237\(^{\text{Np}}\) XS experimental validation. Proposal for JEFF3 modification

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Overview

- Trends from Integral measurements:
  - $^{237}$Np sample oscillation in MINERVE (OSMOSE experiment)
  - Post Irradiation Experiment in UOx fuel; $^{238}$Pu prediction content

- Differential measurements:
  - available thermal capture XS
OSMOSE Experiment performed in MINERVE Facility

Reactivity variation due to sample oscillations in a thermal $\text{UO}_2$ spectrum ($^{232}\text{Th, }^{233,234,236}\text{U, }^{237}\text{Np, }^{238,239,240,241,242}\text{Pu, }^{241,243}\text{Am, }^{244}\text{Cm}$).

Cylindrical column of pellets ($\phi=8.1\text{mm;}\ h=95\text{mm}$) made of $\text{UO}_2$ matrix doped with Actinide.

Admixed masses of the two $^{237}\text{Np}$ samples: 0.1g and 0.6g.
$^{237}$Np Qualification Results

<table>
<thead>
<tr>
<th>(C/E-1) in%</th>
<th>JEF-2.2</th>
<th>JEFF-3.1</th>
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<tbody>
<tr>
<td>$^{237}$Np (0.1g)</td>
<td>-9.9 ± 2.5</td>
<td>-14.4 ± 2.5</td>
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<tr>
<td>$^{237}$Np (0.6g)</td>
<td>-7.3 ± 1.9</td>
<td>-12.2 ± 1.9</td>
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<tr>
<td><strong>Mean Value</strong></td>
<td>-8.6 ± 1.8</td>
<td>-13.3 ± 1.8</td>
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OSMOSE interpretation points out the need to increase $^{237}$Np(n,γ) thermal and resonance integral of JEFF-3.1 by about +13%±2% (1σ).

Exact Perturbation Theory supplies the sensitive energy range for this modification.

Breakdown of the $^{237}$Np poisoning worth in MINERVE is the following:
- **40** are thermal neutron induced $0.0 \text{eV} < T_n < 0.25 \text{eV}$
- **30** are « epithermal » neutron induced $0.25 \text{eV} < T_n < 0.625 \text{eV}$ 1rst resonance
- **30** are « slowing-down » neutron induced $0.625 \text{eV} < T_n < 20.0 \text{MeV}$
Chemical assays in French PWR-UOX assemblies

Chemical assays of $^{238}$Pu content in LWR-UOx fuel with low burnup (<20GWj/t, 5 independent fuel pins) show recurrent underestimation using JEFF3.1:

- $\left( \frac{C}{E} - 1 \right) = -1\% \pm 1\%$ for $^{236}$U prediction
- $\left( \frac{C}{E} - 1 \right) = -1\% \pm 3\%$ for $^{237}$Np prediction
- $\left( \frac{C}{E} - 1 \right) = -8\% \pm 4\%$ for $^{238}$Pu prediction

This is mainly due to an underestimation of $^{237}$Np(n,$\gamma$) cross-section by about $10\% \pm 4\% \ (1\sigma)$
**Differential Trends: thermal XS.**

**Evaluated Thermal Capture Cross-Sections:**

- JEF-2.2: 181b
- JEFF-3.1: 162b

**Experimental Capture Cross-Sections:**

- KATOH (2003)*: 142 ± 3 b
- JUROVA (1984): 158 ± 4 b
- KOBAYASHI (1993): 158 ± 3 b
- ESCH (2005): 168 ± 5 b
- TATTERSALL (1960): 169 ± 3 b
- SMITH (1957); (=BNL) 170 ± 22 b
- BROWN (1956): 172 ± 7 b
- WESTON (1981): 175 ± 5 b
- KOBAYASHI (2005): 181 ± 2 b
- EBERLE (1971): 184 ± 6 b
- SHCHERBAKOV (2005): 185 ± 7 b
- SCHUMAN (1969): 185 ± 12 b
- MINI-INCA (2003): 180 ± 5 b (JEFDODC-1138)

*: the sample activation analysis using Wescott energetic decomposition with Cadmium cut-off is very doubtful due to:

- large uncertainty (15%) on gamma peak emission probability after Activation Product disintegration ($^{238}\text{Np} \rightarrow ^{238}\text{Pu}$)...
- cadmium energy cut-off (~ 0.50eV) is too close to resonance peak ($E_0=0.49\text{eV}$)
Conclusion on $^{237}\text{Np}(n,\gamma)$ evaluation in JEFF3.1

- Recent Integral trends are consistent with Differential measurements.

- Independant integral trends points out that an increase of JEFF-3.1 $^{237}\text{Np}(n,\gamma)$ thermal and epithermal cross sections is required:

  $$+12\% \pm 2\%$$

in agreement with previous JEF2.2 evaluation