Quiz 1.1 – Origins of Quantum Mechanics

Name: Key

**Early QM Experiments**

Sodium metal has a work function of $2.28\ eV$. If sodium metal is irradiated with $450\ nm$ light, what will be the kinetic energy of the ejected photoelectrons?

$$\phi = 2.28\ eV\left(\frac{1.602\cdot 10^{-19}\ J}{1\ eV}\right) = 3.65\cdot 10^{-19}\ J$$

$$E_{photon} = \phi + E_{kinetic}$$

$$E_{photon} = \frac{hc}{\lambda} = \frac{6.626\cdot 10^{-34}\ J\cdot s \cdot 2.998\cdot 10^{8}\ m/s}{450\cdot 10^{-9}\ m} = 4.41\cdot 10^{-19}\ J \qquad E_{kinetic} = E_{photon} - \phi = 7.6\cdot 10^{-20}\ J$$

Find the velocity of the ejected photoelectrons in the above example?

$$E_{kinetic} = \frac{1}{2}mv^2 \rightarrow v = \left(\frac{2\cdot E}{m}\right)^{1/2} = \left(\frac{2\cdot 7.6\cdot 10^{-20}\ J}{9.11\cdot 10^{-31}\ kg}\right)^{1/2} = 4.08\cdot 10^{5}\ m/s$$

Find the de Broglie wavelength of the ejected photoelectrons in the above example?

$$\lambda = \frac{h}{mv} = \frac{6.626\cdot 10^{-34}\ J\cdot s}{9.11\cdot 10^{-31}\ kg \cdot 4.08\cdot 10^{5}\ m/s} = 1.8\cdot 10^{-9}\ m = 1.8\ nm$$

**Bohr Model**

The "Bohr radius" is $52.9\ pm$. The Bohr model has the electrons revolving around the nucleus in an orbit at that radius. Assuming that the ground state must have a single wavelength equal to the orbital circumference, find the velocity of the electron in its orbit. $\lambda = \pi\cdot 2r = 332\ pm = 3.32\cdot 10^{-10}\ m$

$$v = \frac{h}{m\lambda} = \frac{6.626\cdot 10^{-34}\ J\cdot s}{9.11\cdot 10^{-31}\ kg\cdot 3.32\cdot 10^{-10}\ m} = 2.19\cdot 10^{6}\ m/s$$

Find the kinetic energy of the electron in the ground state of the Bohr model, and compare it to the true hydrogen atom ground state energy ($-2.18\times 10^{-18}\ J$)

$$E_{kinetic} = \frac{1}{2}mv^2 = \frac{1}{2}\cdot 9.11\cdot 10^{-31}\ kg\cdot\left(2.19\cdot 10^{5}\ m/s\right)^2 = 2.18\cdot 10^{-18}\ J$$

They are the same magnitude!