Day 1

Calibration

Started with taking peaks of photo-peaks of Na-22.
These have well defined energies
Could also use compton edge and back scatter peak but counts are low and Compton edge is poorly defined.
This calibrates energies to channels.

Noting channel of Compton edge + BSP:

CE: 407 ± 3 chs ← start
423 ± 4 chs ← half way
439 ± 4 chs ← bottom

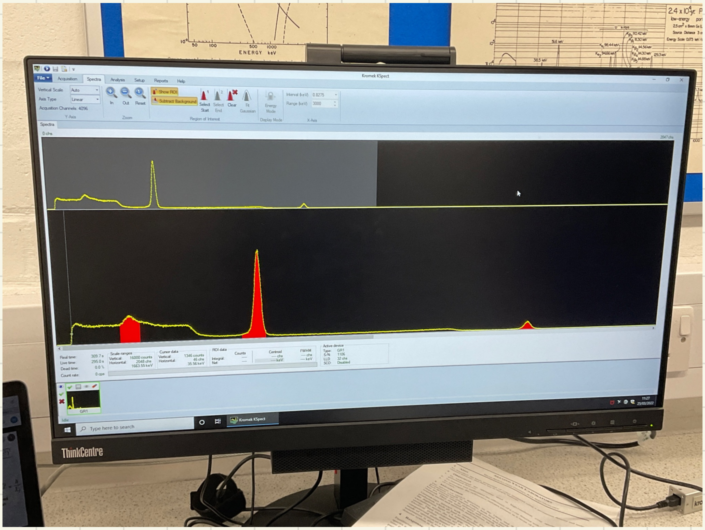
BSP: 221.78 ± 14.45

First Peak

- 630.90 ± 9.76

Second Peak

- 1570.51 ± 10.68



True Values for Na 22:

- Compton edge (half way) = 0.33 ± (2.64%) => 'Validation of energy weighted algorithm for radiation portal monitor using plastic Scintillator'
- First peak: 511 keV ± (16%)
  127 keV ± (11%) => Bismuth Germanate; A High-Z gamma ray and charged particle detector.

Cs-137

Repeating the same for Cs-137:

only 1 peak: True value:

· Peak (gamma energy) = 661.7 KeV

CE: top = 571 chs

mid = 591 chs

bot = 615 chs

BSP = 236.66 ch

Co-60

Same again:

BSP = 272.94 ch

209.6 keV

Compton edge:

T: 1177 chs

M: 1192 chs => 963.4 eV

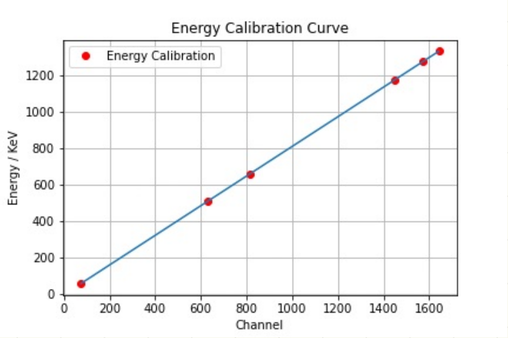
B: 1210 chs

Americium 241

γ decay peak @ 59.5 keV.

All of the above data was used to Calibrate the channel number from the detector to the known energies of the γ decay peaks.

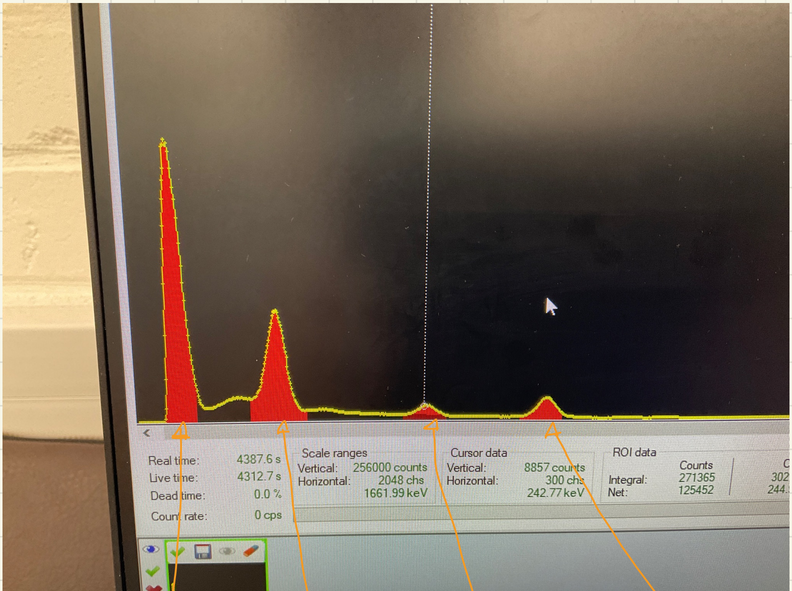
A graph of channel against energy is shown below:



