

## Physics 10164 - Exam 5D

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) Light of wavelength 378 nm illuminates a metal, and electrons escape the metal with a maximum speed of  $7.2 \times 10^5$  meters/sec.
- a) What is the work function of the metal, in eV?
- b) What is the maximum possible wavelength of light that may illuminate the metal and still allow electrons to escape? Answer in nm.

$$\frac{hc}{\lambda} = \frac{(6.626 \times 10^{-34})(3 \times 10^8)}{378 \times 10^{-9} \text{ m}} = 5.26 \times 10^{-19} \text{ J} \\ = 3.29 \text{ eV}$$

$$KE = \frac{1}{2}(9.11 \times 10^{-31})(7.2 \times 10^5)^2 = 2.36 \times 10^{-19} \text{ J} \\ = 1.48 \text{ eV}$$

$$KE = \frac{hc}{\lambda} - \phi$$

$$\phi = \frac{hc}{\lambda} - KE = 3.29 - 1.48 = \boxed{1.81 \text{ eV}}$$

b)  $\frac{hc}{\lambda_c} = \phi$

$$\lambda_c = \frac{(6.626 \times 10^{-34})(3 \times 10^8)}{(1.81 \text{ eV})(1.6 \times 10^{-19} \text{ J/eV})} = 6.86 \times 10^{-7} \text{ m} \\ \text{or } \boxed{686 \text{ nm}}$$

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

- (A)  $n = 8 \rightarrow 3$
- (B)  $n = 2 \rightarrow 4$
- (C)  $n = 1 \rightarrow 3$
- (D)  $n = 5 \rightarrow 2$

- 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?

$$E_8 = -0.213 \text{ eV} \quad (\text{A}) \text{ emission}$$

$$E_5 = -0.544 \text{ eV}$$

$$\Delta E = -0.213 - (-1.51)$$

$$E_4 = -0.850 \text{ eV}$$

$$= 1.30 \text{ eV}$$

$$E_3 = -1.51 \text{ eV}$$

(B) absorption

$$E_2 = -3.40 \text{ eV}$$

$$\Delta E = -0.850 - (-3.40)$$

$$E_1 = -13.6 \text{ eV}$$

$$= 2.55 \text{ eV}$$

(C) absorption

b) largest energy is (D)

$$\Delta E = -1.51 - (-13.6)$$

$$= 12.1 \text{ eV}$$

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

(D) emission

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

$$\Delta E = -0.544 - (-3.40)$$

$$= 2.86 \text{ eV}$$

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

c) lowest abs energy is (B)

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

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

3. (25 pts) A radioactive sample has an activity that is 85% of its initial activity 3.5 years after the initial measurement.
- a) What is the half-life of the substance, in years?
- b) If the activity is 0.055 milli-Curies, how many atoms of the radioactive substance are present?

$$a) a = a_0 e^{-0.693t/T_{1/2}}$$

$$0.85 = e^{-0.693t/T_{1/2}}$$

$$-0.1625 = \frac{-0.693(3.5)}{T_{1/2}}$$

$$T_{1/2} = \frac{-(0.693)(3.5)}{-0.1625} = 14.9 \text{ yrs}$$
$$= 15 \text{ yrs}$$

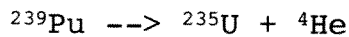
$$b) a = 0.055 \times 10^{-3} \text{ Ci} \cdot \frac{3.7 \times 10^{10} \text{ Bq}}{1 \text{ Ci}}$$
$$= 2.035 \times 10^6 \text{ Bq} = \lambda N$$

$$T_{1/2} = 14.9 \text{ yrs} = 4.71 \times 10^8 \text{ s}$$

$$\lambda = \frac{0.693}{T_{1/2}} = 1.47 \times 10^{-9}$$

$$N = \frac{2.035 \times 10^6}{1.47 \times 10^{-9}} = 1.4 \times 10^{15} \text{ atoms}$$

4. (25 pts) A ceramic Plutonium-239 pellet will be used to power a spacecraft that uses 750 Watts for the spacecraft's 40 year lifetime. The primary reaction used will be alpha decay:



How many grams of Plutonium will be needed for the lifetime of the spacecraft?

Plutonium mass = 239.052156 amu

Uranium mass = 235.043923 amu

Helium mass = 4.002602 amu

$$\begin{aligned} E_{\text{TOT}} &= 750 \text{ J/s} \cdot 40 \text{ yr} \cdot 3.16 \times 10^7 \text{ s/yr} \\ &= 9.48 \times 10^{11} \text{ J} \end{aligned}$$

$$\begin{aligned} E_{\text{reac}} &= \Delta m c^2 \\ &= (239.052156 - 235.043923 - 4.002602)(931.5) \\ &= (.005631)(931.5) \\ &= 5.245 \text{ MeV} = 8.4 \times 10^{-13} \text{ J} \end{aligned}$$

$$E_{\text{TOT}} = N_{\text{reac}} E_{\text{reac}}$$

$$N_{\text{reac}} = \frac{9.48 \times 10^{11}}{8.4 \times 10^{-13}} = 1.13 \times 10^{24} \text{ atoms}$$

$$M_{\text{TOT}} = N m_{\text{Pu}} = 2.7 \times 10^{26} \text{ u} = .448 \text{ kg}$$

or 450 grams