i>	4.19E-13	4.10E-13	4.00E-13	4.01E-13
<i>Lal48</i>	4.94E-14	4.72E-14	4.51E-14	4.53E-14
<i>Cel40</i>	1.77E+00	1.76E+00	1.74E+00	1.74E+00
<i>Cel41</i>	5.63E-02	5.58E-02	5.53E-02	5.53E-02
<i>Cel42</i>	1.57E+00	1.56E+00	1.55E+00	1.55E+00
<i>Cel43</i>	2.18E-03	2.15E-03	2.12E-03	2.12E-03
<i>Cel44</i>	3.71E-01	3.67E-01	3.63E-01	3.64E-01
<i>Cel45</i>	1.65E-06	1.64E-06	1.63E-06	1.63E-06
<i>Cel46</i>	7.40E-06	7.37E-06	7.35E-06	7.35E-06
<i>Cel47</i>	1.11E-07	1.12E-07	1.13E-07	1.13E-07
<i>Cel48</i>	7.41E-08	7.28E-08	7.21E-08	7.23E-08
<i>Cel49</i>	4.67E-13	4.61E-13	4.55E-13	4.57E-13
<i>Cel50</i>	1.85E-13	1.81E-13	1.78E-13	1.79E-13
<i>Pr141</i>	1.53E+00	1.53E+00	1.52E+00	1.52E+00
<i>Pr142</i>	3.59E-05	3.21E-05	2.86E-05	2.89E-05
<i>Pr143</i>	2.08E-02	2.04E-02	2.01E-02	2.01E-02
<i>Pr144</i>	1.57E-05	1.55E-05	1.53E-05	1.54E-05
<i>Pr145</i>	2.64E-04	2.62E-04	2.60E-04	2.60E-04
<i>Pr146</i>	1.45E-05	1.44E-05	1.44E-05	1.44E-05
<i>Pr147</i>	6.03E-06	6.05E-06	6.07E-06	6.08E-06
<i>Pr148</i>	6.13E-07	6.08E-07	6.06E-07	6.07E-07
<i>Pr149</i>	3.56E-07	3.62E-07	3.70E-07	3.70E-07
<i>Pr150</i>	6.92E-13	6.95E-13	7.01E-13	7.03E-13
<i>Pr151</i>	6.31E-10	6.32E-10	6.37E-10	6.38E-10
<i>Pr152</i>	1.02E-13	1.00E-13	9.96E-14	1.00E-13
<i>Pr153</i>	4.92E-14	4.78E-14	4.67E-14	4.71E-14
<i>Nd142</i>	1.90E-02	1.74E-02	1.59E-02	1.60E-02
<i>Nd143</i>	1.26E+00	1.28E+00	1.29E+00	1.29E+00
<i>Nd144</i>	1.05E+00	1.02E+00	9.82E-01	9.85E-01
<i>Nd145</i>	8.81E-01	8.84E-01	8.87E-01	8.87E-01
<i>Nd146</i>	9.19E-01	9.08E-01	8.98E-01	8.99E-01
<i>Nd147</i>	7.45E-03	7.46E-03	7.49E-03	7.49E-03
<i>Nd148</i>	5.34E-01	5.35E-01	5.36E-01	5.37E-01
<i>Nd149</i>	2.95E-05	2.98E-05	3.02E-05	3.03E-05
<i>Nd150</i>	3.09E-01	3.11E-01	3.14E-01	3.14E-01
<i>Nd151</i>	1.88E-06	1.92E-06	1.96E-06	1.97E-06
<i>Nd152</i>	1.23E-06	1.26E-06	1.29E-06	1.30E-06
<i>Nd153</i>	3.59E-09	3.63E-09	3.76E-09	3.78E-09
<i>Nd154</i>	9.74E-10	9.80E-10	9.97E-10	1.00E-09
<i>Nd155</i>	5.55E-13	5.49E-13	5.48E-13	5.52E-13