$y = 0.811917x - 0.809862$

then took Europium peak Channel readings

(next page)



anomolous

151.25 chs | 303.22 chs | 425.81 chs

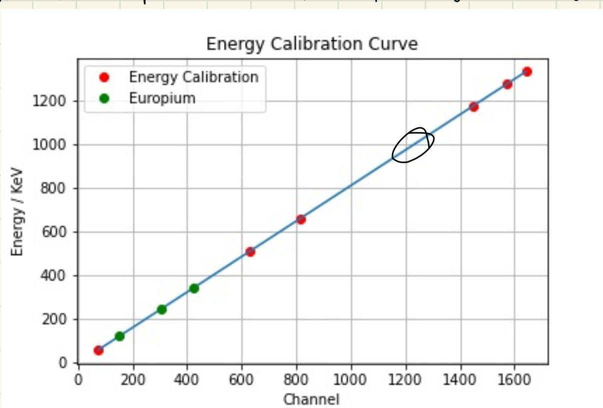
121.9926 keV ← obs | 245.3796 keV | 344.9125 keV

E_{True} = 121.7817 keV | 244.6975 keV | 344.2785 keV

↑ exp

The Calibration curve gave energy values shown in orange above.

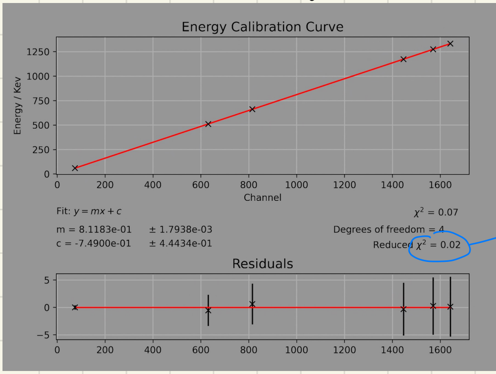
these were Compared to the actual Europium values and a χ^2 was calculated.



The χ^2 between the expected (blue line) and observed (green) was calculated to be $\chi^2 = 0.003$

so $\chi^2_{red} = \frac{\chi^2}{3-1} = 0.02$

This was repeated but errors on energy were included:



$y = (0.812 \pm 0.00179)x - (0.749 \pm 0.44)$

Errors too large

from NIST:

Europium energies:

$121.8 \pm 0.83\%$ keV	
$244.7 \pm 0.71\%$ keV	
$344.3 \pm 0.68\%$ keV	

Measured Eu:

Channel	Energy / keV
151.25	121.99
303.22	245.38
425.81	344.92

χ^2 between energies: $\chi^2 = 0.233$

So $\chi^2_{red} = 0.117$

reasonable χ^2_{red} but
could be improved
by increasing data points
or decrease error bars

Detector Efficiency

The counts being measured depend on a few factors:

$$\underset{\text{Counts}}{\rightarrow} R = \underset{\text{Source Strength}}{S}\ \underset{\text{efficiency}}{\varepsilon}\ \underset{\text{Solid Angle}}{\Omega}\ \underset{\text{relative intensity}}{I}$$

To make readings easier we divide by a relative peak → the source strength and solid angle are constant.

$$\frac{R}{R_R} = \frac{S\varepsilon\Omega I}{S\varepsilon_R\Omega I_R}$$

$$\underbrace{\frac{R}{R_R}}_{\text{relative Counts}} = \underbrace{\frac{\varepsilon}{\varepsilon_R}}_{\text{relative efficiency}}\ \underbrace{\frac{I}{I_R}}_{\text{relative Intensity}} = \qquad \frac{\varepsilon}{\varepsilon_R} = \frac{R/R_R}{I/I_R}$$

