Physics 10164 - Exam 5B

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) An unknown metal is illuminated by many different wavelengths of light, starting at 500 nm and slowly decreasing the wavelength. When the wavelength of light reaches 288 nm, electrons are first detected escaping from the metal.

a) What is the work function (in eV) of this metal?

b) If light of wavelength 210 nm illuminates the metal, what is the maximum speed electrons will have when escaping the metal?

a) $E_\gamma = \frac{hc}{\lambda} = \frac{(6.626\times10^{-34})(3\times10^{8})}{288\times10^{-9}\,m} = 6.90\times10^{-19}\,J$

$\phi = 6.9\times10^{-19}\,J \cdot \frac{1\,eV}{1.6\times10^{-19}\,J} = \boxed{4.31\,eV}$

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

$\frac{1}{2}mv^2 = \frac{(6.626\times10^{-34})(3\times10^{8})}{210\times10^{-9}} - 6.90\times10^{-19}$

$\frac{1}{2}mv^2 = 9.47\times10^{-19} - 6.90\times10^{-19}$

$\frac{1}{2}(9.11\times10^{-31})v^2 = 2.57\times10^{-19}$

$v^2 = 5.63\times10^{11}$

$\boxed{v = 7.5\times10^{5}\,m/s}$

2. (30 pts) A sample of radioactive material has an activity that falls to 72% of its original activity after 25 days.

a) What is the half-life of this material?

b) If the activity at a given time is measured to be 22 Curies, how many radioactive atoms are in the sample?

a) $a = 0.72\, a_0$ for $t = 25$ days or 2.16×10^6 s

$0.72 a_0 = a_0 e^{-\lambda t}$

$0.72 = e^{-\lambda t}$

or $1.52 \times 10^{-7}\ s^{-1}$

$\ln 0.72 = -\lambda t$

$\Rightarrow T_{1/2} = 4.56 \times 10^6$ s

$\lambda = \frac{-\ln .72}{t} = 0.0131\ \text{day}^{-1}$

$T_{1/2} = \frac{0.693}{\lambda} = $ **53 days**

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b) $22\ Ci \cdot \frac{1\ Bq}{2.7 \times 10^{-11}\ Ci} = 8.15 \times 10^{11}\ Bq$

$a = \lambda N \quad \lambda = 1.52 \times 10^{-7}\ s^{-1}$ from above

$N = \frac{a}{\lambda} = \frac{8.15 \times 10^{11}}{1.52 \times 10^{-7}} = $ **5.4×10^{18} atoms**

3. (30 pts) A nuclear reactor provides energy using the nuclear reaction: Plutonium-239 --> Uranium-235 + Helium-4

Plutonium-239 has a mass of 239.052156 amu
Uranium-235 has a mass of 235.043923 amu
Helium-4 has a mass of 4.002603 amu

A space probe is designed to last for 25 years during which time the reactor provides an average power of 1200 Watts. How many kg of Plutonium-239 would be needed for the spacecraft?

$$\Delta m = 239.052516 - 235.043923 - 4.002603$$

$$= .00563 \text{ amu}$$

$$= 5.24 \text{ MeV} = 8.39 \times 10^{-13} \text{ J}$$

$$E_{TOT} = \left(1200 \frac{J}{s}\right)(25 \text{ yr}) \cdot \frac{3.16 \times 10^7 \text{ s}}{\text{yr}}$$

$$= 9.48 \times 10^{11} \text{ J}$$

$$E_{TOT} = N E_{reac}$$

$$N = \frac{9.48 \times 10^{11}}{8.39 \times 10^{-13}} = 1.13 \times 10^{24} \text{ atoms}$$

$$m_{TOT} = N m_0 = (1.13 \times 10^{24})(239 \text{ amu}) \cdot \left(\frac{1.66 \times 10^{-27} \text{ kg}}{1 \text{ amu}}\right)$$

$$= \boxed{0.45 \text{ kg}}$$