Physics 10164 - Exam 5A

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) A metal has a work function of 2.24 eV, and it is illuminated by light of wavelength 425 nm.

a) What is the maximum velocity with which electrons escape from the metal, or do they not escape?

b) What is the cutoff wavelength, above which electrons do not escape the metal? Answer in nm.

$\phi = 2.24\,eV$

a) $E_\gamma = \frac{(6.626\times10^{-34})(3\times10^{8})}{425\times10^{-9}\,m} = 4.68\times10^{-19}\,J$

$= 2.92\,eV$

$KE = E_\gamma - \phi = 0.68\,eV = 1.09\times10^{-19}\,J$

$\frac{1}{2}(9.11\times10^{-31})v^2 = 1.09\times10^{-19}$

$v = 4.90\times10^{5}\,m/s$

b) $\lambda_{cut} \Rightarrow \frac{hc}{\lambda_c} = \phi$

$\frac{(6.626\times10^{-34})(3\times10^{8})}{\lambda_c} = 2.24\,eV$

$\lambda_c = \frac{(6.626\times10^{-34})(3\times10^{8})}{3.58\times10^{-19}\,J} = 5.55\times10^{-7}\,m$

or $555\,nm$

2. (25 pts) Consider the following four electron transitions within a Hydrogen atom:

(A) n = 8 --> 3
(B) n = 2 --> 4
(C) n = 1 --> 3
(D) n = 5 --> 2

a) What is the energy of each transition (in eV)?
b) What is the shortest wavelength photon emitted by a reaction that involves photon emission?
c) What is the wavelength of the least energetic photon absorbed by a reaction that involved photon absorption?

$E_8 = -0.213$ eV
$E_5 = -0.544$ eV
$E_4 = -0.850$ eV
$E_3 = -1.51$ eV
$E_2 = -3.40$ eV
$E_1 = -13.6$ eV

(A) emission
$\Delta E = -0.213 - (-1.51)$
$= 1.30$ eV

(B) absorption
$\Delta E = -0.850 - (-3.40)$
$= 2.55$ eV

(C) absorption
$\Delta E = -1.51 - (-13.6)$
$= 12.1$ eV

(D) emission
$\Delta E = -0.544 - (-3.40)$
$= 2.86$ eV

b) largest energy is (D)

$\frac{hc}{\lambda} = 2.86$ eV

$\lambda = \frac{(6.626 \times 10^{-34})(3 \times 10^{8})}{4.58 \times 10^{-19} \text{ J}}$

$= 4.34 \times 10^{-7}$ m or 434 nm

c) lowest abs energy is (B)

$\frac{hc}{\lambda} = 2.55$ eV

$\lambda = \frac{(6.626 \times 10^{-34})(3 \times 10^{8})}{4.08 \times 10^{-19} \text{ J}} = 4.87 \times 10^{-7}$ m or 487 nm

3. (25 pts) Strontium-90 has a mass of 90.0 amu and a half-life of 28.8 years.

a) What is the activity (in Curies) of 2.2 grams of Sr-90?
b) How many years will pass before the activity of the sample drops to 0.53% of its initial value?

a) $T_{1/2} = 28.8 \text{ yrs} = 9.1 \times 10^{8} \text{ s}$

$$\lambda = \frac{0.693}{T_{1/2}} = 7.61 \times 10^{-10}$$

$$N = \frac{m_{Tot}}{m_{Sr}} = \frac{.0022}{(90u)(1.66 \times 10^{-27} \text{ kg/u})}$$

$$= 1.47 \times 10^{22} \text{ atoms}$$

$$a = \lambda N = 1.12 \times 10^{13} \text{ Bq} \cdot \frac{1 \text{ Ci}}{3.7 \times 10^{10} \text{ Bq}}$$

$$= 303 \text{ Ci}$$

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

$$.0053 = e^{-\lambda t}$$

$$-5.24 = -(7.61 \times 10^{-10})t$$

$$t = 6.89 \times 10^{9} \text{ s}$$

$$= 218 \text{ years}$$

4. (25 pts) The aneutronic reaction p + ^{11}B --> ^{12}C is a potentially beneficial fusion reaction that doesn't generate nuclear waste. If we were to power the United States for one year using only this reaction, how many kg of Boron-11 would we need? Assume the U.S. uses 1.0 TeraWatts (1.0×10^{12}) of power.

Mass of proton = 1.007276 amu
Mass of Boron-11 = 11.009306 amu
Mass of Carbon-12 = 12.000000 amu

$$\Delta m = 1.007276 + 11.009306 - 12 = .016582$$

$$E_{reac} = (.016582)(931.5) = 15.4 \text{ MeV}$$
$$= 2.47 \times 10^{-12} J$$

$$N = \frac{E_{TOT}}{E_{reac}} = \frac{(1. \times 10^{12} W)(3.16 \times 10^7 s)}{2.47 \times 10^{-12}}$$

$$= 1.28 \times 10^{31} \text{ atoms}$$

$$M_{TOT} = N m_B = (1.28 \times 10^{31})(11.01)$$

$$= 1.41 \times 10^{32} \text{ amu}$$

$$= 2.3 \times 10^5 \text{ kg}$$