① 121 peak: 57755 ± 240

② 245 peak: 6312 ± 79

③ 344 peak: 12075 ± 110

↓

Relative Rates:

1 ± 0.006

0.109 ± 0.02

0.209 ± 0.03

Rate:

① $13.39\ \text{Cnts}\ s^{-1}$ $\quad \sigma = 13.39\sqrt{\left(\frac{240}{57755}\right)^2 + \left(\frac{0.1}{4312.7}\right)^2}$ ← negligable

↳ 13.39 ± 0.06 Counts s^{-1}

Error on rate:

$$\sigma_R = R\frac{\sqrt{C}}{C}$$

↓

error on time ~ 0

↓

$$\left(\frac{\sigma_R}{R}\right)^2 = \left(\frac{\sigma_C}{C}\right)^2 + \left(\frac{\sigma_T}{T}\right)^2$$

($\frac{\sigma_T}{T} \approx 0$)

② 1.46 ± 0.02 Counts s^{-1}

③ 2.80 ± 0.03 Counts s^{-1}

Ratios

① $\sigma = 1 \times \sqrt{\left(\frac{0.06}{13.39}\right)^2 \times 2} = 0.006$

②: $\sigma = 0.109 \times \sqrt{\left(\frac{0.02}{1.46}\right)^2 + \left(\frac{0.06}{13.39}\right)^2} = 0.002$

③: $\sigma = 0.209 \times \sqrt{\left(\frac{0.03}{2.80}\right)^2 + \left(\frac{0.06}{13.39}\right)^2} = 0.002$

Energies

121.952

245.35

344.84

411.91

444.95

779.61

964.45

1407.38

Intensities:

		Intensity Ratios:
①:	28.58 %	1
②:	7.58 %	0.265
③:	26.50 %	0.927

So $\frac{\varepsilon}{\varepsilon_R}$:

① 1.000 ± 0.006

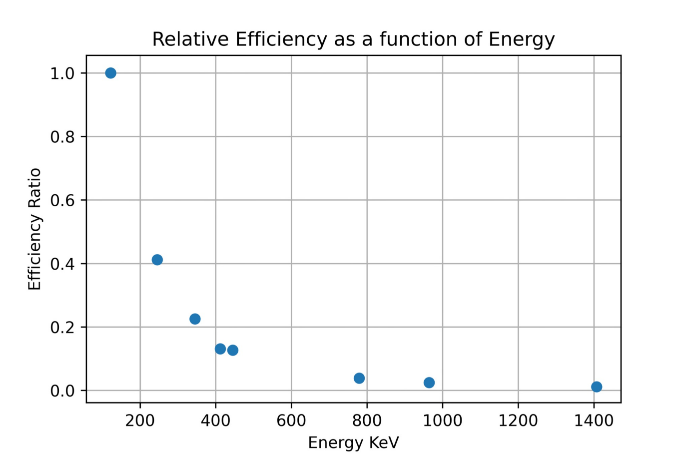
② 0.411 ± 0.005

③ 0.225 ± 0.002

The Europium data gave many peaks but they were dwarfed by the large peaks. Measurements were still taken and are shown:

Efficiency Ratio	Error
1	0.006
0.412	0.005
0.225	0.002
0.131	0.005
0.127	0.005
0.039	0.001
0.025	0.001
0.012	0.001

These were then graphed:



function of form $y = Ax^n$ fitted to this curve.

This had a $\chi^2_{red} = 151.71$.

Barium Data was added to reduce this χ^2 and improve Coeff values.

