Physics 10164 - Exam 5C

Partial credit will be given provided you show all work and are solving parts of the problem correctly. Points will be deducted if you don't show your work even if you get the right answer. Clearly indicate your answer with a circle or a box and remember to include correct units and significant figures.

1. (30 pts) One possible decay sequence for Uranium-238 is:

1 neutron + Uranium-238 --> Thorium-234 + Helium-4 + 1 neutron

The mass of a proton is 1.007276 amu.
The mass of a neutron is 1.008665 amu.
The mass of Uranium-238 is 238.050783 amu.
The atomic number of Uranium is 92.
The mass of Thorium-234 is 234.043596 amu.
The atomic number of Thorium is 90.

$M_{He} = 4.002603$ amu

a) What is the binding energy per nucleon of Uranium-238, in MeV?

b) How much energy (in MeV) is released in the reaction shown above where it turns into Thorium and Helium?

# of protons = 92

# of neutrons = 238 - 92 = 146

$BE = \Delta mc^2$

$\Delta m = 92(1.007276) + 146(1.008665) - 238.050783$

$= 1.883699$

$E = \Delta m(931.5) = 1757.67$

$BE/nuc = \frac{1757.67}{238} = \boxed{7.37 \text{ MeV/nuc}}$

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b) $\Delta m = 238.050783 - 234.043596 - 4.002603$

$= .004584$ u

$\boxed{E = 4.27 \text{ MeV}}$

2. (30 pts) A small cloud of Hydrogen gas is excited in a laboratory experiment by an electric current, and the Hydrogen emits light as its electrons return from their excited states to lower energy levels.

a) What is the energy (in eV) and the wavelength of light associated with the transition from n=4 to n=3?

b) If a filter allows only light of this wavelength to pass through, and the total power detected is 4.5×10^{-8} Watts, how many photons per second are hitting your detector?

a) $E = 13.6\left(\frac{1}{3^2} - \frac{1}{4^2}\right) = \boxed{0.66\ eV}$

b) $E_\gamma = 0.66 * 1.6 \times 10^{-19} = 1.06 \times 10^{-19}\ J$

$E_{TOT} = \left(4.5 \times 10^{-8}\ \frac{J}{s}\right) * (1\ sec)$

$N = \frac{E_{TOT}}{E_\gamma} = \frac{4.5 \times 10^{-8}}{1.06 \times 10^{-19}} = \boxed{4.3 \times 10^{11}\ photons}$

$\frac{1}{\lambda} = 1.097 \times 10^7\left(\frac{1}{3^2} - \frac{1}{4^2}\right)$

$\boxed{\lambda = 1.88 \times 10^{-6}\ m}$

3. (40 pts) A sample of radioactive Carbon-14 (mass = 14 amu) is measured to have an activity of ~~[illegible]~~ 0.35 Ci. Carbon-14 has a half-life of 5700 years.

a) How many grams of Carbon-14 is in the sample?

b) How many years will it take for the activity to diminish to 2.0% of its current value?

$$a = 3.5 \times 10^{-1}\ Ci \cdot \frac{1\ Bq}{2.70 \times 10^{-11}\ Ci} = 1.3 \times 10^{10}\ Bq$$

$$T_{1/2} = 5700\ yrs$$

$$= 1.8 \times 10^{11}\ s$$

$$\lambda = \frac{0.693}{T_{1/2}} = 3.85 \times 10^{-12}$$

$$a = \lambda N$$

$$N = \frac{a}{\lambda} = \frac{1.3 \times 10^{10}}{3.85 \times 10^{-12}} = 3.37 \times 10^{21}\ atoms$$

$$m_{Tot} = N m_C = (3.37 \times 10^{21})(14\ u)\left(\frac{1.66 \times 10^{-27}\ kg}{u}\right)$$

$$= 7.8 \times 10^{-5}\ kg \text{ or } \boxed{0.078\ g}$$

$$\frac{a}{a_0} = e^{-\lambda t}$$

$$0.02 = e^{-\lambda t}$$

$$\ln 0.02 = -\lambda t$$

$$t = \frac{\ln 0.02}{-\lambda} = \frac{-3.91}{-3.85 \times 10^{-12}} = 1.02 \times 10^{12}\ s$$

$$\boxed{32000\ yrs}$$