

Physics 197 Chapter #40
Homework Solutions

Pg#1

Problem #1 (P15): Calculate binding energy and binding energy/nucleon.

$$(a) C_6^{13} = 6(1.007825u) + 7(1.008665u) = 13.1076u$$

$$13.1076u - 13.003354 = .10425u \times 931.5 \text{ MeV/u} = \boxed{97.11 \text{ MeV}}$$

$$= 7.46989 \frac{\text{MeV}}{\text{nucleon}}$$

$$(b) P_b^{208}_{82} = 82(1.007825u) + 126(1.008665u) = 209.773u$$

$$209.773u - 207.9746450u = 1.75678u \times 931.5 \frac{\text{MeV}}{\text{u}} = \boxed{1636.45 \text{ MeV}}$$

$$= 7.86755 \frac{\text{MeV}}{\text{nucleon}}$$

$$(c) Po^{212}_{84} = 84(1.007825u) + 128(1.008665u) = 213.766u$$

$$213.766u - 211.989629u = 1.77679u \times 931.5 \frac{\text{MeV}}{\text{u}} = \boxed{1655 \text{ MeV}}$$

$$+ 7.7767 = 7.80698 \frac{\text{MeV}}{\text{nucleon}}$$

Problem #2 (P17) $R = R_0 A^{1/3}$, $R_0 = 1.2 \times 10^{-15} \text{ m} = 1.2 \text{ fm}$.

Determine nuclear Radii:

$$(a) O^{14} = 1.2(14)^{1/3} = \boxed{2.8896 \text{ fm}}$$

$$(b) Fe^{58} = 1.2(58)^{1/3} = \boxed{4.63877 \text{ fm}}$$

$$(c) Au^{196} = 1.2(196)^{1/3} = \boxed{(6.95829 \text{ fm})}$$

Problem #3 (P29): at $t = 0$ $R(t) = 32000 \frac{\text{cuts}}{\text{sec}}$

at $t = 1 \text{ min}$ $R(t) = 2000 \frac{\text{cuts}}{\text{sec}}$

Can also use
 $R(t) = R_0 e^{-\lambda t}$

$$(a) \neq t_{1/2}: \frac{R(t)}{R_0} = \left(\frac{1}{2}\right)^n \quad n = \ln\left(\frac{R(t)}{R_0}\right) = \frac{\ln\left(\frac{2000 \text{ cuts/s}}{32000 \text{ cuts/s}}\right)}{-0.693} = \frac{-\frac{2000 \text{ cuts/s}}{32000 \text{ cuts/s}}}{-0.693} = 4.00025$$

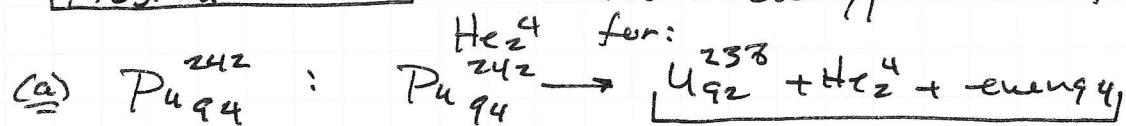
Thus 4 half-lives have elapsed

$$\Delta t = n t_{1/2} > t_{1/2} = \frac{\Delta t}{n} = \frac{60s}{4} = \boxed{15s}$$

$$(b) \lambda: \lambda = \frac{0.693}{t_{1/2}} = \frac{0.693}{15s} = \boxed{0.046 s^{-1}}$$

$$(c) R(t) = R_0 \left(\frac{1}{2}\right)^n > n = \frac{\Delta t}{t_{1/2}} = \frac{120s}{15s} = 8, R(t) = 32000 \left(\frac{1}{2}\right)^8 = \boxed{125 \frac{\text{cuts}}{\text{s}}}$$

Problem #4 (P28): Calculate energy release for 2 particle Pg#2



$$242.058725 = 238.048608 + 4.002603 + \text{energy}$$

$$\text{energy} = 242.058725 - (238.048608 + 4.002603)$$

$$242.058725 - 242.051 = 7.514 \times 10^{-3} \text{ MeV}$$

$$He_2^4 \text{ energy} = 6.99 \text{ MeV}$$



$$211.9896294 - (207.8746564 + 4.0026034) = .0103764 \times 931.5 \text{ MeV}$$

$$He_2^4 \text{ energy} = 9.47 \text{ MeV}$$

Problem #5 (P37): At = 20800 yrs. $R_0 = \frac{15 \text{ decays}}{\text{min-gram}}$ Detector
 $t_{1/2} = 5730 \text{ years.}$ $\text{Efficiency} = 20\%$

The actual counts will be 5x the reading due to the detector efficiency. Minimum = $\frac{7 \text{ cuts}}{\text{min}}$

For living Sample: $R(t) = \frac{15 \text{ dec}}{\text{min-gram}} + N_{\text{grams}}$

Determine # of half-lives: $\Delta t = n (t_{1/2})$ $n = \frac{20800 \text{ yrs}}{5730 \text{ yrs}} = 3.63$

$$R(t) = R_0 \left(\frac{1}{2}\right)^n = 15 \frac{\text{d}}{\text{min}} \left(\frac{1}{2}\right)^{3.63} = 15 \frac{\text{d}}{\text{min}} (.0807) = 1.21 \frac{\text{d}}{\text{min}}$$

Now bring in detector efficiency $R(t) = 5 + 1.21 \frac{\text{d}}{\text{min}}$

$$R(t) = 6.66 \frac{\text{d}}{\text{min}} \quad \frac{7 \text{ cuts}}{\text{min}} + 5 = 35 \frac{\text{cuts}}{\text{min}}$$

$$\frac{35 \text{ cuts}}{1.21 \frac{\text{cuts}}{\text{gram}}} = 28.9 \text{ grams}$$

Problem #6 (P37) : $R_b^{87} \rightarrow Sr^{87}$ $t_{1/2} = 4.9 \times 10^0$ years.