Barium: Time: 4179.5 ± 0.1 s Ref Rate 13.39 ± 0.06 Counts s^{-1} $I_R = 28.58$

E / keV	Counts	Count rates / Counts s^{-1}	Relative Rates	I	Relative I	$\varepsilon / \varepsilon_R$
80.38	201766 ± 1	$48.28 \pm 1.16 \times 10^{-3}$	3.606 ± 0.024	34.06	0.839	0.670 ± 0.005
303.63	22694 ± 1	$5.43 \pm 1.30 \times 10^{-4}$	0.406 ± 0.003	18.33	1.559	0.140 ± 0.001
276.28	12260 ± 1	$2.93 \pm 7.0 \times 10^{-5}$	0.219 ± 0.001	7.164	3.989	0.193 ± 0.001
356.41	53131 ± 1	$12.71 \pm 3.04 \times 10^{-4}$	0.949 ± 0.005	62.05	0.461	0.0969 ± 0.0005

The Source Strength is not the same so will not cancel:

$$\frac{R}{R_R} = \frac{S \varepsilon \cancel{\Omega} I}{S_R \varepsilon_R \cancel{\Omega} I_R}$$

$$\frac{\varepsilon}{\varepsilon_R} = \frac{R I_R S_R}{R_R I S}$$

S is Barium 370×10^3 counts s^{-1} @ Oct 1995

26.5 years.

$= 9672.5$ days

$$S = S_0 e^{-\lambda t}$$

$$S = 370 \times 10^3 e^{-1.80 \times 10^{-4} \times 9672.5}$$

$$= 64874 \pm 160 \text{ counts } s^{-1}$$

$T_{\frac{1}{2}} = 3848 \pm 6$ days

$$\lambda = \frac{\ln 2}{T_{\frac{1}{2}}} = 1.80 \times 10^{-4} \pm 2.8 \times 10^{-7} \text{ days}^{-1}$$

and for Europium: ^{152} 170×10^{3} Bq @ Jan 1974

$T_{\frac{1}{2}} = 4943 \pm 5$ days

$\delta = 2x$

$\sigma_\delta = \delta \times \frac{\sigma_x}{x}$

$= 2\sigma_x$

48.3 years

=

$$\lambda = \frac{\ln 2}{T_{\frac{1}{2}}} = 1.402\times10^{-4} \text{ days}^{-1} \pm 1.42\times10^{-7}$$

$$\lambda = (1.402 \pm 0.001)\times10^{-4} \text{ days}^{-1}$$

So now $S = S_0 e^{-\lambda t}$

$$S(\text{now}) = 14.36\times10^{3} \text{ Counts s}^{-1}$$

$$\left(\frac{\sigma_S}{S}\right)^2 = \cancel{\left(\frac{\sigma_{S_0}}{S_0}\right)^2} + \left(\frac{\sigma_e}{e}\right)^2$$

$$\frac{\varepsilon}{\varepsilon_R} = \frac{R I_R S_R}{R_R I S}$$

$$\frac{\sigma_S}{S} = \frac{\sigma_e}{e}$$

$\sigma(e^{-\lambda t})$

$= e^{-\lambda t} \times \sigma(-\lambda t)$

$= e^{-\lambda t} \times \lambda t \times \frac{\sigma_\lambda}{\lambda}$

$\frac{\sigma_e}{e} = \sigma(-\lambda t)$

$= \lambda t \frac{\sigma_\lambda}{\lambda}$

$= t\sigma_\lambda$

$$\sigma_S = S \times t\,\sigma_\lambda$$

$$= 25.32$$

$$S = 14.36\times10^{3} \pm 25.32$$

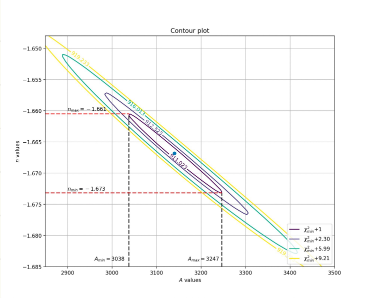
$$S = (14.36 \pm 0.02)\times10^{3} \text{ Counts s}^{-1}$$

$$\frac{S_R}{S} = \frac{14.36\times10^{3}}{6.487\times10^{4}} = 0.2214$$

$$\sigma = \frac{S_R}{S} \times \sqrt{\left(\frac{\sigma_{S_R}}{S_R}\right)^2 + \left(\frac{\sigma_S}{S}\right)^2} = 6.87\times10^{-4}$$

