1 Morning class Week 3 Day 2 The Bohr model and the photoelectric effect

1. **Bohr model:** the model for the electron of H, He^+, Li^{2+}, Be^{3+}, etc...

   (a) Recall the relation $E_{total} = -R_H \frac{Z^2}{n^2}$, an equation which should be memorized. The total energy is always the sum of the kinetic energy, E_{trans} and the potential energy, E_{pot}. In the case of Coulombic (also called electrostatic) forces, the forces holding together electrons and protons, the kinetic energy, $E_{trans} = -\frac{1}{2}E_{pot}$. This latter relation is called the *virial theorem.* State an equation (with an equality sign) relating the kinetic energy of an electron to R_H, Z and n.

   (b) Recall that for a particle not moving at the speed of light, $p = \frac{h}{\lambda}$, $p = mv$, and $E_{trans} = \frac{1}{2}mv^2$, three equations which should be memorized. State an equation (with an equality sign) relating the kinetic energy of an electron to h, m_e (the mass of an electron) and λ.

   (c) Noting R_H, h, and m_e are all constants, express, for the Bohr model, the proportionality relationship between λ and Z and n.

   (d) For a Bohr model electron, if one doubles n, keeping Z constant, what happens to λ? If one doubles λ, keeping Z constant, what happens to n?

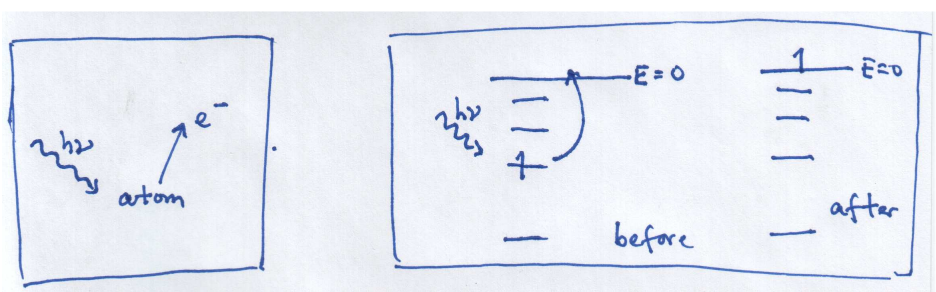
   (e) If Z is constant why, in the Bohr model, is it not possible, in general, to increase λ by exactly 35%?

   (f) For the Coulombic interaction between a positive nucleus and an electron, it is not possible for $E_{pot} > 0$. Please use the fact that kinetic energy is always ≥ 0 and the virial theorem to deduce this statement.

   (g) What is the highest possible total energy for a hydrogen electron?

   (h) When a hydrogen electron has this highest energy, what does the kinetic energy equal?

2. **The photoelectric effect:** When a compound is placed in a beam of light, it is possible for electrons to be emitted (see below).



   (a) Calculate the wavelength of the lowest energy light which can eject an electron from a hydrogen atom whose electron has the $n = 1$ value.

   (b) For metals, if the frequency of the light being absorbed is below a certain frequency no electrons are emitted. Above this threshold frequency, electrons are always emitted. The photelectron spectrum can be graphed as shown in the graph on the next page.

   (c) Examining this graph, please write an equation which correctly captures the behavior described in the graph.

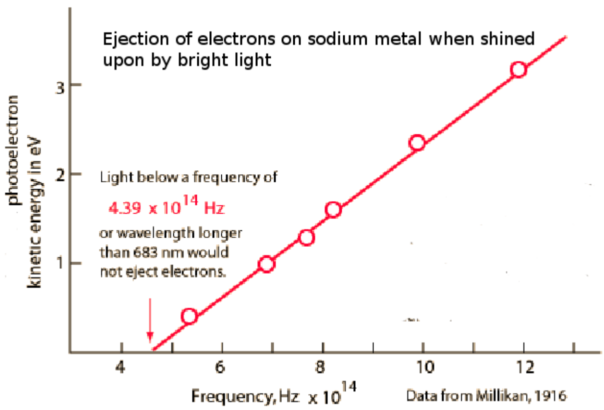


Figure 1: The photoelectric effect based on the original data on sodium metal from Millikan.

2 Prelim style problems

3. **A mystery element**

   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?

4. **The Bohr model, atomic orbitals, and the photoelectric effect**

   (a) An electron in a Li^{2+} occupies the $4p_x$ atomic orbital. What is the shortest wavelength of light that can be emitted by this ion?

   (b) Light is absorbed by this same ion, causing an electron to fly off with speed 1.60×10^6 m s^{-1}. What is the frequency of this light?

5. **"Sacrebleu, I will violate the photoelectric effect!"**

   (a) The French scientist La Cheville-Tordue is investigating the photoelectric effect on a material whose work function is 180.66 kJ/mol. (The work function is the minimum energy required to release an electron from a material.) Calculate the value of ν_o for this value of the work function.

   (b) (10 pts) Prof. La Cheville-Tordue knows that the energy orbital diagram of this same material is as shown below. Based on her knowledge of the energy orbital diagram, Professor La Cheville-Tordue tries shining the material sequentially with two frequencies of light, both of whose frequencies are *smaller* than ν_o with the hope of nevertheless ejecting an electron from the material. Based on the given energy orbital diagram, state a possible value for the first of the two frequencies chosen. For credit, briefly explain the process by which Prof. La Cheville-Tordue hopes to eject an electron.