Physics 10164 - Exam #5b

Show all work. Partial credit will be given provided you show all work and are solving parts of the problems correctly, even if your final answer is incorrect. 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 clearly erase or cross out any work you don't want me to grade) and remember to include the correct units and significant figures in your answer.

1. (30 pts) In the town of Cloudcroft, NM, you can turn South on highway 6563 to reach the National Solar Observatory, located in Sunspot. 6563 has a special meaning, as it represents the wavelength of a photon emitted when a Hydrogen atom's electron drops to level n=2 from a higher level.

a) Determine the energy (in eV) of a photon with a wavelength of 6563 x 10^{-10} meters.

b) Determine which energy level the electron must drop from to end up in level n = 2 and emit a photon with this energy you calculated in part a.

c) Determine the energy (in eV) and the wavelength of the photon emitted when the electron drops from n = 2 to n = 1.

a) $E = \frac{(6.626 \times 10^{-34})(3 \times 10^{8})}{6563 \times 10^{-10}} = 3.03 \times 10^{-19}\ J$

$= 1.89\ eV$

b) $13.6\left(\frac{1}{4} - \frac{1}{9}\right) = 1.89\ eV$ $\quad n = 3$

$13.6\left(\frac{1}{4} - \frac{1}{16}\right) = 2.55\ eV$

etc

c) $13.6\left(\frac{1}{1} - \frac{1}{4}\right) = \boxed{10.2\ eV} = 1.63 \times 10^{-18}\ J$

$\lambda = \frac{hc}{E} = \frac{(6.626 \times 10^{-34})(3 \times 10^{8})}{1.63 \times 10^{-18}} = \boxed{122\ nm}$

2. (30 pts) Sodium has a work function of 2.46 eV. Light illuminates the sodium in an attempt to free electrons from the substance.

a) At what cutoff wavelength (in nm) do electrons first begin to escape from the sodium?

b) At a wavelength of 420 nm, what is the maximum speed of electrons escaping the sodium, in meters/sec?

a) $\lambda_{cutoff} = \frac{hc}{\phi}$ $\quad \phi = 2.46\,eV = 3.94 \times 10^{-19}\,eV$

$$\lambda = \frac{(6.626 \times 10^{-34})(3 \times 10^{8})}{3.94 \times 10^{-19}} = \boxed{505\ nm}$$

b) $E(420\ nm) = 4.73 \times 10^{-19}\,J = 2.96\,eV$

$$K = E - \phi = 0.50\,eV$$

or $0.8 \times 10^{-19}\,J = \frac{1}{2} m_e v^2$

$$v^2 = \frac{2(0.8 \times 10^{-19})}{9.11 \times 10^{-31}} = 1.76 \times 10^{11}$$

$$\boxed{v = 4.2 \times 10^{5}\ m/s}$$

3. (40 pts) Radium-224 has a half-life of 3.6 days and a mass of 224.020212 u.

a) (10 pts) How much Radium-224 (in kg) is required in order for the sample to have an activity of 2.0 Curies?

b) (10 pts) How long (in days) does it take for the activity to drop to a (relatively safe) level of 1.0 microCuries?

a) $T_{1/2} = 3.6 \text{ days} = 3.11 \times 10^5 \text{ s}$

$$\lambda = \frac{0.693}{T_{1/2}} = 2.23 \times 10^{-6}$$

$$R = 2.0 \text{ Ci} \cdot \frac{3.7 \times 10^{10} \text{ Bq}}{\text{Ci}} = 7.4 \times 10^{10} \text{ Bq}$$

$$7.4 \times 10^{10} \text{ Bq} = \lambda N$$

$$N = 3.32 \times 10^{16} \text{ atoms}$$

$$M = 3.32 \times 10^{16} \text{ atoms} \cdot \frac{224 \text{ u}}{\text{atom}} \cdot \frac{1.66 \times 10^{-27} \text{ kg}}{\text{u}}$$

$$= \boxed{1.24 \times 10^{-8} \text{ kg}}$$

b) $1.0 \times 10^{-6} = 2e^{-\lambda t}$

$$-14.5 = -\lambda t$$

$$t = 6.5 \times 10^6 \text{ s} = \boxed{75 \text{ days}}$$

c) (20 pts) When Radium-224 decays, the result is is often an alpha particle (Helium-4 with a mass of 4.002602 u) and Radon-220 (mass of 220.011394 u). Determine how much power is generated by a sample of Radium-224 with an activity of 2.0 Curies. Answer in Watts.

$$\Delta m = m(^{224}Ra) - m(^{220}Rn) - m(^{4}He)$$

$$= 224.020212 - 220.011394 - 4.002602$$

$$= .006216\ u$$

$$E = 5.79\ MeV$$

$$= 9.26 \times 10^{-13}\ J$$

$$P = \frac{9.26 \times 10^{-13}\ J}{reaction} \cdot \frac{7.4 \times 10^{10}\ decays}{sec} = \boxed{.069\ Watts}$$