Physics 10164 - Summer 2019 - Exam #4B

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 is incident on a diffraction grating, resulting in several complete orders of the visible spectrum (400 - 700 nm) being visibly reflected. The red edge of the first order spectrum is reflected at an angle of 9.42° from the normal.

a) What is the angle of reflection for the blue edge of the first order spectrum?
b) How many lines/cm does the grating have?
c) How many complete orders of the visible spectrum can be seen for this grating?

a) $d \sin\theta = \lambda$

$$d = \frac{\lambda}{\sin\theta} = \frac{(700 \times 10^{-9})}{\sin 9.42^\circ} = 4.3 \times 10^{-6} m$$

$$\theta_{blue} = \sin^{-1}\left(\frac{\lambda_{blue}}{d}\right) = \boxed{5.37^\circ}$$

b) $d = 4.3 \times 10^{-6} m = 4.28 \times 10^{-4} cm$

$$n = \frac{1}{d} = \boxed{2340 \text{ lines/cm}}$$

c) For $\theta = 90^\circ$, $\lambda = 700 nm$, find m

$$m = \frac{d}{\lambda} = 6.11, \text{ so } \boxed{6 \text{ orders}}$$

2. (25 pts) A metal surface is illuminated with light of wavelength 345 nm. The ejected photoelectrons have a maximum velocity of 5.4×10^{5} m/s.

a) What is the work function of the metal (in eV)?
b) What is the minimum wavelength photon necessary in order for electrons to escape the metal?

$$(KE)_{max} = \frac{1}{2}(9.11 \times 10^{-31})(5.4 \times 10^{5})^2$$
$$= 1.328 \times 10^{-17} J$$
$$= 0.83 eV$$

$$0.83 = E_\gamma - \phi$$

$$E_\gamma = \frac{(6.626 \times 10^{-34})(3 \times 10^{8})}{345 \times 10^{-9}} = 5.76 \times 10^{-19} J$$
$$= 3.60 eV$$

$$0.83 = 3.60 - \phi \Rightarrow \boxed{\phi = 2.77 eV}$$

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b) Min λ means lowest Energy, so no leftover KE

$$(KE)_{max} = E_\gamma - \phi$$
$$0 = E_\gamma - 2.77 eV$$
$$E_\gamma = 2.77 eV$$

$$\frac{hc}{\lambda} = 4.434 \times 10^{-19}$$
$$\Rightarrow \boxed{\lambda = 448 nm}$$

#3. (25 pts) Iodine-131 (mass = 131 amu) has a half-life of 8.02 days. If 12.0 grams of I-131 is present initially in a sample…

a) How much I-131 (in grams) will be present after 24.0 days have elapsed?
b) What will be activity of the I-131 sample at 24.0 days?
c) After how many days will the activity be 2.00% of its initial value?

a) $M(t) = M_0 e^{-.693t/T_{half}}$ since $N \propto M$

$= 12.0 e^{-0.693(24)/8.02}$

$= \boxed{1.5 \text{ grams}}$

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b) $N = \frac{m_{tot}}{m_I} = \frac{1.5 \times 10^{-3}}{131u * 1.66 \times 10^{-27} \frac{kg}{u}} = 6.94 \times 10^{21}$ atoms

$\lambda = \frac{.693}{T_{half}} = \frac{.693}{(8.02\ d)(86400 \frac{s}{day})} = 1.00 \times 10^{-6}$

$a(t) = \lambda N(t) = \boxed{6.94 \times 10^{15} \text{ Bq}}$

or 1.87×10^{5} Ci

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c) $\frac{N(t)}{N_0} = 0.02 = e^{-.693t/8.02}$

$-3.912 = -\frac{.693t}{8.02}$

$\Rightarrow \boxed{t = 45.3 \text{ days}}$

4. (25 pts) Consider the fusion reaction:

$^2H + ^3H \rightarrow ^4He + ^1n$ + energy

The n represents a neutron with mass = 1.008665 u.
The mass of ^2H is 2.014102 u.
The mass of ^3H is 3.016049 u.
The mass of ^4He is 4.002602 u.

a) How much energy is released by this reaction, in MeV (answer with 3 SF).
b) If the TCU campus uses about 2.1 billion Kw-hr of energy in a given year, how many kg of Hydrogen (assume 5.0 u per reaction) would be needed in order to satisfy this need?

a) $\Delta m = 1.8884 \times 10^{-2} u$

$$\Rightarrow E = \boxed{17.6 \text{ MeV}}$$

b) $E_{tot} = 2.1 \times 10^9 \text{ kW}\cdot\text{hr} \cdot \frac{3.6 \times 10^6 \text{ J}}{\text{kW hr}}$

$= 7.56 \times 10^{15} \text{ J}$

$$N_{reac} = \frac{E_{tot}}{E_{reac}} = \frac{7.56 \times 10^{15}}{17.6 \text{ MeV} \cdot 1.6 \times 10^{-13} \text{ J/MeV}}$$

$= 2.68 \times 10^{27}$ reac

$$m_{tot} = N_{reac}(5u) = 1.3 \times 10^{28} u \cdot \frac{1.66 \times 10^{-27} \text{ kg}}{u}$$

$$= \boxed{22 \text{ kg}}$$