NPL National Physical Laboratory

Nb-95 and Zr-95
Sr-89 and Sr-90

NPL Environmental Radioactivity Comparison Workshop

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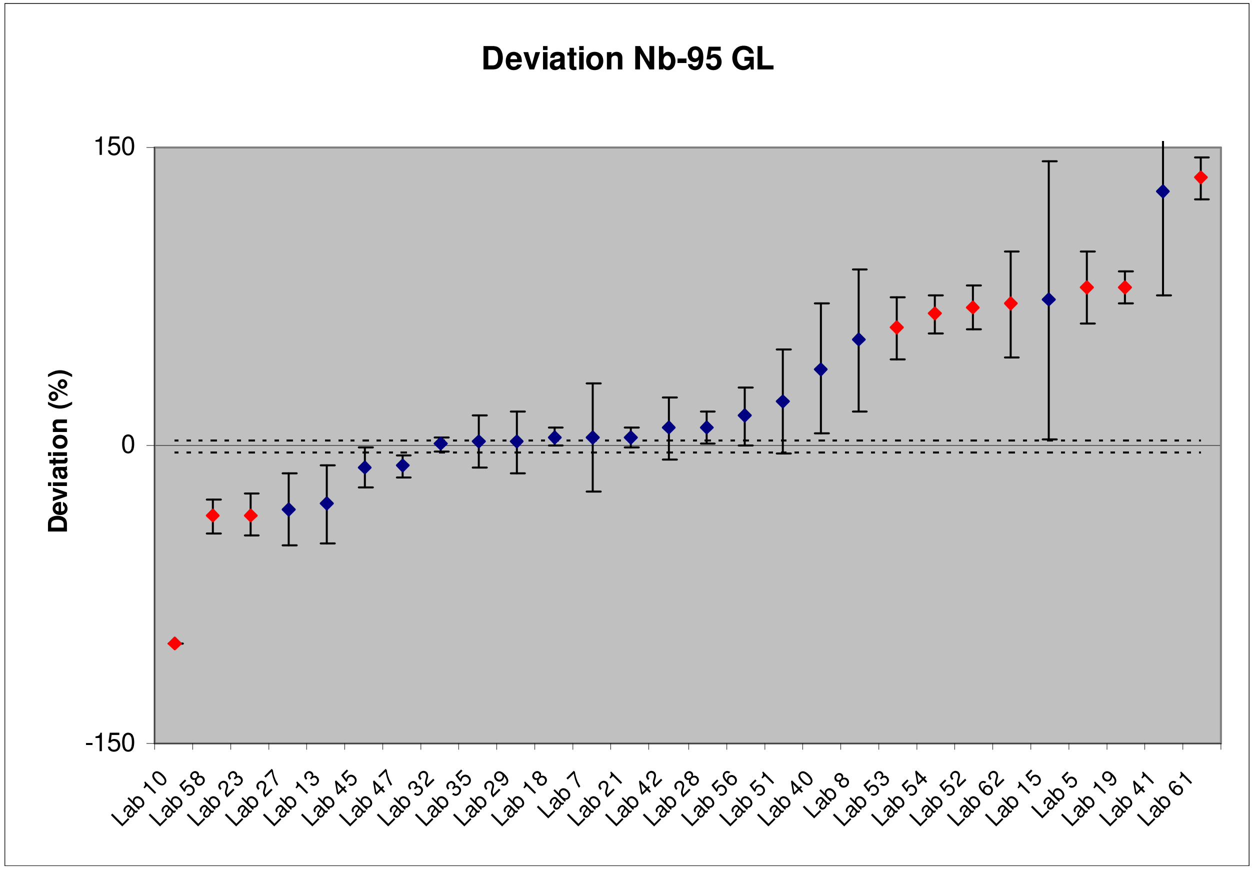
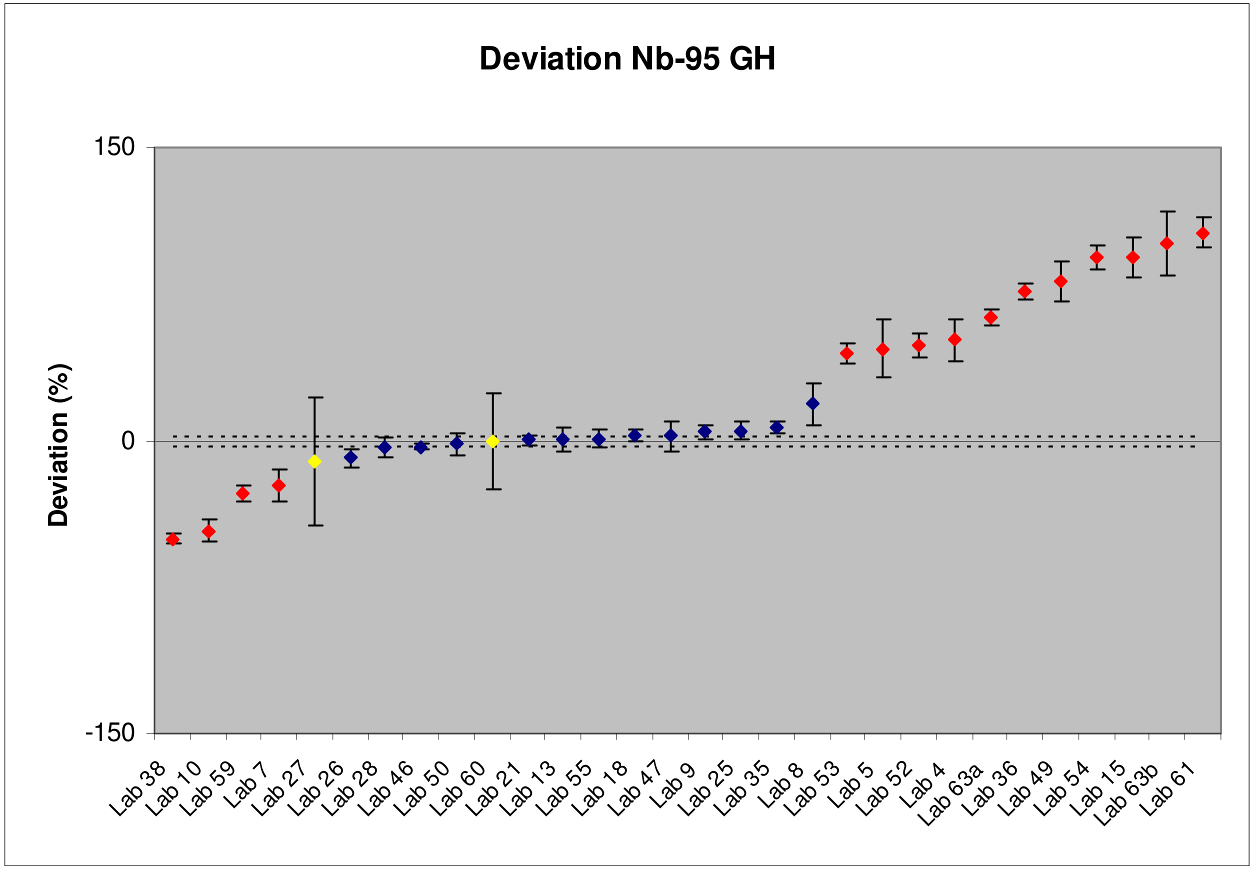
Nb-95 results GL



