1 Cognitive reasoning in the chemical sciences 3.2

1. **Review of Bohr model:** Same questions as yesterday. Please do them, without looking at your previous answers, and please do them as fast as you can.

   (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 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) Assuming R_H, h, and m_e are constant, express the proportionality relationship between λ and Z and n.

2. **The photoelectric effect:** When a metal is shone upon by a bright light, electrons can be emitted. If the frequency of the light is below a certain frequency threshold no electrons are emitted. Above this frequency threshold, electrons are always emitted.

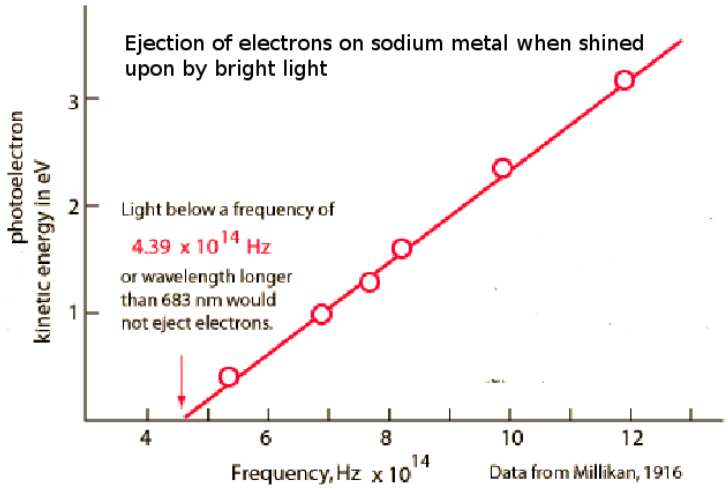
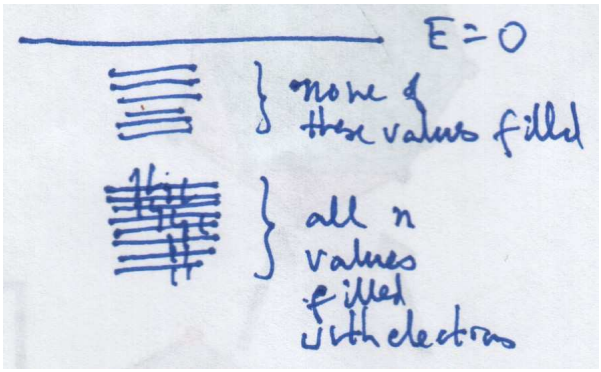


Figure 1: The photoelectric effect based on the original data from Millikan. The photoelectron kinetic energy in this graph is the maximum observed electron kinetic energy.

   (a) Write an equation which correctly captures the behavior descibed in the graph.

   (b) Examine a chemical compound with the electron energy diagram shown below. Assume that the number of electrons which get ejected is proportional to the number of n-values which can be ejected. Explain why the electron energy diagram shown above corresponds to the observed behavior.



3. **A mystery element:** The hydrogen atom obeys the Lyman series, in other words it has specific transitions which correspond to an $n = 2$ electron going down to the $n = 1$ state and in so doing releasing a photon of light, an $n = 3$ electron going down to the $n = 1$ state and in so doing releasing a photon of light, an $n = 4$ electron going down to the $n = 1$ state and in so doing releasing a photon of light, and so forth (see your text-book). Amazingly another one-electron atomic ion is discovered which has all the same transitions as found in the hydrogen atom Lyman series (it could also have more observed frequencies, besides those in the Lyman series). Suggest a possible element and charge for this other ion. Please state your reasoning.