

# 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

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

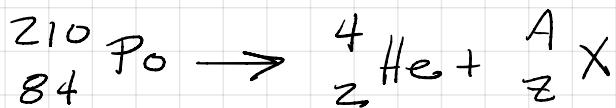
The minus sign just means we are losing atoms, not gaining them

[We are losing  $3.51 \times 10^{16}$  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. $\beta^-$ and $\beta^+$ Decay

(a)



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



and

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

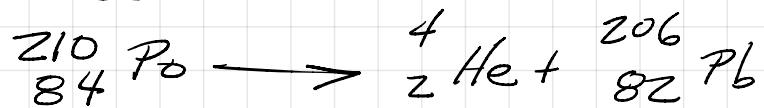
(b) If  $\beta^+$  decay,

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



and  $Z=83$  is Bismuth

## 4. Energy Released in Polonium-210 $\alpha$ -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)  $209.982874 - 209.977052 = 0.005822 \text{ u}$

(d)  $E=mc^2 = 0.005822 \times \frac{1.66054 \times 10^{-27} \text{ kg}}{\text{u}}$   
 $\cdot \left(2.99792458 \times 10^8 \frac{\text{m}}{\text{s}}\right)^2$   
 $= 0.08689 \times 10^{-11} \text{ J}$   
 $= 8.689 \times 10^{-13} \text{ J}$

(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)  $0.005822 \times \frac{931.4 \text{ MeV}}{\text{u}} = 5.423 \text{ MeV}$