Nb-95 results GH



Nb-95 and Zr-95 decay

Zr-95 decays to **Nb-95** or Nb-95m ($p = 0.0118$)

[Nb-95m decays to **Nb-95** ($q = 0.976$) or Mo-95]

Nb-95 decays to **Mo-95**

<u>Half-lives</u>

1. Zr -95	64.032(6) d
2. Nb-95m	3.61(3) d
3. Nb-95	34.991(6) d

The Nb-95 activity may be a function of the Zr-95 activity

Transient equilibrium

$$\frac{A_3(t)}{A_1(t)}=\frac{(1-p)\lambda_3}{(\lambda_3-\lambda_1)}\left(1-e^{(\lambda_1-\lambda_3)t}\right)+\frac{q\,p\,\lambda_2\,\lambda_3}{(\lambda_2-\lambda_1)}\left[\frac{\left(1-e^{(\lambda_1-\lambda_3)t}\right)}{(\lambda_3-\lambda_1)}-\frac{\left(e^{(\lambda_1-\lambda_2)t}-e^{(\lambda_1-\lambda_3)t}\right)}{(\lambda_3-\lambda_2)}\right]$$

$$\textit{for } t\rightarrow\infty, \textit{ and } \lambda_1 \langle \lambda_3 \langle \lambda_2 \textit{ then}$$

$$\frac{A_3(\infty)}{A_1(\infty)} = \frac{(1-p)\lambda_3}{(\lambda_3-\lambda_1)}+\frac{q\,p\,\lambda_2\,\lambda_3}{(\lambda_2-\lambda_1)}\left[\frac{1}{(\lambda_3-\lambda_1)}\right] = \frac{\lambda_3}{(\lambda_3-\lambda_1)}\left[1-p+\frac{q\,p\,\lambda_2}{(\lambda_2-\lambda_1)}\right]=2.206$$

This equation reduces to a transient equilibrium equation by setting $p=0$ *and* $q=1$

$$\frac{A_3(\infty)}{A_1(\infty)} = \frac{\lambda_3}{(\lambda_3-\lambda_1)} = 2.205$$

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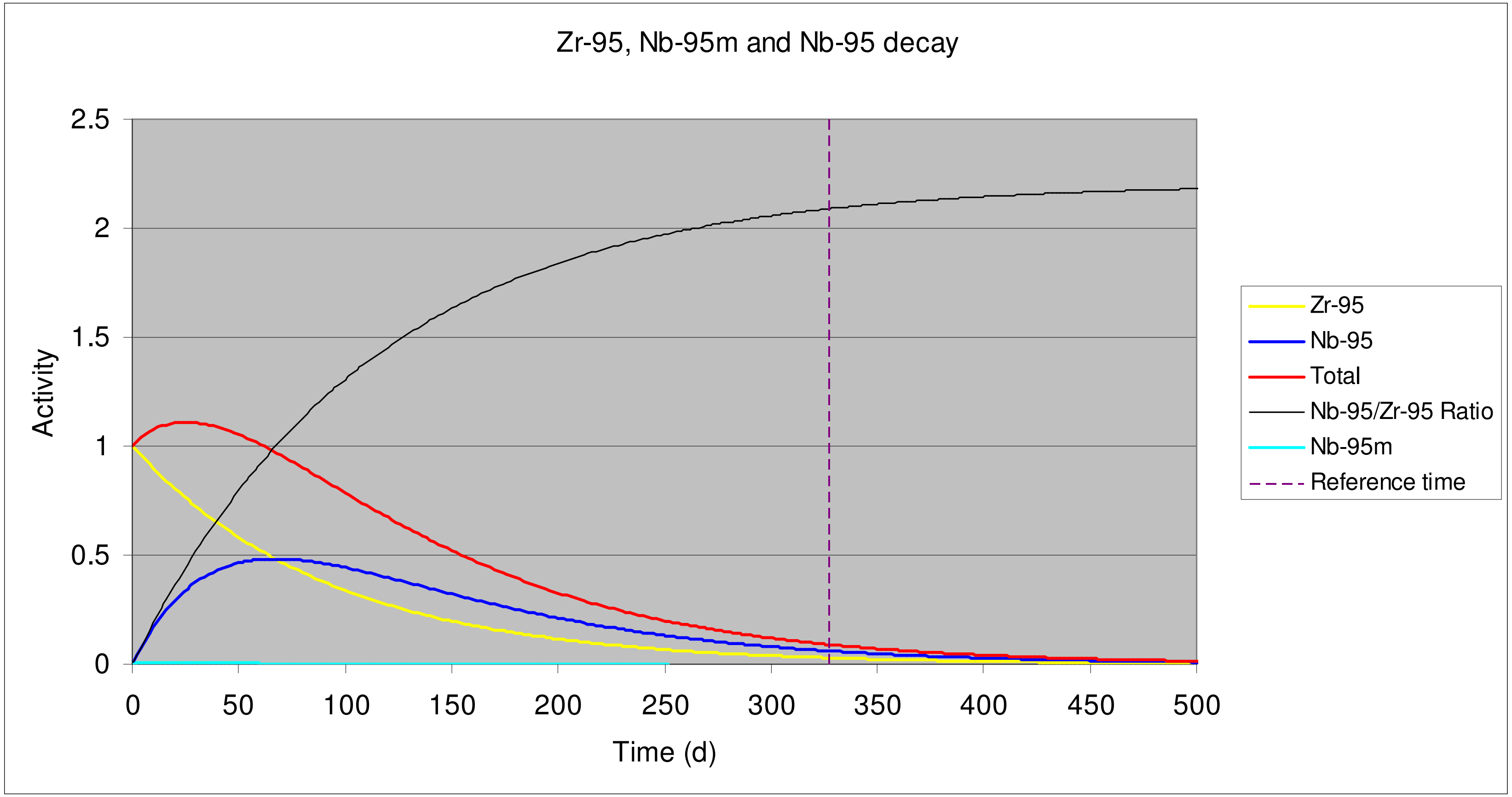
^{95}Zr, ^{95m}Nb and ^{95}Nb activity



