Measurement of $k_0$-values for europium and iridium at FRM II with very high $f$-values

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7. $k_0$-workshop Montreal
reactor FRM I and FRM II
Why do we need the $k_0$-values of Eu and Ir?

• Analysis of Eu in materials from nuclear reactors during their decommissioning.
• Determination of Ir in monochromators for the neutron scattering experiments.
• Ir is one of the important trace elements in the meteorites.
• No $k_0$-values for $^{192}$Ir in the recommended data sheet.
• $^{151}$Eu, $^{153}$Eu, $^{191}$Ir, $^{193}$Ir are all non-$1/v$ nuclides.
\( k_0 \)-formalisms

The modified Høgdahl convention for the most \( 1/v \)-nuclides (1970s):

\[
\rho = \frac{A}{A^*} \cdot \frac{k_0^*}{k_0} \cdot \frac{G^*_th \cdot f + G^*_epi \cdot Q_0^*(\alpha)}{G^*_th \cdot f + G^*_epi \cdot Q_0(\alpha)} \cdot \frac{\epsilon_p^*}{\epsilon_p}; \quad \text{with } f = \frac{\phi^*_{th}}{\phi_{epi}}, A = \frac{N_p}{t_c};
\]

*: comparator

The Westcott convention in the \( k_0 \)-NAA for all incl. non-\( 1/v \) nuclides \( ^{177}\text{Lu}, \ ^{152}\text{Eu} \) etc. (1990s):

\[
\rho = \frac{A}{A^*} \cdot \frac{k_0^*}{k_0} \cdot \frac{G^*_th \cdot g^*(T_n) + G^*_epi \cdot r \sqrt{T_n/T_0} \cdot s_0^*(\alpha)}{G^*_th \cdot g(T_n) + G^*_epi \cdot r \sqrt{T_n/T_0} \cdot s_0(\alpha)} \cdot \frac{\epsilon_p^*}{\epsilon_p};
\]

The simplified Westcott formalism for “non-\( 1/v \) nuclides” (2014*):

\[
\rho = \frac{A}{A^*} \cdot \frac{1}{k_0} \cdot \frac{1 + Q_0^*(\alpha)/f}{g(T_n) + Q_0(\alpha)/f} \cdot \frac{\epsilon_p^*}{\epsilon_p};
\]

if self-shielding is negligible, and Au is used as monitor \( g(T_n)=1? \)

*: R. van Sluijs et al., J Radioanal Nucl Chem (2014)300:539-545
Working with very high $f$-values

Activation in a well thermalized neutron field, e.g. @FRM II with $f > 5000$:

$$ f = \frac{\phi_{th}}{\phi_{epi}} \gg 1, $$

$$ \rho = \frac{A}{A^*} \cdot \frac{k_0^*}{k_0} \cdot \frac{G_{th}^*}{G_{th}} \cdot \frac{\varepsilon_p^*}{\varepsilon_p} $$

for Høgdahl convention.

For Westcott convention: $r \sqrt{T_n/T_0} \approx 0$

$$ \rho = \frac{A}{A^*} \cdot \frac{k_0^*}{k_0} \cdot \frac{G_{th}^* \cdot g^*(T_n)}{G_{th} \cdot g(T_n)} \cdot \frac{\varepsilon_p^*}{\varepsilon_p} ; $$

The contribution of epi-thermal neutron is negligible.

For the simplified Westcott formalism for “non-1/v nuclides”:

$$ Q_0(\alpha)/f \approx 0 $$

$$ k_0 = \frac{A}{A^*} \cdot \frac{1}{\rho} \cdot \frac{1}{g(T_n)} \cdot \frac{\varepsilon_p^*}{\varepsilon_p} \Rightarrow T_n, g(T_n) $$

if self-shielding is negligible, and Au is used as monitor.

If we use standards, $\rho$ is known. Only $T_n$ and $g(T_n)$ should be determined.
Note on the definition of $r$. The quantity $r$ as defined by equation (2) above is just that of previous publications\textsuperscript{1}, but it should be noted that the definition

$$r = (1 - \text{br}) \times \frac{\text{epithermal flux per unit interval of lnE flux (n\bar{v}) in the Maxwellian component}}{\text{neutron density in the Maxwellian component}} \rightarrow 0$$

where $(1 - \text{br}) = \frac{\text{total neutron density}}{\text{neutron density in the Maxwellian component}} \rightarrow 1$
Experiment

Standards:
- Lu, Eu, Ir: ICP Standard 1000 mg/l CertiPUR®, (±0.5%);
- 200 µl of each one pipetted on filter paper ø=16mm;
- Au: 530 IRMM, 0.1% AuAl, 0.1mm foil ø=16mm.