$$= 0.0007$$

$$\frac{S_R}{S} = 0.2214 \pm 0.0007$$

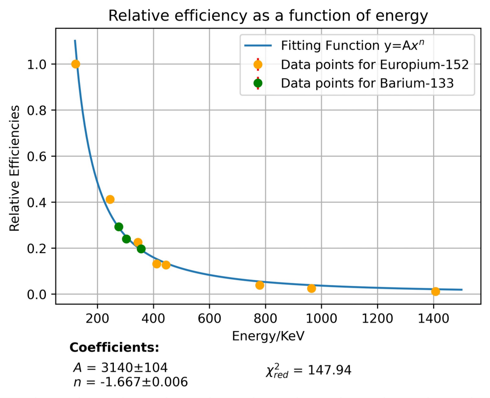


χ^2_{red} is now = 147.94.

This is still large.

Error bars underestimated ?

Values of Barium added to eff curve.

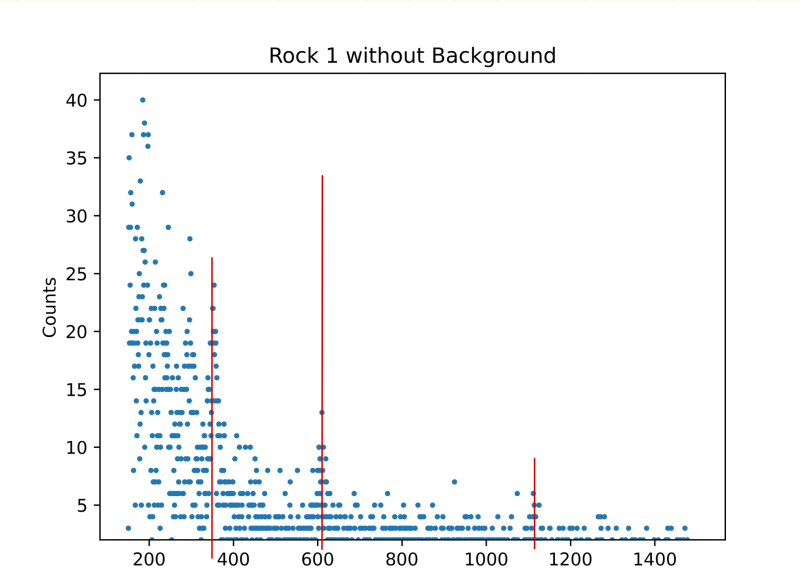


χ^2 Contour plot was made to get errs on Coefficients.

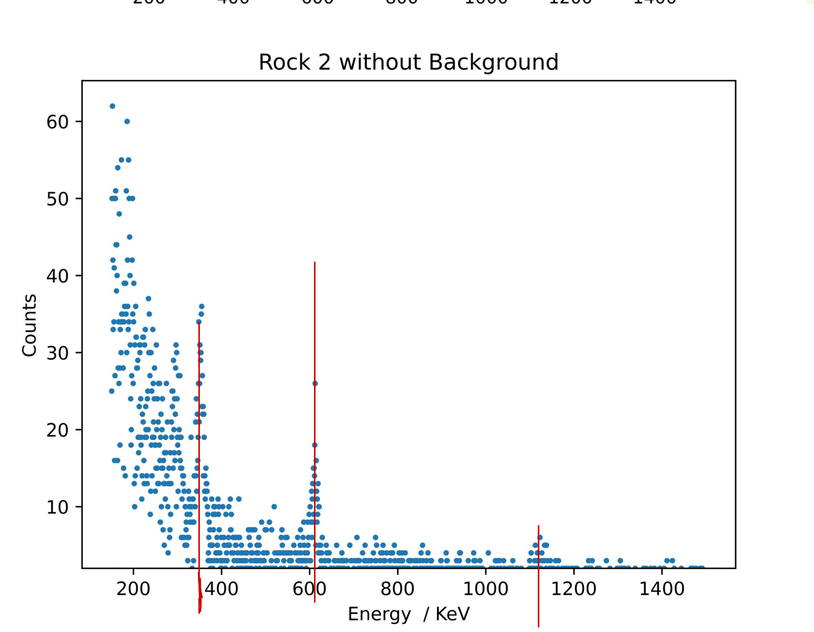
At low energy low energy photons are hard to detect but eff curve doesn't reach this far.

