

PHY140Y

Spring Term – Tutorial 19 Discussion Solutions

28 February 2000

1. (a) Since hydrogen has a ground state energy of -13.60 eV, when it absorbs a 12.75 eV photon, it goes into an excited state with energy

$$E_n = -13.60 + 12.75 \text{ eV} \quad (1)$$

$$= -0.85 \text{ eV} \quad (2)$$

$$= \frac{-13.6}{4^2} \text{ eV}. \quad (3)$$

Thus, it is in the quantum state with $n = 4$. It can therefore go to the energy states

$$E_3 = \frac{-13.60}{3^2} = -1.51 \text{ eV} \quad (4)$$

$$E_2 = \frac{-13.60}{2^2} = -3.40 \text{ eV} \quad (5)$$

$$E_1 = -13.60 \text{ eV}. \quad (6)$$

- (b) The possible ways it can decay to the ground state are:

- $E_4 \rightarrow E_1$ producing a 12.75 eV photon,
- $E_4 \rightarrow E_2$ producing a 2.55 eV photon followed by $E_2 \rightarrow E_1$ producing a 10.20 eV photon,
- $E_4 \rightarrow E_3$ producing a 0.66 eV photon, followed by either $E_3 \rightarrow E_1$ producing a 12.09 eV photon or by the cascade $E_3 \rightarrow E_2 \rightarrow E_1$ producing 1.89 and 10.20 eV photons.

2. (a) The radius would be

$$r_{250} = a_0(250)^2 \quad (7)$$

$$= (5.29 \times 10^{-11})(250)^2 = 3.3 \times 10^{-6} \text{ m}. \quad (8)$$

- (b) Its binding energy is the energy needed to ionize the electron, or

$$E_{bind} = -E_{250} \quad (9)$$

$$= \frac{13.60}{(250)^2} = 2.18 \times 10^{-4} \text{ eV}. \quad (10)$$

- (c) The energy of the emitted photon is

$$\Delta E = -13.6 \left(\frac{1}{(273)^2} - \frac{1}{(272)^2} \right) \quad (11)$$

$$= 9.88 \times 10^{-8} \text{ eV}. \quad (12)$$

The frequency of the corresponding photon is

$$\nu = \frac{\Delta E}{h} \quad (13)$$

$$= \frac{(9.88 \times 10^{-8})(1.60 \times 10^{-19})}{6.63 \times 10^{-34}} = 2.39 \times 10^7 \text{ Hz.} \quad (14)$$

- (a) The de Broglie wavelength of an electron, λ_e , would be less than that of light, λ , provided that

$$\lambda_e = \frac{h}{m_e v_e} < \lambda \quad (15)$$

$$\Rightarrow v_e > \frac{h}{\lambda m_e} \quad (16)$$

$$= \frac{6.63 \times 10^{-34}}{(4.5 \times 10^{-7})(9.11 \times 10^{-31})} = 1.62 \times 10^3 \text{ m/s.} \quad (17)$$

- (b) The electron's velocity must be equal to

$$v_e = \frac{h}{\lambda_e m_e} = 0.73 \text{ m/s.} \quad (18)$$

- (c) The de Broglie wavelength of the Earth is

$$\lambda_E = \frac{h}{m_E v_E} \quad (19)$$

$$= \frac{6.63 \times 10^{-34}}{(3 \times 10^3)(5.97 \times 10^{24})} = 3.7 \times 10^{-62} \text{ m.} \quad (20)$$

At this distance scale, we would already be living in a 10-dimensional world that looks infinite if you believe super string theory.