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. (40 pts) Zinc has a work function of 4.31 eV.

a) What is the longest wavelength of light that can be used to illuminate Zinc such that electrons manage to escape the zinc via the photoelectric effect?

b) If Zinc is illuminated by light with a wavelength of 220 nm, what will be the maximum speed of the escaping electrons?

a) Longest λ = cutoff wavelength

$$\phi = 4.31\,eV = 6.90 \times 10^{-19}\,J = \frac{hc}{\lambda}$$

$$\lambda = \frac{(6.626\times10^{-34})(3\times10^{8})}{6.90\times10^{-19}} = \boxed{288\ nm}$$

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

$$= \frac{(6.626\times10^{-34})(3\times10^{8})}{220\times10^{-9}} - 6.90\times10^{-19}$$

$$= 9.03\times10^{-19} - 6.90\times10^{-19}$$

$$\frac{1}{2}mv^2 = 2.135\times10^{-19}$$

$$v^2 = \frac{2(2.135\times10^{-19})}{9.11\times10^{-31}} \Rightarrow \boxed{v = 6.8\times10^{5}\ m/s}$$

2. (30 pts) Consider the following electron transitions within a Hydrogen atom:

n=8 --> n=4
n=6 --> n=3
n=4 --> n=2

a) Calculate the energy (eV) and wavelength (nm) for the emitted photons in each of these three cases.

b) If we consider a cloud of Hydrogen atoms and use a filter that only allows light through that comes from the n=4 --> n=2 transition, how many photons per second would pass through the filter in order for us to detect a power of 5.4 x 10-8 Watts?

a) $E_2 = -\frac{13.6}{4} = -3.40\ eV$

$E_3 = -\frac{13.6}{9} = -1.51\ eV$

$E_4 = -\frac{13.6}{16} = -0.85\ eV$

$E_6 = -\frac{13.6}{36} = -0.38\ eV$

$E_8 = -\frac{13.6}{64} = -0.21\ eV$

$E_8 - E_4 = \boxed{0.64\ eV} = 1.02 \times 10^{-19}\ J$

$\lambda = \frac{hc}{E} = 1.9 \times 10^{-6}\ m = \boxed{1900\ nm}$

$E_6 - E_3 = \boxed{1.13\ eV} = 1.81 \times 10^{-19}$

$\lambda = \frac{hc}{E} = \boxed{1100\ nm}$

$E_4 - E_2 = \boxed{2.55\ eV} = 4.08 \times 10^{-19}$

$\lambda = \frac{hc}{E} = \boxed{487\ nm}$

b) $E_{TOT} = (5.4 \times 10^{-8}\ \frac{J}{s})(1\ sec) = 5.4 \times 10^{-8}\ J$

$N = \frac{E_{TOT}}{E_{42}} = \frac{5.4 \times 10^{-8}}{4.08 \times 10^{-19}} = \boxed{1.3 \times 10^{11}}$

3. (40 pts) A sample of Strontium-90 (mass = 90 amu) has an activity of 2.4 x 10^{-4} Ci. The half-life of Sr-90 is 29.1 yr.

a) How much Sr-90 (in kg) is in the sample?

b) How many years will it take for the activity to be reduced to 7.5 x 10^{-11} Ci?

a) $T_{1/2} = 29.1\ yr = 9.2 \times 10^{8}\ s$

$$\lambda = \frac{0.693}{T_{1/2}} = 7.54 \times 10^{-10}$$

$$a = 2.4 \times 10^{-4}\ Ci \cdot \frac{1\ Bq}{2.7 \times 10^{-11}\ Ci} = 8.9 \times 10^{6}\ Bq$$

$$a = \lambda N \Rightarrow N = \frac{a}{\lambda} = \frac{8.9 \times 10^{6}}{7.54 \times 10^{-10}} = 1.18 \times 10^{16}$$

$$M_{TOT} = N m_{Sr} = (1.18 \times 10^{16})(90\ u)\left(\frac{1.66 \times 10^{-27}\ kg}{1\ u}\right)$$

$$= \boxed{1.76 \times 10^{-9}\ kg}$$

b) $7.5 \times 10^{-11} = 2.4 \times 10^{-4} e^{-\lambda t}$

$$\ln(3.125 \times 10^{-7}) = -\lambda t$$

$$t = \frac{-14.98}{-7.54 \times 10^{-10}} = 1.986 \times 10^{10}\ s$$

$$= \boxed{630\ yrs}$$