Efficiency calibration:
QCY-48 Multi-nuclide standard solution of Eckert & Ziegler, 500µl on filter paper ø=16mm;
→ All standards have exactly the same geometry.
→ Single efficiency curve for all samples.
Gamma counting

- trivial but carefully!
  - irradiation in 3 channels with different $T_n$ and neutron flux
  - counting in 25 cm to detector $\rightarrow$ coincidence effect negligible
  - very small dead time $<3\%$ $\rightarrow$ pile up effect negligible
  - thin sample matrix $\rightarrow$ gamma-attenuation, self-shielding negligible
  - 208 keV line was used to determine the activity of $^{177}\text{Lu}$;
  - $^{152m}\text{Eu}$ and $^{194}\text{Ir}$ measured after 2-3 days, $^{152}\text{Eu}$, $^{154}\text{Eu}$, $^{192}\text{Ir}$ after 10 days;
  - contribution of $^{152}\text{Eu}$ to the activity of $^{152m}\text{Eu}$ was subtracted $\rightarrow$ correction of interference
  - each sample was measured on 2 detectors $\rightarrow$ reduce random errors;
  - 2 X Ge-detectors, Lynx (Canberra) + DPS,
  - Softwares: Genie + MULTINAA (home-made).
Determination of neutron temperature

- Using Lu standard as temperature monitor
- Using RS Pro Temperature Sensitive Labels (temperature indicators) as control
- Information from the reactor monitoring system: temperature sensors in the D$_2$O system

$$g(T_n) = \frac{A_{\text{Lu-177}}}{A^*} \cdot \frac{1}{\rho} \cdot \frac{1}{k_{0\text{Lu-177}}},$$

$$\downarrow$$

$$T_n$$
irradiation positions in the reactor pool FRM-II (top view)

cold neutron source
T=18K

rabbit system
\( f > 3000, T_n \approx 40^\circ C \)

fishing position
\( f > 5000, T \approx 55^\circ C \)

hot neutron source
T=2000°C

central channel with reactor core
rabbit system @ FRM II

Medium CO₂

Transport tube to RCM (in ca. 100m)

switches

reactor

6x Loading stations

Handling (decay) box

Application: Short time irradiation

NAA

\[ \phi \text{ th} \quad 4.8 \times 10^{12} \sim 7.3 \times 10^{13} / \text{cm}^2 \text{ s} \]

\[ T_{\text{irr}} \quad 1 \text{ min} \sim 1 \text{ h} \]

\[ T_{\text{transport}} \quad 3 \sim 4 \text{ min} \]

size \quad < 12 \text{ cm}^3

medium \quad \text{CO}_2 \rightarrow \text{no direct contact with moderator}
Manual irradiation (fishing) system

Sample container made of Al. direct contact to pool water → better thermal contact

“thimble tube”

\[ \text{D}_2\text{O} \]

\[ \text{H}_2\text{O} \]
Information from reactor monitoring system

D\textsubscript{2}O heat exchanger

- RPA = 47±3°C
- AS = 57±3°C

D\textsubscript{2}O in
D\textsubscript{2}O out

- 34 °C
- 2000 °C
- >20m
- Heat loss in the pipe line!

D\textsubscript{2}O Moderator tank

- pool water H\textsubscript{2}O: T = 37 °C

Cold neutron source (KQ)

Hot neutron source (HQ)

In
Out

- 18 K
- 64 °C
comparison of $g(T_n)$-factors from different data sources, H: Holden 1999, G: Gryntakis 1975, S

\[ y = 0.0074x + 1.5993 \]
\[ R^2 = 0.9999 \]

\[ y = 0.0068x + 1.5563 \]
\[ R^2 = 0.9999 \]
Measured temperature in different channels

