

Manhattan Project - Assignment 3 - Solution

1. Using $R(t) = -\lambda N(t)$ and $\lambda = \frac{\ln 2}{t_{1/2}}$

(a) Convert 138 days to seconds

$$138 \text{ days} = 138 \text{ days} \xrightarrow{\text{day}} \frac{24 \text{ hours}}{\text{day}} \xrightarrow{\text{hour}} \frac{60 \text{ minutes}}{\text{hour}} \xrightarrow{\text{minute}} \frac{60 \text{ seconds}}{\text{minute}}$$

$$= 138 \cdot 24 \cdot 60 \cdot 60 \text{ s} = 11923200 \text{ s}$$

$$= 1.19 \times 10^7 \text{ s}$$

(b) $R = -\lambda N = -\frac{\ln 2}{t_{1/2}} N$

$$N = N_A$$

$$= 6.02 \times 10^{23}$$

$$= -\frac{\ln 2}{1.19 \times 10^7 \text{ s}} \cdot 6.02 \times 10^{23}$$

$$t_{1/2} = 1.19 \times 10^7 \text{ s}$$

$$= -\frac{\ln 2}{1.19} \times 6.02 \times 10^{16} / \text{s}$$

↖ this part I have to stick into a calculator

$$= -3.51 \times 10^{16} / \text{s}$$

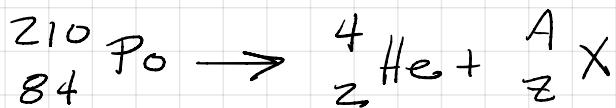
The minus sign just means we are losing atoms, not gaining them

[We are losing 3.51×10^{16} Polonium atoms per second]

(c) $3.51 \times 10^{16} \frac{1}{\text{s}} \cdot \frac{1 \text{ Ci}}{3.7 \times 10^{10} / \text{s}} = 9.5 \times 10^5 \text{ Ci}$

2. Alpha Decay of Polonium-210

(a) The A and Z that balance



are $A=206$, $Z=82$.

(b) That is Lead (symbol Pb).

The isotope is Lead-206. We could also have written: ${}^{206}_{82}\text{Pb}$.

3. β^- and β^+ Decay

(a)

| | A | Z | N |
|----------|-----|-----|-----|
| Polonium | 210 | 84 | 126 |

If β^- decay, Z increases by 1 and N decreases by 1 and A stays the same

| A | Z | N |
|-----|-----|-----|
| 210 | 85 | 125 |

and $Z=85$ is Astatine \leftarrow I never heard of it

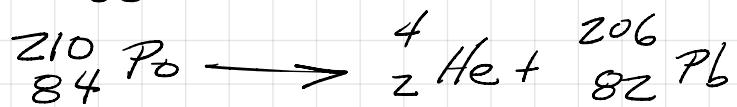
(b) If β^+ decay,

Z decreases by 1
 N increases by 1
 A stays the same

| A | Z | N |
|-----|-----|-----|
| 210 | 83 | 127 |

and $Z=83$ is Bismuth

4. Energy Released in Polonium-210 α -Decay



(a) Total mass on the left-hand side is simply 209.982874 u.

(b) Total mass on right-hand side is

| | |
|----------|---------------------|
| Helium-4 | 4.002603 u |
| Lead-206 | 205.974449 u |
| Total | <u>209.977052 u</u> |

Here we only have four significant figures

$$(c) 209.982874 - 209.977052 = 0.005822 u$$

$$(d) E=mc^2 = 0.005822 u \cdot \frac{1.66054 \times 10^{-27} \text{ kg}}{1 \text{ u}} \cdot \left(2.99792458 \times 10^8 \frac{\text{m}}{\text{s}} \right)^2$$

$$= 0.08689 \times 10^{-11} \text{ J}$$

$$= 8.689 \times 10^{-13} \text{ J}$$

$$(e) 8.689 \times 10^{-13} \text{ J} \cdot \frac{1 \text{ eV}}{1.602176634 \times 10^{-19} \text{ J}}$$

$$= 5.423 \times 10^6 \text{ eV}$$

$$(f) 5.423 \times 10^6 \text{ eV} = 5.423 \text{ MeV}$$

$$(g) 0.005822 u \cdot \frac{931.4 \text{ MeV}}{1 \text{ u}} = 5.423 \text{ MeV}$$

↖ we are $\frac{1}{3}\%$ off of the accepted value