<i>Pm147</i>	2.21E-01	2.30E-01	2.43E-01	2.42E-01
<i>Pm148</i>	1.18E-03	1.14E-03	1.07E-03	1.08E-03
<i>Pm148M</i>	3.86E-03	4.29E-03	4.66E-03	4.65E-03
<i>Pm149</i>	1.15E-03	1.11E-03	1.07E-03	1.08E-03
<i>Pm150</i>	3.04E-07	2.52E-07	2.09E-07	2.13E-07
<i>Pm151</i>	2.82E-04	2.88E-04	2.95E-04	2.95E-04
<i>Pm152</i>	4.93E-07	5.04E-07	5.20E-07	5.20E-07
<i>Pm152M</i>	1.81E-08	2.00E-08	2.22E-08	2.22E-08
<i>Pm153</i>	3.80E-07	3.88E-07	4.02E-07	4.05E-07
<i>Pm154</i>	9.75E-08	9.90E-08	1.02E-07	1.02E-07
<i>Pm154M</i>	5.36E-09	5.80E-09	6.42E-09	6.44E-09
<i>Pm155</i>	4.32E-09	4.40E-09	4.56E-09	4.59E-09
<i>Pm156</i>	5.67E-10	5.76E-10	6.02E-10	6.05E-10
<i>Pm157</i>	1.47E-12	1.44E-12	1.45E-12	1.46E-12
<i>Sm147</i>	1.14E-01	1.19E-01	1.26E-01	1.25E-01
<i>Sm148</i>	2.41E-01	2.39E-01	2.32E-01	2.33E-01
<i>Sm149</i>	9.18E-03	1.29E-02	1.93E-02	1.88E-02
<i>Sm150</i>	3.96E-01	3.89E-01	3.80E-01	3.81E-01
<i>Sm151</i>	5.21E-02	6.58E-02	8.43E-02	8.30E-02
<i>Sm152</i>	1.83E-01	1.87E-01	1.93E-01	1.93E-01
<i>Sm153</i>	1.16E-03	1.10E-03	1.02E-03	1.03E-03
<i>Sm154</i>	8.77E-02	8.83E-02	8.98E-02	9.02E-02
<i>Sm155</i>	8.82E-07	9.04E-07	9.42E-07	9.49E-07
<i>Sm156</i>	1.53E-05	1.58E-05	1.67E-05	1.68E-05
<i>Sm157</i>	1.31E-07	1.33E-07	1.38E-07	1.40E-07
<i>Sm158</i>	4.80E-08	4.83E-08	4.98E-08	5.05E-08
<i>Eu151</i>	1.82E-04	2.91E-04	4.77E-04	4.61E-04
<i>Eu152</i>	1.80E-04	2.59E-04	3.58E-04	3.51E-04
<i>Eu153</i>	2.28E-01	2.24E-01	2.17E-01	2.18E-01
<i>Eu154</i>	7.33E-02	7.28E-02	7.02E-02	7.07E-02
<i>Eu155</i>	1.76E-02	1.75E-02	1.83E-02	1.83E-02
<i>Eu156</i>	4.03E-03	3.39E-03	2.83E-03	2.89E-03
<i>Eu157</i>	2.05E-05	2.01E-05	2.03E-05	2.06E-05
<i>Eu158</i>	5.60E-07	5.67E-07	5.88E-07	5.98E-07
<i>Eu159</i>	1.09E-07	1.09E-07	1.14E-07	1.17E-07
<i>Eu160</i>	2.90E-10	2.89E-10	3.07E-10	3.18E-10
<i>Gd152</i>	2.01E-04	2.32E-04	2.62E-04	2.60E-04
<i>Gd154</i>	7.62E-03	7.40E-03	7.02E-03	7.08E-03
<i>Gd155</i>	5.96E-04	8.13E-04	1.22E-03	1.19E-03
<i>Gd156</i>	1.34E-01	1.22E-01	1.12E-01	1.13E-01

<i>Gdl157</i>	6.31E-04	8.80E-04	1.35E-03	1.32E-03
<i>Gdl158</i>	5.26E-02	5.19E-02	5.17E-02	5.24E-02
<i>Gdl159</i>	9.53E-06	9.44E-06	9.65E-06	9.87E-06
<i>Gdl160</i>	4.12E-03	4.16E-03	4.40E-03	4.54E-03
<i>Gdl161</i>	4.16E-09	4.21E-09	4.68E-09	4.94E-09
<i>Tbl159</i>	8.54E-03	8.63E-03	8.95E-03	9.10E-03
<i>Tbl160</i>	2.16E-04	2.08E-04	2.03E-04	2.08E-04
<i>Tbl161</i>	1.88E-05	1.83E-05	1.93E-05	2.04E-05
<i>Dyl160</i>	9.85E-04	9.71E-04	9.74E-04	9.94E-04
<i>Dyl161</i>	1.60E-03	1.65E-03	1.79E-03	1.86E-03
<i>Dyl162</i>	7.69E-04	7.69E-04	8.43E-04	8.99E-04
<i>Dyl163</i>	6.95E-04	6.83E-04	7.39E-04	8.10E-04
<i>Dyl164</i>	2.89E-04	3.01E-04	3.39E-04	3.79E-04
<i>Dyl166</i>	8.57E-08	8.95E-08	1.23E-07	1.42E-07
<i>Hol165</i>	1.62E-04	1.35E-04	1.24E-04	1.43E-04
<i>Er166</i>	5.70E-05	5.30E-05	5.68E-05	6.49E-05
<i>Er167</i>	4.02E-06	4.47E-06	6.45E-06	7.52E-06
<i>Er168</i>	1.15E-05	1.15E-05	1.38E-05	1.65E-05