<table>
<thead>
<tr>
<th>irradiation No.</th>
<th>R07352</th>
<th>R0742</th>
<th>R06809</th>
<th>R06808</th>
<th>R07281</th>
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<tr>
<td>channel</td>
<td>AS</td>
<td>RPA3</td>
<td>RPA3</td>
<td>RPA5</td>
<td>RPA2</td>
</tr>
<tr>
<td>duration</td>
<td>20 min</td>
<td>30 min</td>
<td>30 min</td>
<td>10 min</td>
<td>60 min</td>
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<tr>
<td>th. Flux [/cm²s]</td>
<td>1.2E+13</td>
<td>4.8E+12</td>
<td>4.8E+12</td>
<td>3.9E+13</td>
<td>1.5E+13</td>
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<tr>
<td>$f$</td>
<td>5200</td>
<td>6370</td>
<td>6370</td>
<td>3370</td>
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<td>25 cm</td>
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<td>25 cm</td>
<td>25 cm</td>
<td>25 cm</td>
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<td>$T_n$ [°C]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gryntakis</td>
<td>51 ± 2 °C</td>
<td>47 ± 2 °C</td>
<td>39 ± 2 °C</td>
<td>39 ± 2 °C</td>
<td>38 ± 2 °C</td>
</tr>
<tr>
<td>Holden</td>
<td>42 ± 2 °C</td>
<td>37 ± 2 °C</td>
<td>30 ± 2 °C</td>
<td>30 ± 2 °C</td>
<td>29 ± 2 °C</td>
</tr>
<tr>
<td>label</td>
<td>54°C&lt;\text{T}&lt;60°C</td>
<td>46°C&lt;\text{T}&lt;49°C</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

→ possible reason: influence of the cold and hot neutron sources? End of reactor cycle?
→ Okay, then, we calculate the $k_0$-values with different temperature values.
$g(Tn)$-factors of $^{151}$Eu from different data sources

**$g(Tn)$ vs. Temperatur [°C]**

- **Holden_1999**
- **Slujis_2015**
- **Westcott_1970 (no data)**
- **Gryntakis_1975**

- Linear (Holden_1999)
- Linear (Slujis_2015)
- Linear (Westcott_1970 (no data))
- Linear (Gryntakis_1975)

Equations and $R^2$ values:

- $y = -0.0008x + 0.9628$
  - $R^2 = 0.997$

- $y = -0.0009x + 0.9191$
  - $R^2 = 0.9957$

- $y = -0.0009x + 0.917$
  - $R^2 = 0.9957$

Delta > 4%
$g(T_n)$-factors of $^{153}$Eu from different data sources

- Holden_1999
- Slujis_2015
- Westcott_1970
- Gryntakis_1975

$y = -0.0003x + 1.0344$
$R^2 = 0.9999$

$y = -0.0005x + 1.0362$
$R^2 = 0.9982$

$y = -0.0003x + 0.9796$
$R^2 = 0.9997$

$y = -0.0001x + 0.9887$
$R^2 = 0.9999$

$\Delta > 5\%$
$g(Tn)$-factors of $^{191}$Ir from different data sources

\[
y = 0.0001x + 1.0301 \\
R^2 = 0.9995
\]

\[
y = 0.0001x + 1.0098 \\
R^2 = 0.9983
\]

\[
y = -4E-05x + 0.9973 \\
R^2 = 0.9815
\]

$\Delta>4\%$
$g(T_n)$-factors of $^{193}$Ir from different data sources

- Holden_1999 (no data)
- Slujis_2015
- Westcott_1970
- Gryntakis_1975
- Linear (Holden_1999 (no data))
- Linear (Slujis_2015)
- Linear (Westcott_1970)
- Linear (Gryntakis_1975)

\[ y = 0.0002x + 1.0173 \quad R^2 = 0.9999 \]

\[ y = 0.0002x + 1.0143 \quad R^2 = 0.9999 \]

$\Delta < 2\%$

$\Delta = 20 \, ^\circ C$
measured $k_0$-values of $^{152}$Eu using $g(T_n)$ of Grynatiiks compared to recommended values

3 irradiations in different channels calculated with 2 temperature values
measured \( k_0 \)-values of \(^{152m}\)Eu using \( g(T_n) \) of Grynatiks compared to recommended values

3 irradiations in different channels, calculated with 2 temperature values

Same temperature \( \rightarrow \) similar results
measured $k_0$-values of $^{154}$Eu using $g(T_n)$ of Grynatiks compared to recommended values

