

H₃₋₁: Radioactive Decay

Apparatus

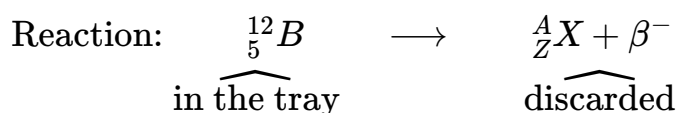
About 200 small cubes, marked \odot and \otimes on two faces; two trays; 2 x 500ml beakers; periodic table of the elements; 2 sheets graph paper.

Introduction

In this model of radioactive decay, the cubes represent atoms. They are either parent (not decayed) atoms or daughter (decayed) atoms. When a cube is thrown at random, if a marked face of the cube faces up, then the atom has decayed.

Decay Model 1

(uses 1 tray and 1 beaker only)



1. Count the cubes. This is N_0 , the number of parent atoms of ${}_{5}^{12}\text{B}$ at time $t=0$.
2. Place all the cubes in a beaker and empty the beaker into a tray. Shake the tray until all the cubes lie flat (do not touch any cubes).
3. Each time you empty a beaker into a tray, 0.01s has elapsed. Record the time $t = 0.01\text{s}$. Discard cubes showing \odot or \otimes (these are atoms of ${}_{Z}^A\text{X}$, the daughter atoms). Count and record N , the number of cubes left in the tray.
4. Place the cubes now in the tray into the beaker. Empty the beaker into the tray and shake as before. Record $t = 0.02\text{s}$. Discard decayed atoms. Record the new number N of cubes left in the tray.

5. Continue for $t = 0.03, 0.04, 0.05, \dots 2.5\text{s}$, or until $N = 0$.

6. Tabulate your readings as follows:

t /s	0	0.01	0.02	0.03				etc.
N	$N_0 =$							

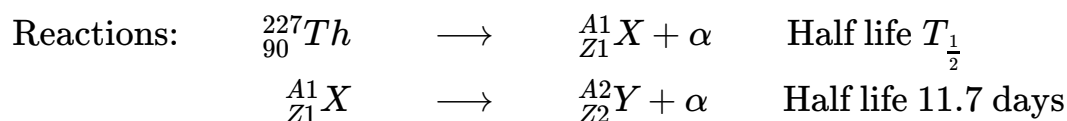
Analysis

1. Plot a graph of N vs. t . From the graph find the half life $T_{\frac{1}{2}}$. The decay rate (lambda λ) is related to the half life as follows: $\lambda = \ln \frac{2}{T_{\frac{1}{2}}}$
2. Using the formula: $\frac{dN}{dt} = -\lambda N$, calculate the decay rate when $t = 0$. Find the graph's gradient at time $t = 0$; is this the same (approximately) as the calculated value?
3. On the same sheet of graph paper, plot another curve showing the number of daughter atoms.
4. Find A , Z , and X . Is this atom stable?

Decay Model 2

(uses 2 trays and 2 beakers)

In this experiment, tray #1 contains ${}^{227}_{90}\text{Th}$ atoms and tray #2 contains ${}^{A1}_{Z1}\text{X}$ daughter atoms. These daughter atoms decay again and are discarded.



1. Place all the cubes into tray #1, count them, and record number N_0 at time $t = 0$. Record for tray #2 that $N_0 = 0$ at $t = 0$.
2. Place tray#1 cubes into beaker #1, return to tray #1 and shake tray to settle the cubes. Move cubes showing \otimes into tray #2. Record N for tray #1 and tray #2 at this time $t = 5$ days.

3. FIRST: Place cubes from tray #2 into beaker #2. Return to tray #2 and shake.
Discard cubes showing \odot .
SECOND: Place cubes from tray #1 into beaker #1. Return to tray #1 and shake.
Move cubes showing \otimes to tray #2.
THEN: Count and record N for trays #1 and #2 at $t = 10$ days.
4. Continue repeating step 3, letting $t = 15, 20, 25, \dots$ up to 200 days. (Each time you perform step 3, t advances by 5 days).
5. Tabulate your readings as follows:

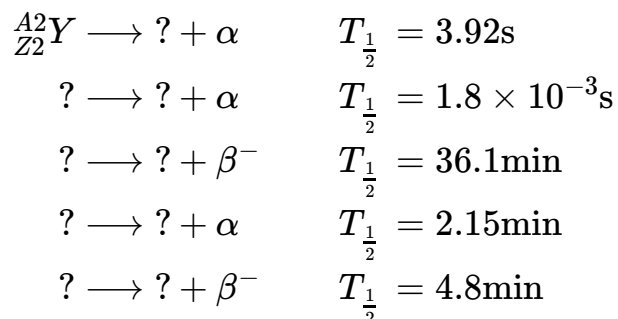
t /days		0	5	10	15	20	25	
tray #1	N	$N_{\bullet} =$						etc.
tray #2	N	$N_{\bullet} = 0$						

Analysis

1. On the same piece of graph paper plot N vs. t for trays #1 and #2 to obtain two curves.
2. Using the #1 curve, find $T_{\frac{1}{2}}$ for ${}^{227}_{90}\text{Th}$. Calculate λ and thus find N at $t = 40$ days (use $N = N_0 e^{-\lambda t}$). Check that the value of N at $t = 40$ days is about the same by using the graph, and note this value.
3. Explain carefully why the curve #2 has the shape that it does.
4. Use the reaction equations given above to determine $A1, Z1, X$ and also $A2, Z2$, and Y .

Questions

1. ${}^{A2}_{Z2}\text{Y}$ is unstable and decays. There follows a whole series of decays, ending with a stable atom, as follows:



Write down the above set of reactions, deducing each of the ?s, giving atomic mass, atomic number, and symbol in each case.

2. A sample of ${}_{90}^{227}\text{Th}$, when left for 30 days, is found to contain a lot of ${}_{90}^{227}\text{Th}$, ${}_{Z1}^{A1}\text{X}$, and the final stable isotope. There is very little of ${}_{Z2}^{A2}\text{Y}$ and the four intermediate isotopes. Why?
3. Draw a decay chain to map the complete series of seven decays from ${}_{90}^{227}\text{Th}$ to the stable isotope.

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