1 Cognitive reasoning in the chemical sciences 3.11

Some of the following questions you have seen before. Others are new. In either case, please solve these problems without referring to any prior work or your notes. And please try to to work on these problems alone. you will work on these questions together in class.

1. An ion has a single electron. The longest wavelength of radiation absorbed by this ion in its lowest energy state is 7.60 nm. (a) Which ion is this? (b) What is the minimum energy (in units of J) required to completely remove this electron from the ion in its lowest energy state?

2. An atomic ion with a single electron has an unknown nuclear charge, Z. When the ion is in its $n = 3$ excited state, the ion has a threshold frequency,ν_o of $1.46 \times 10^{15} s^{-1}$. What is Z?

3. A metal M forms an oxide X. X has the empirical formula MO_2 and is 13.38 mass percent oxygen. When heated X gives off oxygen and converts to Y, which is 9.334 mass percent oxygen. (a) What is the identity of metal M? (b) What is the empirical formula of the compound Y?

4. In Chem 2070 you receive clickers. These clickers transmit light at a frequency of 915MHz (M stands for mega (10^6); Hz stands for Hertz. One Hertz is 1 s^{-1}). (a) Suppose your seat in Baker 200 is 40 ft away from the receiver. Express this wavelength in clicker wavelengths. (b) Suppose the energy of the hydrogen atom has the absurdly high energy of $-2.690 \times 10^{-22} J$. Could this atom absorb photons from your clicker? Justify your answer with a numerical calculation.

5. There are two basic sets of equations governing waves.

   (a) For waves moving at the speed of light:

   $$v = \nu\lambda$$

   $$E = h\nu.$$

   (b) For electron waves moving orders of magnitude slower than the speed of light:

   $$v = \nu\lambda$$

   $$E_K = \frac{1}{2}mv^2$$

   $$p = mv$$

   $$p = \frac{h}{\lambda}.$$

   (c) Consider two ocean waves. Both ocean waves travel at the same velocity and have the same amplitude, but the frequency of wave A is 5 times faster than wave B. Which wave has a bigger wavelength? What is the ratio of the two wavelengths? Draw a picture of wave A and wave B. Which ocean wave imparts more energy per second against a sea-wall or dike? Can we understand qualitatively why increasing the wavelength decreases the energy in both the case of light and electron waves (electron waves are called orbitals)?

6. The work function, W, of a metal specifies the minimum energy required to remove an electron from that metal, and is often expressed as an energy per mole of electrons. For cesium, $W = 206kJ/mol^{-1}$. (a) A sample of Cs is irradiated with blue light. Are electrons ejected? Justify your answer with a calculation. (b) A sample of Cs is irradiated with light of wavelength 2.95×10^{-7}, and electrons are ejected. What is the speed in ms^{-1} of these electrons?

7. Hydrogen is discovered to emit light at four adjacent wavelengths (it emits at other wave lengths as well): 410.1 nm, 434.0 nm, 486.1 nm and 656.3 nm. Calculate the energies and frequencies of these four wavelengths. The hydrogen atom obeys the equation

$$\nu = C(\frac{1}{2^2} - \frac{1}{n^2})$$

. Based on this data, iteratively calculate the value of C. Please do not look up this value on the web or in your text-book until after you have solved the problem.

8. A mystery compound, Y, has *empirical* formula $C_2H_3O_2S$. Compound Y reacts with aqueous sodium hydroxide to produce water and the compound Z according to the *balanced* equation,

$$2\text{NaOH(aq)} + \text{Y} \longrightarrow 2\text{H}_2\text{O(aq)} + \text{Z(aq)}$$

5.00 g of compound Y and 27.5 ml of 2.0 M NaOH(aq) react completely, with neither material left over. What is the *molecular* formula of Y?

9. An atom of hydrogen can emit light in a process that leaves the electron in its lowest energy state. The longest wavelength of light that can be emitted in this process is called λ_a, and the next longest is called λ_b. Calculate λ_b.