3 irradiations in different channels calculated with 2 temperature values

Same temperature $\rightarrow$ similar results
average \( k_0 \)-values of \( g(T_n) \) of Gryntakis compared to recommended values

Interference of 121 keV and 123 keV → big standard deviation

3 irradiations in different channels calculated with 2 temperature values
Determination of neutron temperature
Determination of neutron temperature
Measured $k_0$-values of $^{152}\text{Eu}$, $^{154}\text{Eu}$ and $^{152m}\text{Eu}$

<table>
<thead>
<tr>
<th>nuclide</th>
<th>Energy (keV)</th>
<th>Holden</th>
<th>Unc. %</th>
<th>Gryntakis</th>
<th>Unc. %</th>
<th>k0-Rec.</th>
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<tr>
<td>$^{152}\text{Eu}$</td>
<td>121.8</td>
<td>12.59</td>
<td>5.1</td>
<td>12.62</td>
<td>5.1</td>
<td>12.80</td>
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<td>244.7</td>
<td>3.45</td>
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<td>3.44</td>
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<tr>
<td></td>
<td>344.3</td>
<td>11.87</td>
<td>1.7</td>
<td>11.91</td>
<td>1.7</td>
<td>11.90</td>
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<td></td>
<td>443.9</td>
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<td>1.7</td>
<td>1.44</td>
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<td>1.39</td>
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<td>778.9</td>
<td>5.80</td>
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<td>867.4</td>
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<td>1.9</td>
<td>1.91</td>
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<td>1.88</td>
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<td>964.1</td>
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<td>1085.9</td>
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<td>1112.1</td>
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<td>9.51</td>
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<td>$^{154}\text{Eu}$</td>
<td>248</td>
<td>1.64E-01</td>
<td>2.6</td>
<td>1.56E-01</td>
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<td>591.8</td>
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<td>996.4</td>
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<td>$^{152m}\text{Eu}$</td>
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<td>7.8</td>
<td>1.72</td>
<td>7.8</td>
<td>1.48</td>
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<td>5.32E-01</td>
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<td>841.6</td>
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<td>1.9</td>
<td>2.63</td>
<td>1.9</td>
<td>2.49</td>
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</tbody>
</table>

→ Average values of totally 6 results (measured on 2 detectors and from 3 irradiations)
→ Calculated with same $T_n$, no difference bw. H&G for $^{152}\text{Eu}$ und $^{152m}\text{Eu}$; but 5-10% for $^{154}\text{Eu}$
Comparsion to other ref. values

average $k_0$-values of $^{152}$Eu using $g(T_n)$ of Holden compared to recommended values

→Similar trend

$T_n = 40^\circ C$
$T_n = 30^\circ C$
Comparison to other ref. values

average $k_0$-values of $^{152m}$Eu using $g(T_n)$ of Holden compared to recommended values

- $T_n=40^\circ C$
- $T_n=30^\circ C$

- Cimpan_2016_25°C(?)
- mean values Grynatisks
- mean values Holden
- mean values Holden (local $T_n$)
Comparison to other ref. values

average $k_0$-values of $^{154}$Eu using $g(T_n)$ of Holden compared to recommended values
## Measured $k_0$-values of $^{192}$Ir and $^{194}$Ir

<table>
<thead>
<tr>
<th>Energy (keV)</th>
<th>this work</th>
<th>Unc. (%)</th>
<th>ref. 1)</th>
<th>Unc. (%)</th>
<th>ref.2)</th>
<th>Unc. (%)</th>
<th>ref. 3) Unc. (%)</th>
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<td>$^{192}$Ir</td>
<td>296</td>
<td>1.11</td>
<td>2.0</td>
<td>1.15</td>
<td>1.4</td>
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<td>308.5</td>
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<td>1.3</td>
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<td>468.1</td>
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<td>1.89</td>
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<td>$^{194}$Ir</td>
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<td>2.2</td>
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</tbody>
</table>

Ref:
1) de Cort, 2003 At. Data Nucl. Tab. 85:47
2) c.Chilian JRNC 2014 300:609-613
3) A. Stopic et al., JRNC (2014) 300:593–597

$\rightarrow$ The values of $^{192}$Ir seem to be about 3% lower.
Uncertainty of \( g(T_n) \)

