Cross-section measurement for neutron-induced fission of minor actinides with lead slowing-down spectrometer at KURRI (Kyoto U. Research Reactor Institute)

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Contents of cross section measurements for (n,f) of MAs

1. Introduction

2. Device of neutron source: lead slowing down spectrometer (KULS) (10^3 – 10^4 higher flux than TOF, at ~5m flight length)

3. Development of fission fragment detectors

4. Results of 237Np(n,f), 245,248Cm(n,f) will be shown. (and 241,242m,243Am(n,f))

5. Next our project; experiments by J-PARC is planning.

Lead spectrometer

Neutron flux of Lead and TOF spectrometers

245,248Cm(n,f) is mission of the JST project
Minor Actinides (MAs) in High Level Nuclear Waste (HLW) cause an environmental burden due to their long-term radio-toxicities.

Transmutation or incineration using reactors, or accelerator-driven subcritical systems are needed.

If these are realized, MAs can be reduced and/or used as an energy resource.

To evaluate the feasibility of this technique (for FR, FBR), nuclear data of neutron-induced reaction (capture cross section and fission cross section) are indispensable.

Precise measurements of \((n, \gamma)\), \((n, f)\) etc. for MAs are needed.
Ta target for neutron generation

- Tantalum plates (stack target) (effective thickness 6cm)
- 30MeV electron pulse beam (by LINAC)
- Ta(γ,n) reaction
- Neutrons slow down by elastic&inelastic scattering in KULS (Time of “traveling” in lead blocks)

**Device: KULS**
(Kyoto University Lead slowing-down Spectrometer)

1.5x1.5x1.5m³

Consist of 1600 lead blocks (20x10x10cm³)

**Detector + sample**

* Irradiation together with a reference sample whose σ(n,f) is well known (²³⁵U)
Determination of neutron energy by the time of traveling

Resonance absorption of Several metals in Bi hall

Using the resonance peaks of Cu, Au, Te, In,

Dip is the ratio of neutron spectrum “with” to “without” Te filter.

Calibration line

$E_n = \frac{K}{(t - t_0)^2}$

$K = 178 \text{ keV} \cdot \text{us}^2$

$t_0 = 0.51 \text{ us}$
Fission fragment detector
(MLPPIC : Multi-Layered Parallel Plate Ionization Chamber)

- 2 samples placed back-to-back → objective sample & reference sample (the ratio of fission cross sections)

- 2 identical detector for each sample
  Operation condition of detector
  - 10Torr iso-butane
  - -500V on cathodes

FF

235U

MAs

Shaping amp (CAEN N568B)
PHA&Timing (IWATSU A3100)
Purification by ion exchange method

Precipitation procedure:

- $^{237}$Np solution (dil. HNO$_3$, 20mL)
- Sm$^{3+}$ carrier
- phenolphthalein
- NH$_3$ water

~ pH 10

Filtration

Dryness
Selection of fission events

- Fission fragments are detected by 2 layers of PPIC in coincidence.
Cross section of MAs can be deduced using that for U–235(n,f)

But this method is limited in only the energy region 100eV to 1keV, where the resonance structure is small.
Cross sections deduced by $^{235}\text{U}(n,f)$ and $^{10}\text{B}(n,\alpha)$ reaction
(normalization to the absolute value)

$^{237}\text{Np}(n,f)$

- JENDL-3.3 (broadened)
- $^{235}\text{U}(n,f)$ reference
- $^{10}\text{B}(n,\alpha)$ reference

(simple $1/v$ cross section for the neutron energy)

Absolute value: $^{235}\text{U}$ (●) is normalized to 100 eV ~ 1 keV
$^{237}$Np(n,f)

Evaluated by nuclear data center JAEA

Good agreement
$^{245}\text{Cm}(n,f)$

Due to the different resolution function between JENDL and KULS??

Evaluated by nuclear data center JAEA
$^{248}\text{Cm}(n,f)$

Evaluated by nuclear data center JAEA
$^{248}\text{Cm}(n,f)$

Evaluated by nuclear data center JAEA

- Resonance energy (eV): 76.1
- Neutron width (meV): 95.1
- Capture width (meV): 26
- Fission width (meV): 4.2 → 5.1
## Systematic uncertainties

<table>
<thead>
<tr>
<th>Source of the uncertainty</th>
<th>$^{237}$Np (n,f)</th>
<th>$^{242}$mAm (n,f)</th>
<th>$^{245}$Cm (n,f)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of atoms of MA</td>
<td>12</td>
<td>7.2</td>
<td>2.4</td>
</tr>
<tr>
<td>Number of atoms of $^{235}$U</td>
<td>4.9</td>
<td>5.2</td>
<td>4.9</td>
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<tr>
<td>Selection of fission of MA</td>
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<td>&lt;0.1</td>
<td>&lt;0.1</td>
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<tr>
<td>Selection of fission of $^{235}$U</td>
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<td>0.2</td>
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<tr>
<td>Solid angle for MA</td>
<td>1.9</td>
<td>2.1</td>
<td>5.6</td>
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<tr>
<td>Solid angle for $^{235}$U</td>
<td>1.9</td>
<td>2.1</td>
<td>3.9</td>
</tr>
<tr>
<td>Total (%)</td>
<td>13</td>
<td>14</td>
<td>8.7</td>
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<tr>
<td>Source of the uncertainty</td>
<td>$^{241}$Am (n,f)</td>
<td>$^{243}$Am (n,f)</td>
<td>$^{248}$Cm (n,f)</td>
</tr>
<tr>
<td>--------------------------------</td>
<td>-----------------</td>
<td>-----------------</td>
<td>-----------------</td>
</tr>
<tr>
<td>Number of atoms of MA</td>
<td>2.5</td>
<td>2.8</td>
<td>2.6</td>
</tr>
<tr>
<td>Number of atoms of $^{235}$U</td>
<td>5.4</td>
<td>5.2</td>
<td>5.4</td>
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<td>Selection of fission of MA</td>
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<td>4.1</td>
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<tr>
<td>Total (%)</td>
<td>6.5</td>
<td>12</td>
<td>9.3</td>
</tr>
</tbody>
</table>
Next plan: Schematic view of BL04

Measurement position middle collimator outlet connector cover object of 27m

The measurement position of 21.5m

Upstream section basic cover object

Downstream section basic cover object

J-PARC Neutron beam

LaBr or Ge spectrometer group

MA actinides

Fission neutron

Prompt $\gamma$-ray

Fission fragment

Liquid scintillator for measure the number of fission neutrons, and neutron energy etc.

Ionization chamber and silicon detector group for measurement of fission cross section etc.
Summary

- MLPPIC was developed and used for getting the fission cross sections of MAs

- Cross sections for $^{237}\text{Np}$, $^{245,248}\text{Cm}$, (and $^{241,242m,243}\text{Am}$): 6 nuclides have been measured

- The experiment in J-PARC is planning now
Masamune is worried; heaps of rubble in east and radioactivities in south

Thank you for your attention!