Newcastle University

School of Maths, Stats, and Physics

Cloud Chambers

Worksheet (Answers)

Not for distribution to students

Question 1

Watch carefully for the trails of cloud left by the alpha particles. You should see that they are fairly short, around 5 cm long. Why do they stop?

Question 2

The number of radioactive nuclei remaining in a sample decreases exponentially. If we know the initial number of atoms N_0, we can work out the number remaining after a given time t using the equation

$$N(t) = N_0 e^{-\lambda t} ,$$

where λ is the **decay constant**. This is related to the **half life** $t_{\frac{1}{2}}$ (the time it takes for the number of particles to halve) by the equation

$$\lambda = \frac{\ln(2)}{t_{\frac{1}{2}}} .$$

We can define the **activity** as the number of particles decaying per second, or the rate of change of the number of particles. This is given by

$$A = -\frac{dN}{dt} = \lambda N .$$

Watch your cloud chamber for 10 seconds, and count the number of trails you see in this time. Repeat this three times, and fill in the table below:

Time (s)	Number of Trails

Average: 25 to 30

What is the activity of the source? $A =$ ~ 2.5 s^{-1}

Expect a lot of variation for the activity between groups.

Question 3

The half-life of thorium-232 (^{232}Th) is 1.4×10^{10} yr. How many atoms of ^{232}Th are there in your source? There are $3.155\,76 \times 10^{7}$ s in a year.

Answer:

$$A = \frac{\ln(2)N}{t_{\frac{1}{2}}} \Rightarrow N = \frac{At_{\frac{1}{2}}}{\ln(2)} = \frac{2.5 \times 1.4 \times 10^{10} * 3.15576 \times 10^{7}}{\ln(2)} \approx 1.59 \times 10^{18}$$

$N =$ 1.59×10^{18}

The atomic mass of ^{232}Th is 232.038 u. What is the mass of your source? (you may use $1\,\mathrm{u} = 1.66 \times 10^{-27}$ kg, $N_A = 6.02 \times 10^{23}\,\mathrm{mol}^{-1}$)

Answer:

$$m = N \times m_{atomic} \times 1.66 \times 10^{-27} = 1.59 \times 10^{18} \times 232.038 \times 1.66 \times 10^{-27} \approx 0.000614 \tag{1}$$

$m =$ 0.000614 g

We already know that alpha particles produced near the centre of the source don't have as much kinetic energy by the time they leave the source. In fact, much of the alpha particles produced near the centre will never leave the sample. The rod is 2 mm in diameter. Assuming that we only see alpha particles from the outermost 22 µm of the rod, adjust your answer to the previous question to account for this.

Answer: Note that this is not correct; an incorrect assumption has been made which is addressed in the extension task.Let $R = 1$ mm, $r = 0.05$ mm, $L = 175$ mm is the length of the rod.

$$V_{active} = \pi r^2 L\,, \quad V_{total} = \pi R^2 L\,, \quad \Rightarrow \frac{V_{active}}{V_{total}} = \frac{r^2}{R^2} = \frac{0.022^2}{1^2} = 0.000484 \tag{2}$$

Therefore, the total mass is $m_{total} = \frac{m}{0.000484} \approx 1.27$ g.

$m =$ ~ 0.25 g

The total mass of the rod is 10.5 g (it is mostly tungsten, a very dense metal). What percentage of the rod is ^{232}Th?

~ 12.1 % ^{232}Th.