\( g(T_n) \)-factors of \(^{176}\text{Lu}\) from different data sources

\[
\begin{align*}
\text{Holden}_1999 & : y = 0.0074x + 1.5993, \quad R^2 = 0.9999 \\
\text{Slujis}_2015 & : y = 0.0069x + 1.5723, \quad R^2 = 0.9999 \\
\text{Westcott}_1970 & : y = 0.007x + 1.5601, \quad R^2 = 1 \\
\text{Gryntakis}_1975 & : y = 0.0068x + 1.5563, \quad R^2 = 0.9999
\end{align*}
\]

\(~10\%\) 
\(~\Delta = 20\, ^\circ\text{C}\)
Uncertainty of $g(T_n)$

$g(T_n)$-factors of $^{151}$Eu from different data sources

- **Holden_1999**
- **Slujis_2015**
- **Westcott_1970 (no data)**
- **Gryntakis_1975**

### Linear Regression Lines

- $y = -0.0008x + 0.9628$, \( R^2 = 0.997 \)
- $y = -0.0009x + 0.9191$, \( R^2 = 0.9957 \)
- $y = -0.0009x + 0.917$, \( R^2 = 0.9957 \)

### Graph Details

- **Uncertainty**: \( \Delta = 20 \, ^\circ \text{C} \)
- **Range**: \( g(T_n) \) from 0.8 to 0.98
- **Temperature Range**: 0 to 140 \( ^\circ \text{C} \)

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Uncertainty of \( g(T_n) \)

\[ g(T_n) \text{-factors of } ^{153}\text{Eu from different data sources} \]

- Holden_1999
- Sluis_2015
- Westcott_1970
- Gryntakis_1975
- Linear (Holden_1999)
- Linear (Sluis_2015)
- Linear (Westcott_1970)
- Linear (Gryntakis_1975)

\[ \text{Uncertainty of } g(T_n) \approx 1\% \]

\[ y = -0.0003x + 1.0340 \quad R^2 = 0.9999 \]

\[ y = -0.0005x + 1.0362 \quad R^2 = 0.9982 \]

\[ y = -0.0003x + 0.9796 \quad R^2 = 0.9997 \]

\[ \Delta = 20 ^\circ \text{C} \]
Uncertainty of $g(T_n)$

$g(T_n)$-factors of $^{191}$Ir from different data sources

- $\gamma = 0.0001x + 1.0301$  
  $R^2 = 0.9995$

- $\gamma = 0.0001x + 1.0098$  
  $R^2 = 0.9983$

- $\Delta = 20 \, ^\circ C$

- $g(T_n)$

- $0.95$ to $1.2$

Temperatur [°C]

- $0$ to $140$

Data sources:
- Holden_1999 (no data)
- Slujis_2015
- Westcott_1970 (?)
- Gryntakis_1975
Uncertainty of $g(T_n)$

$g(T_n)$-factors of $^{193}\text{Ir}$ from different data sources

- Holden_1999 (no data)
- Slujis_2015
- Westcott_1970
- Gryntakis_1975
- Linear (Holden_1999 (no data))
- Linear (Slujis_2015)
- Linear (Westcott_1970)
- Linear (Gryntakis_1975)

Temperature [°C]:
- $y = 0.0002x + 1.0173$
  - $R^2 = 0.9999$
- $\Delta = 20$ °C

Uncertainty of $g(T_n)$: <1 %
Uncertainty of the $k_0$-values

Propagation of uncertainties for single measurement:

$$
\Delta k_0 = k_0 \cdot \sqrt{\left(\frac{\Delta A}{A}\right)^2 + \left(\frac{\Delta A^*}{A^*}\right)^2 + \left(\frac{\Delta \rho}{\rho}\right)^2 + \left(\frac{\Delta g(T_n)}{g(T_n)}\right)^2 + \left(\frac{\Delta \varepsilon_p}{\varepsilon_p}\right)^2 + \left(\frac{\Delta \varepsilon_p^*}{\varepsilon_p^*}\right)^2}
$$

- $\frac{\Delta N_p}{N_p} \approx 0.5\%$
- $\frac{\Delta \rho}{\rho} \approx 0.5\%$
- $\frac{\Delta \varepsilon_p}{\varepsilon_p} \approx 2\%$

$\frac{\Delta k_0}{k_0} \approx 3.6\%$

$\frac{\Delta k_0}{k_0} \approx 2.4\%$

- $\frac{\Delta g(T_n)}{g(T_n)} \approx 2\%$ for $^{152}$Eu and $^{152m}$Eu
- $\frac{\Delta g(T_n)}{g(T_n)} \approx 1\%$ for $^{154}$Eu and $^{192}$Ir
conclusions

• With very high $f$ values, the determination of $k_0$-values can be simplified.

