JAEA FNS decay Heat experiment revisited with EAF-2005.1

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Integral experiments

JAEA Fusion Neutron Source (FNS)

- 14 Mev neutron generated by a 2 mA, 350 KeV Deuteron beam (80 degree line) impinging on a stationary tritium-bearing titanium target:
  \[ \approx 1.0 \times 10^{10} \text{n/cm}^2\cdot\text{s} \] on small samples

- 32 samples irradiated (5 Min. and 7 Hours) -1996
  - Cooling times from 1 Min. - 1 Hour and 1 Hour – 400 days
  - Analysed with EAF-97 and FENDL/A-2.0, \( \Rightarrow \) EAF-99/2001

- 73 samples irradiated (5 Min.) –1998-99
  - Cooling times from 30 Seconds – 1 Hour
    \( \Rightarrow \) short half life isotope measurements
  - 10 hours and 180 hours irradiations have been performed as well on all samples (but not processed, analysed yet)
  - Masses from 4 to 100 mg
  - Metallic foil, metallic powder, oxide, carbonate, carbide, dioxide..
  - Analysed with EAF-99/2001 \( \Rightarrow \) EAF-2003=JEFF-3.0/A
FNS Neutron Spectra

Four different irradiation positions

Neutron fluence monitored by $^{27}\text{Al} \ (n,\alpha)\text{Na}^{24}$

< 1 Kev High Standard Deviation
## Irradiated Materials

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Foil samples 25x25 mm2  
Powder sandwiched by adhesive tape of 24x24 mm2  

73 Different materials
7 Hours irradiation; hrs to 400 days cooling times

-For 28 Materials

always better with EAF-05 and/or within the experimental uncertainty
5 Min. irradiation; sec. to one hour cooling time
Dominant radionuclide and pathways analysis

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<th>Dominant path</th>
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<td>O16(n,p)N16</td>
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<tr>
<td>K39(n,2n)K38</td>
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<td>K39(n,2n)K38m</td>
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<td>K39(n,2p)Cl38m</td>
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<td>K41(n,a)Cl38m</td>
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<td>K39(n,2p)Cl38</td>
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<td>K41(n,a)Cl38</td>
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<tr>
<td>K39(n,2p)Cl38m(IT)Cl38</td>
<td>4.7%</td>
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<tr>
<td>K41(n,a)Cl38m(IT)Cl38</td>
<td>24.3%</td>
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5 Min. irradiation; K38 T½ 7.610 minutes

EAF-2005 XS  TALYS-5; ADJUST
K39(n,2n)K38  6.324E-03±2.0E+01%
K 39(n,2n)K38m  1.174E-03±4.0E+01%

EAF-2003 XS  ADL-3; DEL
K39(n,2n)K 38  4.904E-03±2.0E+01%
K39(n,2n)K 38m  1.208E-03±4.0E+01%

+28% ??? on group averaged XS ??

Both decay data from ukpadd6.3 ??

It requires a deeper level of investigation
5 Min. irradiation; sec. to one hour cooling time
Ga74; $T_{1/2}$ 8.117 minutes

**Comparison of XS Data**

**EAF-2005 XS**
- Ge74(n,p)Ga74: $1.268E-02\pm6.3E+01\%$
- Ge74(n,p)Ga74m: $5.695E-03\pm6.3E+01\%$

**EAF-2003 XS**
- Ge74(n,p)Ga74: $6.621E-03\pm6.3E+01\%$
- Ge74(n,p)Ga74m: $2.974E-03\pm6.3E+01\%$

+91% not justified, even by differential data.
5 Min. irradiation; sec. to one hour cooling time
Mo91; $T_\frac{1}{2}$ 15.49 m

EAF-2005      IEAF-2001; EXP
Mo92(n,2n)Mo91  2.611E-01±2.0E+01%  
Mo92(n,2n)Mo91m  3.640E-02±2.0E+01%

EAF-2003      ADL-3; EXP
Mo92(n,2n)Mo91  1.895E-01±2.0E+01%  
Mo92(n,2n)Mo91m  2.555E-02±2.0E+01%

+37% on the ground; not backup by integral data
Mo91; T½ 15.49 m

XS on isomer is however, better in EAF-2005
5 Min. irradiation; sec. to one hour cooling time
W186; $T_{\frac{1}{2}}$ 3.7 days

Abundance Re-185 37.4%, Re-187 62.3%

<table>
<thead>
<tr>
<th>Source</th>
<th>Energy (eV)</th>
<th>Cross section (b)</th>
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<td>3.0E+00</td>
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The (n,2n) increase is not justified
W-186; $T_{1/2}$ 3.7 days

The ground excitation is problematic
5 Min. irradiation; sec. to one hour cooling time

Ir FNS–00 5 Min. Irradiation

Heat Output [microW]

Time After Irradiation [Min]
Ir192m; $T_{1/2} = 1.4$ m

**EAF-2005**
- $^{193}\text{Ir}(n,2n)^{192}\text{Ir}$ 1.227E+00±2.0E+01%
- $^{193}\text{Ir}(n,2n)^{192}\text{Ir}_{m}$ 5.145E-01±2.0E+01%
- $^{193}\text{Ir}(n,2n)^{192}\text{Ir}_{n}$ 3.466E-01±2.0E+01%

**EAF-2003**
- $^{193}\text{Ir}(n,2n)^{192}\text{Ir}$ 1.368E+00±6.1E+01%
- $^{193}\text{Ir}(n,2n)^{192}\text{Ir}_{m}$ 2.559E-01±6.1E+01%
- $^{193}\text{Ir}(n,2n)^{192}\text{Ir}_{n}$ 1.859E-01±6.1E+01%

The total XS increase is not justified
Ir$^{192m}$; $T_{1/2}$ 1.4 m

Ir-$^{193}$(n,2n)Ir-$^{192}$

Cross section (b)

Energy (eV)

0.0E+00 5.0E-01 1.0E+00 1.5E+00 2.0E+00 2.5E+00

5.0E+06 9.2E+06 1.3E+07 1.8E+07 2.2E+07 2.6E+07 3.0E+07

Systm
AEP94 n
JAE94 n
JUL72 g
IBJ84
IBJ79

None of the increases (g or n) seems justified
But, all the others looked like this one

Although, not as this accurate
Conclusions

- FNS 5 minutes irradiation and decay heat measurements from 30 seconds up to 1 hours cooling for 28 different materials


- FNS 7 hours irradiation and decay heat measurement from minutes up to 400 days (~13 months) for 73 different materials

  EAF-2005 would lead the pack of EAF files with only a few correction mainly due to model calculation type evolutions, thousands of them........EAF-2007 will account for those minute drawbacks
Conclusions

➢ For only very small number of excitation function (5 over hundreds) the integral experiments do not agree with:
  ➢ differential data
  ➢ expert knowledge
  ➢ model calculation

➢ It is important to repeat such type of benchmarking to ascertain data change or data evolution

➢ Subtle changes may have surprising effects

➢ It is, however, remarkable that with such a huge increase in number of channels and with the extension of the energy range to 60 Mev the overall performance of EASY-2005 has been kept at such a high and unique level