Light and Energy Course Activities

1. When a laser is pointed at a zinc metal surface (Φ = 7.85 x 10^{-19}J), an electron is ejected with a velocity of 1.44 x 10^5 m/s. What is the wavelength of light that is emitted by the laser?

$E_{photon} = \phi + E_k$

$\phi = 7.85 \times 10^{-19}$ J

$E_k = \frac{1}{2}(9.109\times10^{-31} kg)(1.44\times10^5 m/s)^2 = 9.44\times10^{-21}$ J ← mass of electron

$E_{photon} = 7.94\times10^{-19}$ J

$E = \frac{hc}{\lambda}$

$\lambda = \frac{hc}{E} = \frac{(6.626\times10^{-34})(2.998\times10^8)}{7.94\times10^{-19}}$

$\lambda = 2.5\times10^{-7}$ m

$\lambda = 250$ nm

2. Use Coulomb's Law to explain each of these statements about ionization energy:

$E_p \propto -\frac{q_1 q_2}{r}$

Nitrogen > Carbon

same shell, so about the same r

N has more protons, so $q_1(N) > q_1(C)$

Carbon > Silicon

silicon is in a larger shell, so greater r

this decreases the $e^- \rightarrow$ proton interaction

Silicon < Chlorine

$q_1(Cl) > q_1(Si)$

3. Consider a hydrogen atom.

   a. What energy level corresponds to the ground state? n = 1

   b. What energy level corresponds to the 1st excited state? n = 2

   c. What energy level corresponds to the 2nd excited state? n = 3

   d. Calculate the energy of the 5th, 6th, and 7th energy states.

$E_5 = \frac{-2.18\times10^{-18} J}{5^2}(1)^2 = -8.72\times10^{-20}$ J

$E_6 = \frac{-2.18\times10^{-18} J}{6^2}(1)^2 = -6.056\times10^{-20}$ J

$E_7 = \frac{-2.18\times10^{-18} J}{7^2}(1)^2 = -4.45\times10^{-20}$

   e. Why would it not make sense if these energies were positive?

The electron would be repelled from the atom, not attracted to it

(remember $E_p \propto \frac{q_1 q_2}{r}$ ... $E_p > 0$ means that like-charged particles are interacting)

f. How much energy is needed to excite an electron from n=5 to n=6?

$\Delta E = E_6 - E_5$

$\Delta E = -6.056 \times 10^{-20} J - (-8.72 \times 10^{-20} J) = 2.664 \times 10^{-20} J$

g. What is the wavelength of the photon that is emitted from hydrogen when an electron relaxes from the 7th energy level to the 2nd energy level?

$\Delta E = -E_{photon}$

$E_2 = \frac{-2.18 \times 10^{-18} J}{2^2}(1)^2 = -5.4 \times 10^{-19} J$

$\Delta E = E_2 - E_7$

$\Delta E = -5.4 \times 10^{-19} - (-4.45 \times 10^{-20})$

$E_7 = -4.45 \times 10^{-20} J$ (calculated above)

$\Delta E = -5.005 \times 10^{-19} J$

$E_{photon} = 5.005 \times 10^{-19} J$

$E = \frac{hc}{\lambda}$ $\lambda = \frac{hc}{E} = \frac{6.626 \times 10^{-34} J \cdot s (2.998 \times 10^8 m/s)}{5.005 \times 10^{-19} J} = 3.97 \times 10^{-7} m$

397 nm

h. Calculate the ionization energy of an electron in the ground state of a hydrogen atom. Remember that ionization refers to completely overcoming any attraction between an electron and the nucleus.

$n = 1$

$E_1 = \frac{-2.18 \times 10^{-18} J}{1^2}(1)^2 = -2.18 \times 10^{-18} J$

$E_{final} = \emptyset$! ← this means that there is no interaction between the e^- + the nucleus

$\Delta E = 0 - (-2.18 \times 10^{-18} J) = 2.18 \times 10^{-18} J$

4. Consider H, Li^{2+} and C^{5+}. Calculate the ground state energy for the one electron in each of these atoms. Use Coulomb's law to explain why it makes sense that carbon has the lowest energy ground state.

$Z = 1$ $Z = 3$ $Z = 5$

H: $E_1 = \frac{-2.18 \times 10^{-18} J}{1^2}(1)^2 = -2.18 \times 10^{-18} J$

Li^{2+}: $E_1 = \frac{-2.18 \times 10^{-18} J}{1^2}(3)^2 = -1.962 \times 10^{-27} J$

C^{5+}: $E_1 = \frac{-2.18 \times 10^{-18} J}{1^2}(6)^2 = -7.85 \times 10^{-17} J$

Carbon has more protons, so the one e^- has a larger positive charge to interact with

H: $E_p \propto \frac{(+1)(-1)}{r} = \frac{-1}{r}$

C: $E_p \propto \frac{(+6)(-1)}{r} = \frac{-6}{r}$