### Appendix 3: Mid-cycle 1-group cross sections of most important actinides

n,fission 1-group cross-sections (BU 25.0 GWd/tHM)				
Isotope	ThPu	ThPuNp	ThPuNpAm	ThTRU
<i>IDs</i>	<i>Weighted using the total neutron flux</i>			
<i>U232</i>	11.62000	11.09000	10.43000	10.48000
<i>U233</i>	23.97000	21.76000	18.97000	19.14000
<i>U234</i>	0.56470	0.57340	0.58470	0.58390
<i>U235</i>	12.46000	11.08000	9.57500	9.67700
<i>U236</i>	0.35420	0.35170	0.34890	0.34900
<i>U238</i>	0.12020	0.12240	0.12540	0.12530
<i>Np237</i>	0.62270	0.63290	0.64600	0.64520
<i>Pu238</i>	1.84900	1.83300	1.81600	1.81800
<i>Pu239</i>	20.77000	17.41000	13.80000	14.04000
<i>Pu240</i>	0.64880	0.65830	0.67100	0.67020
<i>Pu241</i>	28.04000	24.47000	20.59000	20.84000
<i>Pu242</i>	0.50130	0.50980	0.52090	0.52020
<i>Pu244</i>	0.43690	0.44450	0.45460	0.45390
<i>Am241</i>	0.79550	0.77740	0.74730	0.74860
<i>Am242m</i>	183.80000	158.10000	71.38000	72.89000
<i>Am243</i>	0.49620	0.50080	0.50490	0.50450
<i>Cm242</i>	0.44070	0.44120	0.44360	0.44350
<i>Cm243</i>	41.50000	37.90000	33.29000	33.53000
<i>Cm244</i>	0.87910	0.88410	0.89110	0.88330
<i>Cm245</i>	42.82000	38.22000	32.91000	25.09000
<i>Cm246</i>	0.60760	0.61220	0.61800	0.66250
<i>Cm247</i>	15.66000	14.65000	13.07000	18.28000
<i>Cm248</i>	0.83000	0.82740	0.82420	0.83220
<i>Cm250</i>	0.54480	0.55400	0.56610	0.66710
<i>Bk249</i>	0.93880	0.87470	0.80110	0.68440
<i>Cf249</i>	65.85000	58.59000	49.53000	40.33000
<i>Cf250</i>	8.92200	8.18100	7.24200	1.13500
<i>Cf251</i>	176.70000	154.70000	127.90000	88.60000
<i>Cf252</i>	4.35000	4.18500	3.96600	3.96300

n,gamma 1-group cross-sections (BU 25.0 GWd/tHM)				
Isotope	ThPu	ThPuNp	ThPuNpAm	ThTRU
<i>IDs</i>	<i>Weighted using the total neutron flux</i>			
<i>U232</i>	5.36500	4.99300	4.56300	4.58900
<i>U233</i>	3.93000	3.62500	3.21000	3.23200
<i>U234</i>	17.55000	16.62000	14.97000	15.05000
<i>U235</i>	4.65700	4.33000	3.94900	3.97400
<i>U236</i>	8.95700	8.40200	7.71000	7.74400
<i>U238</i>	7.21200	6.92800	6.49500	6.51800
<i>Np237</i>	19.90000	17.39000	14.97000	15.11000
<i>Pu238</i>	8.05000	7.02200	5.91600	5.99500
<i>Pu239</i>	11.43000	9.55300	7.53300	7.66900
<i>Pu240</i>	24.41000	20.54000	15.84000	16.16000
<i>Pu241</i>	9.12300	7.83700	6.43800	6.53700
<i>Pu242</i>	13.25000	11.66000	9.74800	9.90300
<i>Pu244</i>	2.83500	2.77400	2.69100	2.69900
<i>Am241</i>	37.11000	32.22000	25.04000	25.40000
<i>Am242m</i>	40.50000	34.58000	12.97000	13.25000
<i>Am243</i>	39.50000	35.29000	26.64000	26.92000
<i>Cm242</i>	3.30000	3.18100	3.02400	3.03700
<i>Cm243</i>	6.19300	5.65600	5.00100	5.03800
<i>Cm244</i>	15.47000	14.57000	13.44000	10.89000
<i>Cm245</i>	7.15800	6.38400	5.49500	3.71500
<i>Cm246</i>	2.85100	2.74100	2.59200	2.92300
<i>Cm247</i>	9.86700	8.99800	7.87400	8.46400
<i>Cm248</i>	6.95200	6.70800	6.39700	5.92300
<i>Cm250</i>	50.28000	47.81000	43.86000	7.61900
<i>Bk249</i>	100.80000	88.14000	73.43000	46.34000
<i>Cf249</i>	23.29000	20.72000	17.47000	10.06000
<i>Cf250</i>	236.90000	211.80000	175.90000	140.80000
<i>Cf251</i>	73.95000	64.14000	52.54000	34.36000
<i>Cf252</i>	1.73800	1.66100	1.56700	1.40100