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How to decay-correct for Nb-95?

Three possible cases:

-Nb-95 and Zr-95 are in equilibrium (ratio = 2.21)

Also assume equilibrium after correction and use the half-life value of Zr-95

-Ratio is found to be higher than 2.21

Subtract the equilibrium part and use the half-life values of Nb-95 and Zr-95

-Ratio is found to be lower than 2.21 (this exercise: 2.09)

Use the following formulae;

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Formulae (simplified case)

$$\frac{A_3(t)}{A_1(t)} = \frac{\lambda_3}{(\lambda_3 - \lambda_1)}\left(1 - e^{(\lambda_1 - \lambda_3)t}\right)$$

Rearrange to calculate t_{stm} :

$$t_{stm} = \frac{\ln\left[1 - \frac{A_3(t_{stm})(\lambda_3 - \lambda_1)}{A_1(t_{stm})\,\lambda_3}\right]}{(\lambda_1 - \lambda_3)}$$

Calculate t_{ref} and $A_1(t_{ref})$ and use :

$$A_3(t_{ref}) = \frac{\lambda_3}{(\lambda_3 - \lambda_1)}\left(1 - e^{(\lambda_1 - \lambda_3)t_{ref}}\right) A_1(t_{ref})$$

Example

NPL value Nb-95 / Zr-95 ratio at 1 October 2005:	2.09(2)
Measurement on 1 December 2005:	2.14(2)
Decay correction for Nb-95: 1.935 * (2.09 / 2.14) =	1.89

<u>Nb-95 overestimation:</u>

Transient Nb-95 / Zr-95 equilibrium (i.e., Zr-95 decay correction)	2.4%
Secular equilibrium (1:1) with Nb-95 decay correction	42%
Simple Nb-95 decay correction	77%

Caveat

Simplified case, because it:

-Ignores Nb-95m

-Ignores ingrowth and decay during measurement time

Ingrowth / decay during measurement (Desmond MacMahon)

$$A_3\left(t_{ref}\right) = \frac{\lambda_3\, C_3\left(t_{em} - t_{stm}\right)}{\left(e^{-\lambda_3 t_{stm}} - e^{-\lambda_3 t_{em}}\right)} - \frac{\lambda_3\, R_1}{\lambda_1}\frac{\left(e^{-\lambda_1 t_{stm}} - e^{-\lambda_1 t_{em}}\right)}{\left(e^{-\lambda_3 t_{stm}} - e^{-\lambda_3 t_{em}}\right)} - \frac{\lambda_3\, R_2}{\lambda_2}\frac{\left(e^{-\lambda_2 t_{stm}} - e^{-\lambda_2 t_{em}}\right)}{\left(e^{-\lambda_3 t_{stm}} - e^{-\lambda_3 t_{em}}\right)}$$

