Session #6: Homework Solutions

Problem #1

For a proton which has been subjected to an accelerating potential (V) of 15 Volts, determine its deBroglie wavelength.

Solution

$$E_K = eV = \frac{m_p v^2}{2} \quad ; \qquad v_p = \sqrt{\frac{2\ eV}{m_p}}$$

$$\lambda_p = \frac{h}{m_p v} = \frac{h}{m_p\sqrt{\frac{2eV}{m_p}}} = \frac{h}{\sqrt{2eVm_p}} = \frac{6.63 \times 10^{-34}}{(2 \times 1.6 \times 10^{-19} \times 15 \times 1.67 \times 10^{-27})^{\frac{1}{2}}} = 7.4 \times 10^{-12}\ \text{m}$$

Problem #2

Electrons are accelerated by a potential of 10 Volts.

(a) Determine their velocity.

(b) Determine their deBroglie wavelength (λ_p).

(c) Will these electrons, on interaction with hydrogen atoms, be able to excite the ground state electrons in hydrogen?

Solution

The definition of an eV is the energy gained by an electron when it is accelerated through a potential of 1V, so an electron accelerated by a potential of 10V would have an energy of 10 eV.

(a) $E = \frac{1}{2}mv^2 \;\rightarrow\; v = \sqrt{2E/m}$

$E = 10\ \text{eV} = 1.60 \times 10^{-18}\ \text{J}$

m = mass of electron = 9.11×10^{-31} kg

$$v = \sqrt{\frac{2 \times 1.6 \times 10^{-18}\ \text{J}}{9.11 \times 10^{-31}\ \text{kg}}} = 1.87 \times 10^{6}\ \text{m/s}$$

(b) λ_p = h/mv

$$\lambda_p = \frac{6.63 \times 10^{-34}}{9.11 \times 10^{-34} \text{ kg} \times 1.87 \times 10^{6} \text{m / s}} = 3.89 \times 10^{-10} \text{ m}$$

(c) The energy the electrons have ($E = e.V = 1.6 \times 10^{-18}$ J) must be compared with the smallest energy required to excite a H electron – that needed to move the electron from the n=1 shell to the n=2 shell.

$$E = k\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right) = 2.18 \times 10^{-18} \text{ J} \left(\frac{1}{4} - \frac{1}{1}\right) = 1.64 \times 10^{-18} \text{ J}$$

The E that the electrons have (1.6×10^{-18} J) is less than that required to excite an electron from the n=1 to the n=2 shell (1.64×10^{-18} J), so **no excitation could occur**.

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