Radiation Biology, Protection and Applications

(PHYS-450)

PRACTICE EXERCISES

Week 07

SOLUTIONS

Please calculate the given exercises. Please note that the practice exercises will not be graded, you will only receive feedback.

Problem 1:

How many alpha and beta particles are emitted by a nucleus of an atom of the uranium series, which starts as ${}^{238}_{92}U$ and ends as stable ${}^{206}_{82}Pb$?

A:

238 – x.(4) = 206

X = 8

Z:

92 – 8.2 + y.(1) = 82

y = 6

8 alpha particles

6 beta particles

Problem 2:

A typical smoke detector contains a ^{241}Am source with an activity of 30 kBq. What is the mass of the ^{241}Am? (T1/2=432.2years)

$$\lambda = \frac{\ln(2)}{T_{1/2}} = \frac{\ln(2)}{13,639,195,520\,\mathrm{s}} \approx 5.082 \times 10^{-11}\,\mathrm{s}^{-1}$$

The activity A is related to the number of radioactive atoms N by:

$$A = \lambda N \implies N = \frac{A}{\lambda}$$

$$N = \frac{30,000\,\mathrm{Bq}}{5.082 \times 10^{-11}\,\mathrm{s}^{-1}} \approx 5.904 \times 10^{14}\,\mathrm{atoms}$$

$$n = \frac{5.904 \times 10^{14} \text{ atoms}}{6.022 \times 10^{23} \text{ mol}^{-1}} \approx 9.801 \times 10^{-10} \text{ mol}$$

The molar mass M of ^{241}Am is approximately 241 g/mol.

$$m = n \times M = (9.801 \times 10^{-10} \text{ mol}) \times (241 \text{ g/mol}) \approx 2.362 \times 10^{-7} \text{ g}$$

Problem 3:

When will 5 GBq of $^{131}_{53}I$ $(T_{1/2} = 8.05\ days)$ and 2 GBq of $^{32}_{15}P$ $(T_{1/2} = 14.3\ days)$ have equal activities?

$$5\ x\ e^{-\frac{ln2}{8.05}\ x\ t} = 2\ x\ e^{-\frac{ln2}{14.3}\ x\ t}$$

***t* = 24.34 days**

Problem 4:

A solution with a radioisotope ^{24}Na of activity A_0 = 2 kBq was injected into the blood of a person. Volume activity a_v of the blood was measured 5 hours after the injection and it was determined to be 265 kBq/m^3. Determine the volume of the person's blood in liters. The half-life of ^{24}Na is 15 hours.

The initial volume activity of ^{24}Na after the injection into the blood is

$$a_0 = A_0/V,$$

where V is the volume of the blood.

Activity is decreasing exponentially with the time. Thus,

$$a_V(t\_5h) = A_0/V \text{ x } \exp(-\lambda \text{ x } t\_5h)$$

$$V = A_0/\ a_V(t) \text{ x } \exp(-\lambda.t) = 2x10^3/(265x10^3) \text{ x } \exp(-\ln 2x5/15) = 6 \text{ l}$$

The volume of the blood is 6 liters.

Problem 5:

What was the age of the rock sample acquired during the Apollo 17 mission in 1972, if the isotopic ratio $^{87}_{38}Sr/^{87}_{37}Rb$ was found to be 0.065? The decay reaction can be expressed as follows: $^{87}_{37}Rb \rightarrow ^{87}_{38}Sr + ^{0}_{-1}\beta\ ;\ \ T_{1/2} = 4.7\ x\ 10^{10}\ years.$

$$N/N_0 = e^{-\frac{ln2}{T_{1/2}}\ x\ t}$$

$N_0 = N + N_{decay} = N + 0.065\, N = 1.065\, N$

$t = -\ \frac{T_{1/2}}{\ln 2}\ .ln\frac{N}{N_0} =$ 4.3 x 10^9 years

t = 4.3 x 10^9 years