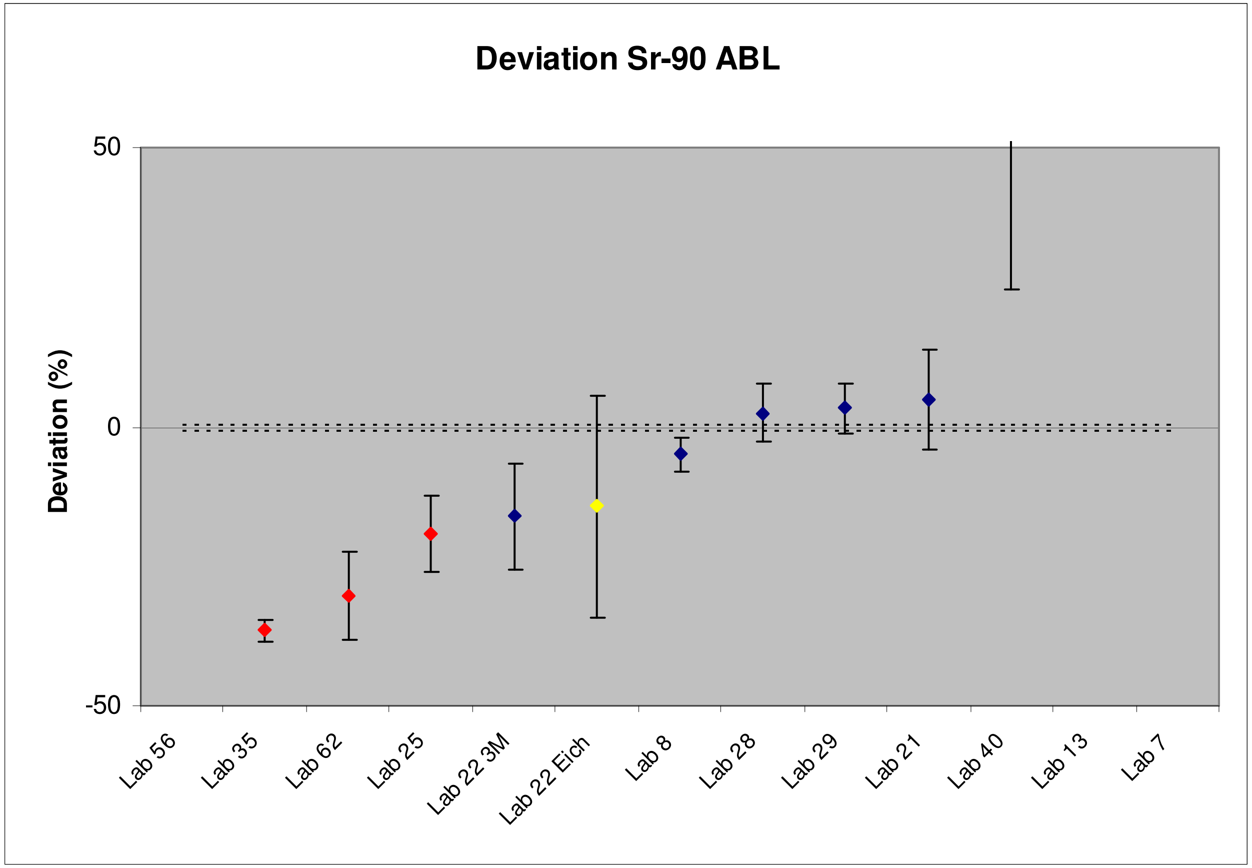
$$+ \quad \left(R_1 + R_2\right)$$

$$Where: \quad R_1 = \frac{\lambda_3\, A_1\left(t_{ref}\right)}{\left(\lambda_3 - \lambda_1\right)}\left[1 - p + \frac{q\, p\, \lambda_2}{\left(\lambda_2 - \lambda_1\right)}\right]$$

