1) A flashlight emits 1.5W of power. Assuming a frequency of $5.2 \times 10^{14}$ Hz for the light, determine the number of photons given off per second.

The energy of each photon is given by $E = hf$, or $E = (6.63 \times 10^{-34} \text{J} \cdot \text{s})(5.2 \times 10^{14} \text{Hz}) = 3.45 \times 10^{-19} \text{J}$

Dividing 1.5W by this energy gives $4.4 \times 10^{18}$ photons per second.

2) The work function of gold is 4.58 eV. What frequency of light must be used to eject electrons from a gold surface with a maximum kinetic energy of $6.48 \times 10^{-19} \text{J}$? Is this light visible to the human eye?

Converting to Joules, $(4.58 \text{eV})(1.6 \times 10^{-19} \text{J/eV}) = 7.33 \times 10^{-19} \text{J}$

This is the energy necessary to just barely eject the electrons from gold. We need to add the extra kinetic energy to get the energy of the photon. $E_{\text{photon}} = 1.38 \times 10^{-18} \text{J}$.

The frequency is given by $E = hf$. $f_{\text{photon}} = 2.1 \times 10^{15} \text{Hz}$

This light is in the ultraviolet range of the spectrum and cannot be seen by humans.

3) Find the wavelength of the photon required to excite a hydrogen atom from the $n=2$ state to the $n=5$ state.

$$E_2 = \frac{-13.6 \text{eV}}{2^2} = -3.4 \text{eV}$$

$$E_5 = \frac{-13.6 \text{eV}}{5^2} = -0.544 \text{eV}$$

$$\Delta E = E_{\text{photon}} = 2.856 \text{eV}$$

$$E = \frac{hc}{\lambda} \Rightarrow \lambda = \frac{hc}{E} = \frac{(4.14 \times 10^{-15} \text{eV} \cdot \text{m/s})(3 \times 10^8 \text{m/s})}{2.856 \text{eV}} = 4.35 \times 10^{-7} \text{m} = 435 \text{nm}$$

This light would be blue.

4) An excited hydrogen atom could, in principle, have a radius of 1mm. What would be the value of $n$ for a Bohr orbit of this size? What would the energy of the atom be?

The radius of the smallest Bohr orbit is $r_1 = 5.3 \times 10^{-11} \text{m}$. This comes from formula 28.15 in the book. The larger orbits are related by $r_n = (n^2)(r_1)$. So putting the given orbit in for $r_n$ and solving for $n$ gives $n = 4340$.

$$E_{4340} = \frac{-13.6 \text{eV}}{4340^2} = 7.22 \times 10^{-7} \text{eV} = -1.15 \times 10^{-25} \text{J}$$
5) An X-ray photon scatters from a free electron at rest at an angle of 175° relative to the incident direction. If the scattered photon has a wavelength of 0.32 nm, what is the wavelength of the incident photon?

\[ \lambda' - \lambda = \frac{h}{mc} (1 - \cos \theta) \]

\[ 0.32 \cdot 10^{-9} m - \lambda = \frac{6.63 \cdot 10^{-34} J \cdot s}{(9.11 \cdot 10^{-31} kg)(3 \cdot 10^8 \text{ m/s})} (1 - \cos 175°) \]

\[ \lambda = 3.15 \cdot 10^{-10} m = .315 \text{ nm} \]

6) What speed must a neutron have if its de Broglie wavelength is to be equal to the interionic spacing of table salt (0.282 nm)?

\[ \lambda = \frac{h}{mv} \]

\[ 0.282 \cdot 10^{-9} m = \frac{6.63 \cdot 10^{-34} J \cdot s}{(1.67 \cdot 10^{-27} \text{ kg})(v)} \Rightarrow v = 1408 \frac{m}{s} \]

(Had to look up the mass of a neutron)

7) The uncertainty in position of a proton confined to the nucleus of an atom is roughly the diameter of the nucleus. If this diameter is 7.5x10^{-15} m, what is the uncertainty in the proton’s momentum?

\[ \Delta x \cdot \Delta p_x \geq \frac{h}{2\pi} \]

\[ \Delta p_x \geq \frac{6.63 \cdot 10^{-34} J \cdot s}{(2\pi)(7.5 \cdot 10^{-15} \text{ m})} \Rightarrow \Delta p_x \geq 1.4 \cdot 10^{-20} \text{ kg} \cdot \text{m/s} \]

8) The measurement of an electron’s energy requires a time of 10 ns. What is the smallest possible uncertainty in the electron’s energy?

\[ \Delta E \cdot \Delta t \geq \frac{h}{2\pi} \]

\[ \Delta E_{\text{min}} = \frac{6.63 \cdot 10^{-34} J \cdot s}{(2\pi)(10 \cdot 10^{-9} \text{ s})} \Rightarrow \Delta E_{\text{min}} = 1.06 \cdot 10^{-26} \text{ J} \]

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