# Physics 197 Chapter #40
## Homework Solutions

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

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

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

$\boxed{= 7.46999 \frac{MeV}{nucleon}}$

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

$209.773u - 207.976650u = 1.79679u \times 931.5\frac{MeV}{u} = \boxed{1636.45MeV}$

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

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

$213.766u - 211.988629u = 1.776794u \times 931.5\frac{MeV}{u} = \boxed{1655MeV}$

~~1.7767~~ $\boxed{= 7.80698 \frac{MeV}{nucleon}}$

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

Determine nuclear Radii:

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

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

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

**Problem #3 (P29)**: at $t=0$ $R_0 = 32000\frac{cts}{sec}$

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

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

(a) $t_{1/2}$: $\frac{R(t)}{R_0} = \left(\frac{1}{2}\right)^n$ $\quad n = \frac{\ln\left(\frac{R(t)}{R_0}\right)}{-.693} = \frac{\ln\left(\frac{2000\ cts/s}{32000\ cts/s}\right)}{-.693} = 4.00085$

Thus 4 half lives have elapsed

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

(b) $\lambda$: $\lambda = \frac{.693}{t_{1/2}} = \frac{.693}{15s} = \boxed{.046s^{-1}}$

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

**Problem #4 (P 28)**: Calculate energy release for α particle $He_2^4$ for:

(a) $Pu_{94}^{242}$ : $Pu_{94}^{242} \rightarrow U_{92}^{238} + He_2^4 + \text{energy}$

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

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

$$242.058725 - 242.051 = 7.514 \times 10^{-3} u \times 931.5 \frac{MeV}{u}$$

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

(b) $Po_{84}^{212}$ : $Po_{84}^{212} \rightarrow Pb_{82}^{208} + He_2^4 + \text{energy}$

$$211.988629u - (207.976650u + 4.002603u) = .010376u \times 931.5 \frac{MeV}{u}$$

$$\boxed{He_2^4 \text{ energy} = 9.67\ MeV}$$

**Problem #5 (P 37)**: $\Delta t = 20\,800$ yrs. $R_0 = 15 \frac{decays}{min\text{-}gram}$ Detector Effeciency = 20%
$t_{1/2} = 5730$ years.

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

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

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

$$R(t) = R_0 \left(\tfrac{1}{2}\right)^n = 15 \frac{d}{m g}\left(\frac{1}{2}\right)^{3.63} = 15 \frac{d}{m\text{-}g}(.0807) = 1.211 \frac{d}{m\text{-}g}$$

Now bring in detector effeciency ~~$R(t) = 5 \times 1.211 \frac{d}{m g}$~~

~~$R(t) = 6.06 \frac{d}{m g}$~~ $7 \frac{cts}{min} \times 5 = 35 \frac{cts}{min}$

$$\frac{35 \frac{cts}{min}}{1.211 \frac{cts}{m\text{-}gram}} = \boxed{28.9 \text{ grams}}$$

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

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

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

$\frac{N(t)}{N_0}$ is 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 $n$: $\frac{\ln(.9946)}{\ln(\frac{1}{2})} = 7.81 \times 10^{-3}$

$\Delta t = n\, t_{1/2} = 7.81 \times 10^{-3}\,(4.9 \times 10^{10} \text{ years}) = 3.8 \times 10^{8}$ years

**Sample is $3.8 \times 10^{10}$ years old**

**Problem #7 (P45)** $E = 210 \frac{\text{MeV}}{\text{fission}}$, Power $= 400$ MWatts ~~sec~~.

$400 \times 10^6$ ~~Watts~~ $\frac{\text{Joules}}{\text{sec}} \times 1 \text{ sec} = 400 \times 10^6 \text{ Joules} = 2.5 \times 10^{27} \text{ eV}$
$= 2.5 \times 10^{21}$ MeV

$\frac{\text{fission}}{\text{sec}} = \frac{2.5 \times 10^{21} \text{ MeV}}{210 \frac{\text{MeV}}{\text{fission}}} =$ **$1.2 \times 10^{19} \frac{\text{fissions}}{\text{second}}$**

**Problem #8 (P66)**: $8.2 \times 10^{14} \frac{\text{Joules}}{\text{year}}$ $\frac{200 \text{ MeV}}{U^{238} \text{ fission}}$. Assume 100% effeciency.

$8.2 \times 10^{14}$ Joules $= 5.11 \times 10^{32}$ MeV This is the total energy required

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

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

$2.56 \times 10^{30} \text{ nuclei} \times \frac{238 \text{ grams}}{\text{mole}} \times \frac{1}{6.02 \times 10^{23} \frac{\text{nuclei}}{\text{mole}}} = 1.011 \times 10^{9}$ grams

**$\approx 1 \times 10^{6}$ kg**

**Problem #9 (P38):** $R_0 = 115\ \frac{\text{decays}}{\text{min}}$

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

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

$$n = \frac{\ln\left(\frac{60.5}{115}\right)}{-.693} = .93$$

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

$$t_{1/2} = \frac{4.54 \text{ days}}{.93} = \text{~~15.63 days~~ } \boxed{4.88 \text{ days}}$$

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

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

$$n = \frac{\ln\left(\frac{R_0}{R(t)}\right)}{-.693} = 3.52,\quad \Delta t = n\, t_{1/2} = 3.52\,(4.88 \text{ days})$$

$$\Delta t = 17.2 \text{ days} \boxed{17.2 \text{ days}}$$

**Problem #10 (P54):**

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

$C_6^{14} \rightarrow C_6^{13} + n_0 + \text{energy} >$ ~~14.003242 − 13.005138 − 1.008665u~~

~~Δm = 13.005738 − (14.003242 +~~ Δm = 13.003354 + 1.008665 − 14.003242

Δm = ~~14.00~~ ~~13.003354 − (14.003242 − 1.008665)~~ u = .00877u

$E_b = .00877u \times 931.5 \frac{\text{MeV}}{u} = \boxed{8.18 \text{ MeV}}$

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

$Li_3^7 \rightarrow Li_3^6 + n$

Δm = 7.016004u − (6.015125u + 1.008665u) = ~~2.009u~~ .00778u

$E_b =$ ~~2.009u +~~ $.00778u \times 931.5 \frac{\text{MeV}}{u} = \boxed{7.25 \text{ MeV}}$