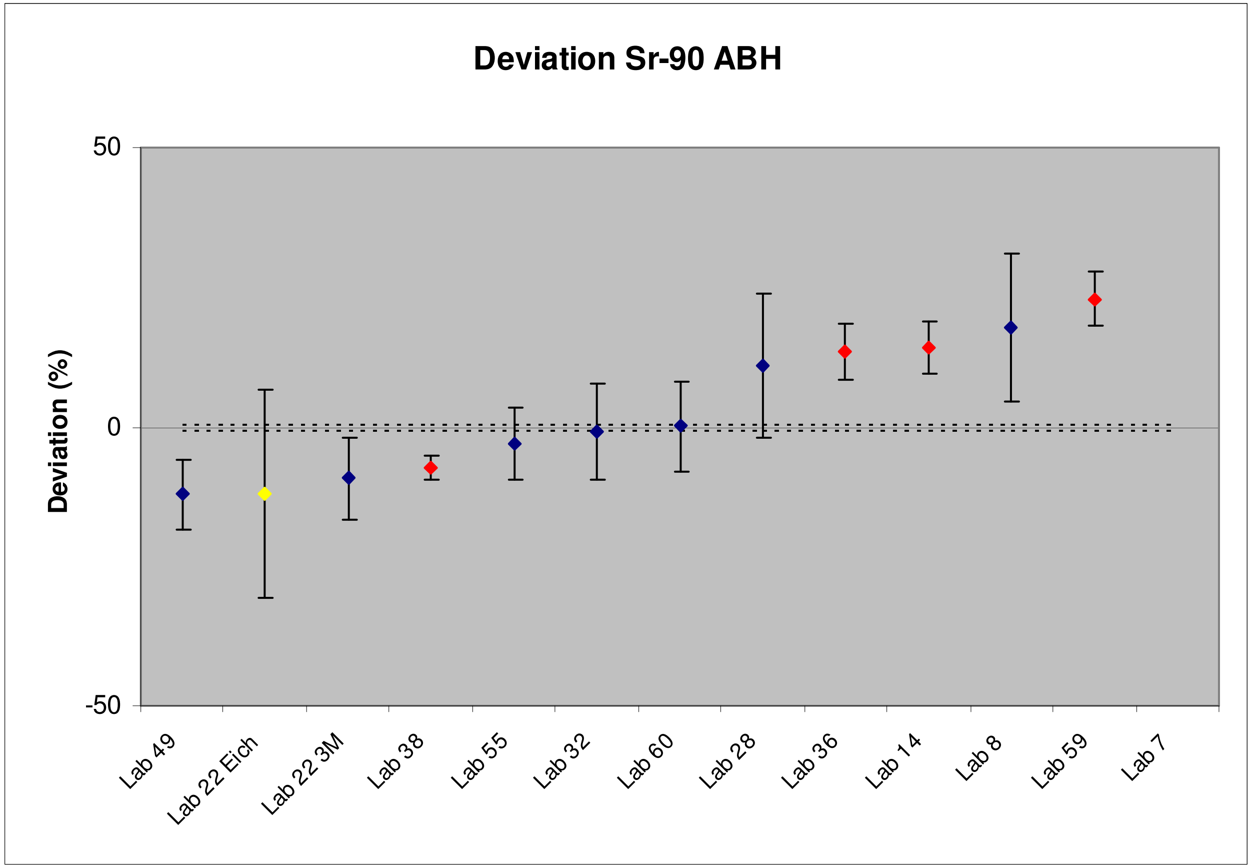
and

$$R_2 = \frac{q\,\lambda_3}{\left(\lambda_3 - \lambda_2\right)}\left[A_2\left(t_{ref}\right) - \frac{p\,\lambda_2\, A_1\left(t_{ref}\right)}{\left(\lambda_2 - \lambda_1\right)}\right]$$

Sr-90 results ABL



Sr-90 results ABH



Sr-90 and Sr-89

Both high-yield beta emitting fission products

Practically impossible to separate chemically

	half-live (d)	E_{max} (keV)
Sr-89	50.57(3)	1495.1(22)
Sr-90	10551(14)	545.9(14)
Y-90	2.6684(13)	2279.8(17)