At high energy detector eff falls. High ergy photons Compton Scatter (electron doesn't absorb, reflects) So high E photons not recorded by detector.

Graphs for Both rocks - background.
Readable peaks shown.



No noticable difference between Rock samples.



Pb-214 → Bi

E_γ = 351.932

I = 46.96

Bi-214 → Po

E_γ = 609.316

I = 46.42

Bi-214 → Po

E_γ = 1120.295

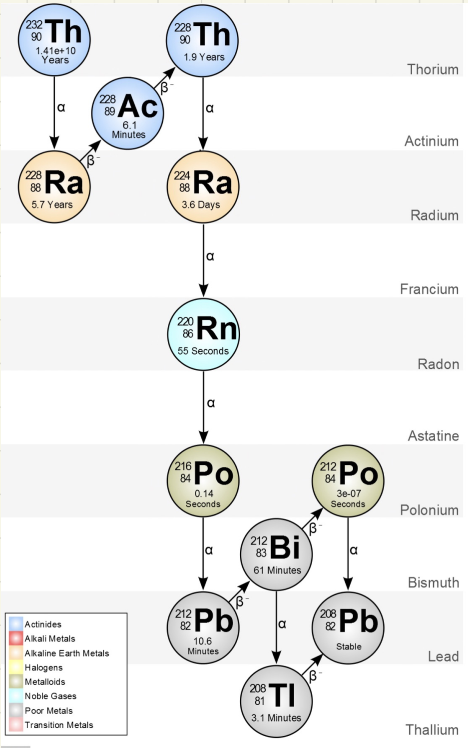
I = 15.14

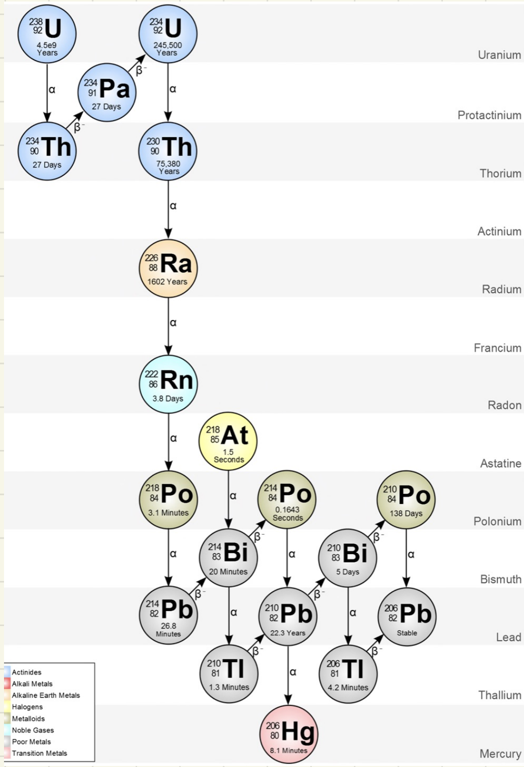
Sample analysis - Rock

The detector took background readings (no source) for 52 mins

This data was exported and was taken from Measurements

The decay chain for U^{238} and Th^{232} are shown:





only some transitions emit γ -v α, β.

mud

Contains Cs-137 ($E = 661.7$ keV)

The Cesium data was retaken:

Cesium receipt date: June, 1964 → 57.83 years

↳ Activity @ date: $10\,\mu Ci$, $370\,kBq$

$R = 370 \times 10^3\ s^{-1}$

$\sigma_N = N \frac{\sigma_\lambda}{\lambda}$

$N_0 = \frac{R_0}{\lambda} = (5.06 \pm 0.01) \times 10^{14}$ nuclei

$M_0 = 5.06 \times 10^{14} \times 1.67 \times 10^{-27} \times 137$

$= (1.158 \pm 0.003) \times 10^{-10}$ kg

$M_{now} = M_0 e^{-\lambda t_{now}}$

$= (3.06 \pm 0.01) \times 10^{-11}$ kg

$\sigma(e^{-\lambda t})$

$= e^{-\lambda t} \times \sigma(-\lambda t)$

$= e^{-\lambda t} \times \lambda t \times \frac{\sigma_\lambda}{\lambda}$

$\sigma(e^{-\lambda t}) = 9.14 \times 10^{-4}$

$\sigma(M_{now}) = M_{now} \sqrt{\left(\frac{\sigma_{M_0}}{M_0}\right)^2 + \left(\frac{\sigma_e}{e}\right)^2}$

