Physics 10164 - Exam ~~5~~ 4B

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. (25 pts) The work function of an unknown metal is 3.88 eV. If light of sufficient energy shines on the metal, some electrons will be able to escape, but they will have an insignificant amount of kinetic energy once they do.

a) What is the cutoff wavelength for the metal?

b) For what wavelength of light will electrons escape with a maximum speed of 1.7×10^6 m/s?

$$E_\gamma = 3.88\,eV = 6.21 \times 10^{-19}\,J = \frac{hc}{\lambda}$$

$$\lambda = \frac{(6.626\times10^{-34})(3\times10^{8})}{6.21\times10^{-19}} = 3.20\times10^{-7}$$

$$\boxed{\lambda = 320\,nm}$$

b) $KE = E_\gamma - \phi$

$$KE = \frac{1}{2}mv^2 = 1.316\times10^{-18}\,J = 8.225\,eV$$

$$E_\gamma = 8.225 + 3.88 = 12.105\,eV$$
$$= 1.94\times10^{-18}\,J$$

$$\lambda = \frac{hc}{E} = 1.03\times10^{-7}\,m$$

or $\boxed{103\,nm}$

2. (25 pts) An electron is in energy level n = 6 in a neutral Hydrogen atom.

a) What is the shortest wavelength of light that can be emitted by an electron transitioning out of this level?

b) What is the longest wavelength of light that can be absorbed by an electron transitioning out of this level?

c) What has a greater energy difference, a photon emitted when the electron moves from n = 6 -> n = 2 or a photon emitted when the electron moves from n = 2 -> n = 1? Calculate both and compare.

a) Emission = $6 \to 5$

$6 \to 4$

⋮

$6 \to 1$

Shortest λ = highest ΔE = $n = 6 \to 1$

$$\frac{1}{\lambda} = 1.097 \times 10^{7}\left(\frac{1}{1} - \frac{1}{36}\right) \Rightarrow \lambda = 9.38 \times 10^{-8}\,m$$

or **93.8 nm**

b) Longest λ = lowest ΔE → $n = 6 \to 7$

$n = 6 \to 8$ } absorption

⋮

$6 \to \infty$

$$\frac{1}{\lambda} = 1.097 \times 10^{7}\left(\frac{1}{36} - \frac{1}{49}\right) = 1.24 \times 10^{-5}\,m$$

or **12.5 μm**

c) $E(6 \to 2) = 13.6\left(\frac{1}{4} - \frac{1}{36}\right) = 3.02\,eV$

$E(2 \to 1)$ $= 13.6\left(1 - \frac{1}{4}\right) =$ **10.2 eV**

↑ larger

3. (25 pts) Cobalt-56 is a common by-product of nuclear fission weapons and it has a half-life of 77.3 days. A sample of Cobalt-56 is found to have an activity of 450 Curies.

a) What is the mass of the sample, in grams?
b) How many years will it take for the activity to decrease to a level of 7.0 microCuries?

a) $a = 450\ Ci = 1.665 \times 10^{13}\ Bq = \lambda N$

$$\lambda = \frac{0.693}{(77.3)(86400\ \frac{sec}{day})} = 1.04 \times 10^{-7}$$

$$N = \frac{1.665 \times 10^{13}}{1.04 \times 10^{-7}} = 1.6 \times 10^{20}\ \text{atoms}$$

$$m = (1.6 \times 10^{20})(56)\left(\frac{1.66 \times 10^{-24}\ g}{u}\right)$$

$$= \boxed{1.49 \times 10^{-2}\ g}$$

b) $$\frac{a(t)}{a_0} = \frac{7.0 \times 10^{-6}}{450} = e^{-(1.04 \times 10^{-7})t}$$

$$-17.98 = -(1.04 \times 10^{-7})t$$

$$t = 1.73 \times 10^{8}\ s$$

$$= \boxed{5.5\ \text{years}}$$

4. (25 pts) The D-T fusion reaction is:

$^2H + ^3H \rightarrow ^4He + n + \text{energy}$

The n represents a neutron with mass = 1.008665 u.
The mass of ^2H is 2.014102 u.
The mass of ^3H is 3.016049 u.
The mass of ^4He is 4.002602 u.

If the TCU campus uses 2.8 billion kW-hr of energy in a year, how many kg of Hydrogen (assume 5.0 u per reaction from the combined mass of ^2H and ^3H) would be needed in order to satisfy this?

$$E_{reac} = \Delta m c^2$$

$$= .018884 * 931.5 = 17.6 \text{ MeV}$$

$$= 2.81 \times 10^{-12} \text{ J}$$

$$E_{tot} = 2.8 \times 10^9 \text{ kW}\cdot\text{hr} \cdot \frac{3.6 \times 10^6 \text{ J}}{\text{kW hr}} =$$

$$= 1.01 \times 10^{16} \text{ J}$$

$$1.01 \times 10^{16} = N (2.81 \times 10^{-12})$$

$$N = 3.587 \times 10^{27} \text{ reac} \cdot \frac{5.0 \text{ u}}{\text{reac}} \cdot \frac{1.66 \times 10^{-27} \text{ kg}}{\text{u}}$$

$$= \boxed{29.8 \text{ kg}}$$