Pg #3

Measured Ratio of Sr^{87} to $Rb^{87} = .0054$

We want to use $\frac{N(t)}{N_0} = \left(\frac{1}{2}\right)^n$ $\left(\text{or } \frac{N(t)}{N_0} = e^{-\lambda t} \right)$

$\frac{N(t)}{N_0}$ \hookrightarrow the amount of Rb present now as compared to t_0 .

Since Ratio $\frac{Sr^{87}}{Rb^{87}} = .0054$

Rb^{87} present now $= 1 - .0054 = .9946$

Thus $\frac{N(t)}{N_0} = .9946 = \left(\frac{1}{2}\right)^n$

Solving for n : $\frac{\ln(.9946)}{\ln(\frac{1}{2})} = 7.81 \times 10^{-3}$

$\Delta t = n t_{1/2} = 7.81 \times 10^{-3} (4.9 \times 10^0 \text{ years}) = 3.8 \times 10^0 \text{ years}$

Sample is 3.8×10^0 years old

Problem #7 (P45)

$E = 210 \frac{\text{MeV}}{\text{fission}}$, Power = $400 \frac{\text{kWatt-sec}}{\text{sec}}$

$400 \times 10^3 \frac{\cancel{\text{kWatt-sec}}}{\text{sec}} \times 1 \text{ sec} = 400 \times 10^3 \text{ Joules} = 2.5 \times 10^{17} \text{ eV}$

$\frac{\text{fission}}{\text{sec}} = \frac{2.5 \times 10^{17} \text{ MeV}}{210 \frac{\text{MeV}}{\text{fission}}} = \boxed{\frac{1.2 \times 10^{19} \text{ fissions}}{\text{second}}}$

Problem #8 (P66) : $7.2 \times 10^{19} \frac{\text{Joules}}{\text{year}}$ $200 \frac{\text{MeV}}{\text{U}^{238} \text{ fission}}$. Assume 100% efficiency.

$7.2 \times 10^{19} \text{ Joules} = 5.11 \times 10^{32} \text{ MeV}$ This is the total energy required

of fissions (Reactions) = $\frac{5.11 \times 10^{32} \text{ MeV}}{200 \text{ MeV/fission}} = 2.56 \times 10^{30} \text{ fissions}$

each fission involves 1 Uranium ~~nuclei~~ $\Rightarrow 2.56 \times 10^{30} \text{ nuclei}$

$2.56 \times 10^{30} \text{ nuclei} + \frac{1}{6.02 \times 10^{23} \frac{\text{nuclei}}{\text{mole}}} = \frac{1.011 \times 10^9 \text{ moles}}{= 1 \times 10^6 \text{ kg}}$

Problem #9 (P58): $R(t) = 115 \frac{\text{decays}}{\text{min}}$

Pg #4

After 4 & 13 hours $R(t) = 60.5 \frac{\text{decays}}{\text{min}}$

(a) Determine $t_{1/2}$: $\frac{R(t)}{R_0} = \left(\frac{1}{2}\right)^n > \frac{60.5}{115} = \left(\frac{1}{2}\right)^n$

$$n = \frac{\ln\left(\frac{60.5}{115}\right)}{-0.693} = .93$$

$$\Delta t = t_{1/2} n, t_{1/2} = \frac{\Delta t}{n}, \Delta t = 4.54 \text{ days}$$

$$t_{1/2} = \frac{4.54 \text{ days}}{.93} = \boxed{4.88 \text{ days}}$$

(b) time for $R(t) = 10 \frac{\text{decays}}{\text{min}}$

$$R(t) = R_0 \cdot \left(\frac{1}{2}\right)^n$$

$$n = \ln\left(\frac{R_0}{R(t)}\right) = 3.52, \Delta t = n t_{1/2} = \frac{3.52}{.93} (4.88 \text{ days})$$

$$\Delta t = \frac{17.2}{.93} \text{ day} = \boxed{17.2 \text{ days}}$$

Problem #10 (P54):

(a) Energy to remove a neutron from C_6^{14} :

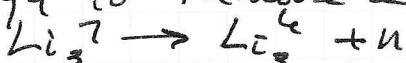
$$C_6^{14} \rightarrow C_6^{13} + n + \text{energy} > 14.003242 - 13.005738 - 1.008665$$

$$\Delta m = 13.005738 / (14.003242 + \Delta m) = 13.003354 + 1.008665 / 14.003242$$

$$\Delta m = 14.003354 - (14.003242 - 1.008665) u = 10.87 u$$

$$\Delta E_b = 1.06877 u \times 931.5 \frac{\text{MeV}}{u} = \boxed{9.18 \text{ MeV}}$$

(b) Energy to remove a neutron from Li_3^7 :



$$\Delta m = 7.016004 u - (4.015125 u + 1.008665 u) = 2.009 u, 0.07784$$

$$E_b = 2.009 u + 0.07784 \times 931.5 \frac{\text{MeV}}{u} = \boxed{7.25 \text{ MeV}}$$