$\sigma = 1.33 \times 10^{-13}$

∴ mass of Cs-137 in the mud is this x ratio of count rates:

$M_{in\,mud} = M_{now} \times Ratio = 1.59 \times 10^{-14}$ kg

$\sigma = M_{in\,mud} \sqrt{\left(\frac{\sigma_{M_{now}}}{M_{now}}\right)^2 + \left(\frac{\sigma_{Ratio}}{Ratio}\right)^2}$

$= 1.99 \times 10^{-15}$ kg

$\boxed{\text{Mass of Cs-137 in mud: } (1.59 \pm 0.19) \times 10^{-14}\ \text{kg}}$

Peak of Cs Source → 2109 ± 1 Counts

579.0 ± 0.1 s

Count rate: 3.64 Counts s^{-1}

$R = \frac{2109}{579} = 3.642 \pm R \sqrt{\left(\frac{0.1}{579}\right)^2 + \left(\frac{1}{2109}\right)^2}$

$R_{Cs} = 3.642 \pm 0.002$

mud: 8 ± 1 Counts

4224.2 ± 0.1 s

$R_{mud} = (1.89 \pm 0.23) \times 10^{-3}$

$\sigma_{\frac{x}{y}} = \frac{x}{y} \sqrt{\left(\frac{\sigma_x}{x}\right)^2 + \left(\frac{\sigma_y}{y}\right)^2}$

Ratio: $\boxed{\frac{R_{mud}}{R_{Source}} = (5.19 \pm 0.65) \times 10^{-4}}$

Cs has a half life of ~ $\underbrace{30.05 \pm 0.08 \text{ years}}_{\text{Source}} = 951441120\ s$

$= 951.4 \times 10^6\ s$

$\lambda = \frac{\ln 2}{30.05} = 0.023 \pm 6.12 \times 10^{-5}$, $\lambda = (7.313 \pm 0.019) \times 10^{-10}\ s^{-1}$

$\lambda = \frac{\ln(2)}{T_{\frac{1}{2}}}$ $\boxed{= (23.06 \pm 0.06) \times 10^{-3}\ \text{years}^{-1}}$

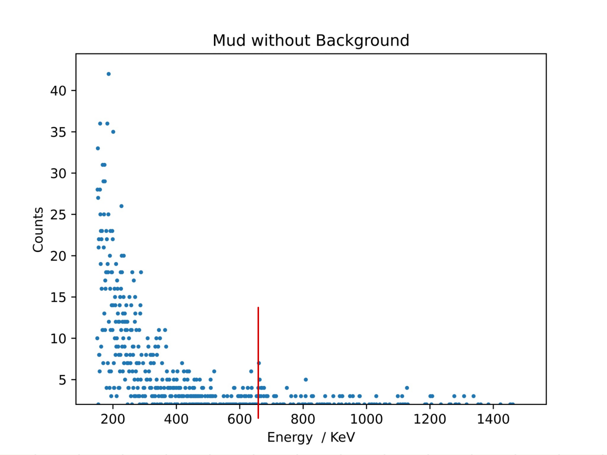
$\sigma_\lambda = \frac{\partial \lambda}{\partial T_{\frac{1}{2}}} \sigma_{T_{\frac{1}{2}}}$

$= -\frac{\ln(2)}{T_{\frac{1}{2}}^2} \times \sigma_{T_{\frac{1}{2}}}$

$= \frac{\lambda}{T_{\frac{1}{2}}} \times \sigma_{T_{\frac{1}{2}}}$

$\sigma_\lambda = \frac{0.023}{30.05} \times 0.08$

$= 6.12 \times 10^{-5}$



Brazil Nuts

Brazil nuts are high in Potassium 40, Radium-226 and Radium-228

E_γ = 1460 keV, 4784 keV, 13.52 keV

Too large for efficiency of detector

low energy photons difficult to read or cancelled by background.

All files in Desktop / uni / year 2 / labs / gamma