Gamma activity of ^{40}K in natural materials.

(I) Preparation: Learn operation of NaI(Tl) scintillation detector system. Adjust & then fix the amplifier gain in order to see ^{60}Co gamma peaks.

(II) Experiments:

(1) **Record a background spectrum** (without any source). Count for one whole day.

(2) **Record a spectrum of KCl sample** with mass $m \approx 60$ g**.** Count also for one whole day.

(III) Analysis:

Mass of **KCl:** $m = 60$ g

Mass of K in sample = $(\frac{m}{W_{\mathrm{KCL}}})W_{\mathrm{K}} = 31.5$ g

where molar mass of KCl = W_{KCL} = 74.56 g/mole

molar mass of natural K = W_{K} =39.098 g/mole

(Note: Try to distinguish formula weight and molar mass.)

Abundance (% of ^{40}K atoms in natural K): $C = 0.0117\%$

Mass of ^{40}K nuclei in sample: $(\frac{m}{W_{\mathrm{KCL}}})W_{\mathrm{K}}C = 3.68\times10^{-3}$ g

Number of ^{40}K nuclei in sample: $N = (\frac{m}{W_{\mathrm{KCL}}})C(6.02\times10^{23}) = 5.67\times10^{19}$

Calculate activity of ^{40}K in sample:

Decay of ^{40}K: ($t_{1/2}$= 1.28×10^{9} y)

Decay modes: β^- -decay: $^{40}\mathrm{K} \rightarrow {}^{40}\mathrm{Ca} + \mathrm{e}^- + \bar{\nu}_e$ (89.28%)

and EC (electron capture): $^{40}\mathrm{K} \rightarrow {}^{40}\mathrm{Ar} + \mathrm{e}^+ + \nu_e$ (10.67%)

^{40}Ar emits gamma rays with energy 1.4608 MeV.

$\therefore$ branching ratio for this gamma decay: $B = 10.67\%$.

Activity of sample: $A = -\frac{dN}{dt} = \lambda N = \frac{\ell n2}{t_{1/2}}N = (1.717\times10^{-17})(5.67\times10^{19}) = 974$ Bq

Emission rate of 1.4608 MeV gamma from sample (in all directions) $= AB = 104$ Bq.

The emission rate (AB) can be measured by the NaI(Tl) detector.

It is proportional to the count rate (n):

$n = ABG\varepsilon_i$ (as discussed in "Notes on Nuclear Detectors")

where n is the peak area of the full energy peak (1.4608 MeV) in the spectrum.

The detector efficiency ε_i depends on gamma energy. It can be obtained using a standard source emitting gamma rays with similar energy.

Then $n_s = A_s B_s G\varepsilon_i$

Here we assume similar detecting geometry (same value of G).

The **standard source** for this experiment is **^{60}Co** ($t_{1/2}$= 5.272 y).
Its activity = 373.9 kBq on July 1, 1983.
To calculate current activity A_s, use calculator in
http://www.ehs.washington.edu/rso/calculator/activity_calc.shtm
Put the source on top of NaI(Tl) detector & record a gamma spectrum of ^{60}Co for 300 sec.
^{60}Co emits gamma rays: 1.173238 MeV (99.87%) & 1.332501 MeV (99.98%).
The total emission rate of these two gamma rays is $A_s B_s$
where B_s = (99.87% + 99.98%).
n_s is the total area of these two peaks in the spectrum.
Then n can be determined from $\frac{n}{n_s} = \frac{AB}{A_s B_s}$.
Compare result with the calculated value.

(IV) Specific activity (s)

It is defined as $s = \frac{\text{decay rate}}{\text{mass of isotope}}$.

$\therefore$ Specific activity of ^{40}K, $s = \frac{974 \text{ Bq}}{3.68 \times 10^{-3} \text{ g}} = 2.65 \times 10^5$ Bq/g.

Note: This includes all decay branches (β & γ).

Specific activity of natural potassium, $s = \frac{974 \text{ Bq}}{31.5 \text{ g}} = 30.9$ Bq/g.

According to Radionuclide and Radiation Protection Data Handbook 2002*, $s = 2.54 \times 10^5$ Bq/g for ^{40}K.
* **Ref. :** Radiation Protection Dosimetry, vol. 98, pp.1-168 (2002).