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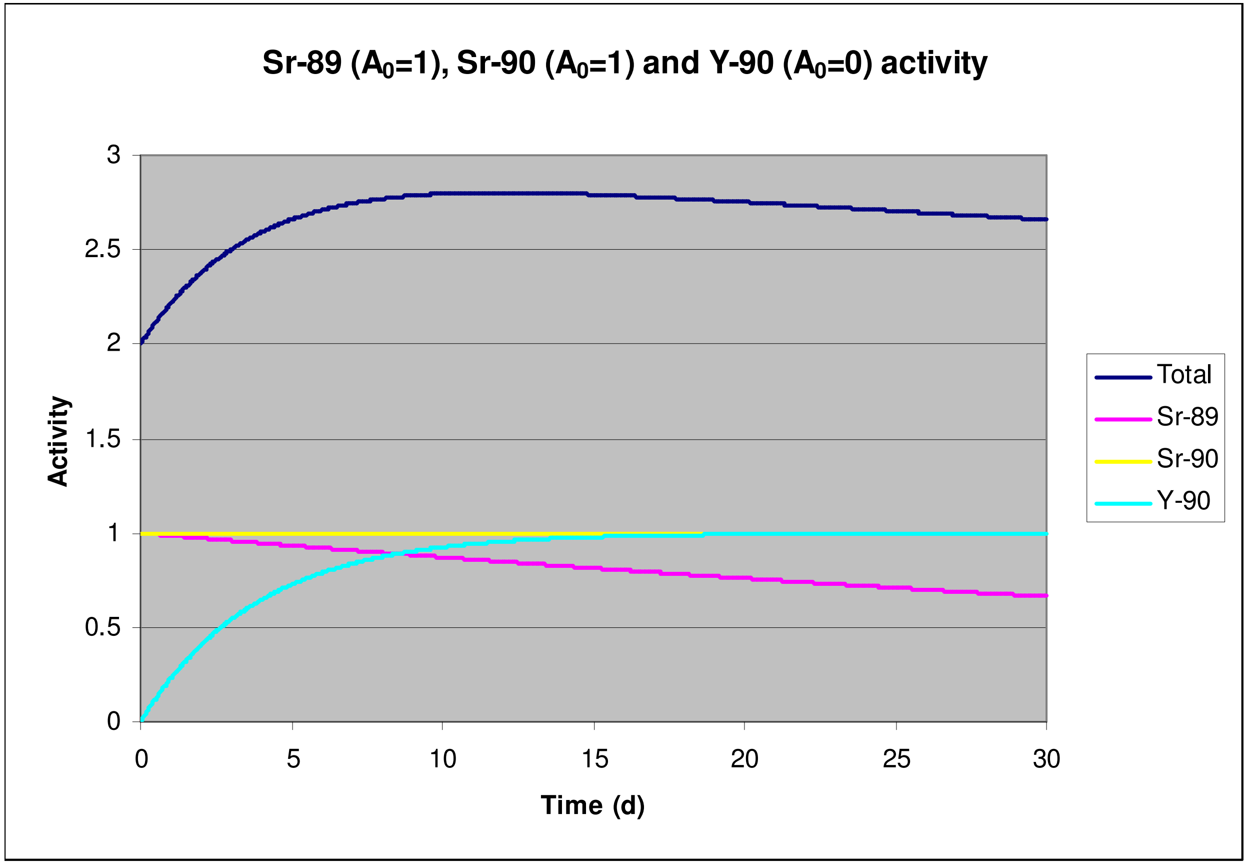
Sr-89, Sr-90 and Y-90 as a function of time



What to do?

(i) Wait until Y-90 / Sr-90 equilibrium (~20 d). Count. Wait for ~50 d. Count again.

(ii) Separate Y-90 from Sr and note time. Count several times within the first 15 d.

(iii) Combination of Cerenkov counting and LSC. Separate Y-90 from Sr. Determine Sr-89 (Cerenkov). Determine Sr-89 and Sr-90 (LSC). Substract Sr-89 from Sr-90.

(iv) Spectrum deconvolution.

Thank you.