• $g(Tn)$ factors from different literature have influence on the determination of temperature and $k_0$-values of Eu isotopes.

• Compared to the reference values, we found differences under 3% for the $k_0$-values of most main gamma-lines of $^{152}$Eu, $^{154}$Eu, $^{192}$Ir, $^{194}$Ir and 5~6% for $^{152m}$Eu (except 122 keV).

• The main uncertainty is the neutron temperature (especially for $k_0$-values of $^{152}$Eu) and $\text{eff}$. even if the real neutron temperature is 20 K higher or lower than the measured value, the influence on the $k_0$ values is not higher than 3%.

• But we are fighting for the last 3% of the $k_0$-values.

• Therefor, the measurement of local neutron temperature is important.
Thank you for your attention!

Merci de votre attention!
Advantages of high $f$-values

$$k_0 = \frac{A}{A^*} \cdot \frac{1}{\rho} \cdot \frac{1}{g(T_n)} \cdot \frac{\varepsilon_p^*}{\varepsilon_p}$$

If we use standards, $\rho$ is known. Only $T_n$ and $g(T_n)$ have to be determined. No influence of other parameters.

Propagation of uncertainties $\rightarrow$ optimize the experiment conditions:

$$\Delta k_0 = k_0 \cdot \left[ \left( \frac{\Delta A}{A} \right)^2 + \left( \frac{\Delta A^*}{A^*} \right)^2 + \left( \frac{\Delta \rho}{\rho} \right)^2 + \left( \frac{\Delta g(T_n)}{g(T_n)} \right)^2 + \left( \frac{\Delta \varepsilon_p^*}{\varepsilon_p^*} \right)^2 + \left( \frac{\Delta \varepsilon_p}{\varepsilon_p} \right)^2 \right]$$

$$\frac{\Delta N_p}{N_p} \approx 0.5\%$$

$$\frac{\Delta \rho}{\rho} \approx 0.5\%$$

$$\frac{\Delta g(T_n)}{g(T_n)} < 3\%$$

$$\frac{\Delta \varepsilon_p}{\varepsilon_p} \approx 2\%$$
reactor design:

- thermal power: 20 MW
- thermal neutron flux: $5 \cdot 10^{14} \text{ cm}^{-2}\text{s}^{-1}$, undisturbed
- Fuel element: 8.1 kg $\text{U}_3\text{Si}_2$ (93 % U-235)
- 60 d/ cycle, 4 cycles /a
- single small core in $\text{D}_2\text{O}$-moderator tank
- very pure $\phi_{th}$
- 5 vertical channels for NAA
- max. $\phi_{th} \sim 2\text{E}14/\text{cm}^2\text{s}$
efficiency curve @ 25 cm

Starting point: efficiency curve of a multi-standards point source (QCY48) on a Ge-detector with Al-cap
measured $k_0$-values

Average values from 3 irradiations and with different $g(T_n)$-factors.

same temperature $\rightarrow$ similar results
$\rightarrow$ small influence of different $g(T_n)$ factors

Interference of 121 keV and 123 keV $\rightarrow$ big deviation

average $k_0$-values of $^{152}$Eu using $g(T_n)$ of Holden compared to recommended values

Tn=40 °C
Tn=30 °C
measured $k_0$-values

Average $k_0$-values of $^{152\text{m}}\text{Eu}$ using $g(T_n)$ of Holden compared to recommended values

- 6% higher than the recommended values
- Interference with $^{152}\text{Eu}$?
- Correction not good enough?

Same temperature $\rightarrow$ similar results

$\rightarrow$ small influence of different $g(T_n)$ factors
measured $k_0$-values

average $k_0$-values of $^{154}$Eu using $g(T_n)$ of Holden compared to recommended values

Same temperature but different results

$\Rightarrow$ Big influence of different $g(T_n)$ factors?