Solution 11

Q1. A) The electron in a hydrogen atom makes a transition from the n=2 energy level to the ground level (n =1). Find the wavelength and frequency of the emitted photon.

$$hf = R_H \left|\left(\frac{1}{n_i^2} - \frac{1}{n_f^2}\right)\right|$$

$$hf = (2.179 \times 10^{-18} J) \left|\left(\frac{1}{2^2} - \frac{1}{1^2}\right)\right|$$

$$hf == (2.179 \times 10^{-18} J) \left(\frac{3}{4}\right)$$

$$hf = 1.63 \times 10^{-18} J$$

$$f = \frac{1.63 \times 10^{-18} J}{6.63 \ \times 10^{-34} J.s} = 2.46 \times 10^{15} Hz$$

$$\lambda = \frac{c}{f} = \frac{\left(3 \times 10^{8} \frac{m}{s}\right)}{2.46 \times 10^{15} Hz} = 1.21 \times 10^{-7} m = 121\ nm$$

B) In interstellar space, highly excited hydrogen atoms called Rydberg atoms have been observed. Find the wavelength to which radio astronomers must tune to detect signals from electrons dropping from the n =273 level to the n = 272 level.

$$hf = R_H \left|\left(\frac{1}{n_i^2} - \frac{1}{n_f^2}\right)\right|$$

$$hf = (2.179 \times 10^{-18} J) \left|\left(\frac{1}{273^2} - \frac{1}{272^2}\right)\right|$$

$$hf == (2.179 \times 10^{-18} J)(9.88 \times 10^{-8})$$

$$hf = 2.15 \times 10^{-25} J$$

$$f = \frac{2.15 \times 10^{-25} J}{6.63 \times 10^{-34} J.s} = 3.25 \times 10^{8} Hz$$

$$\lambda = \frac{c}{f} = \frac{\left(3 \times 10^{8} \frac{m}{s}\right)}{3.25 \times 10^{8} Hz} = 0.923\ m = 923\ mm$$

---

3. An isolated atom of a certain element emits light of wavelength 520 nm when the atom falls from its fifth excited state into its second excited state. The atom emits a photon of wavelength 410 nm when it drops from its sixth excited state into its second excited state. Find the wavelength of the light radiated when the atom makes a transition from its sixth to its fifth excited state.

(a) The fifth excited state must lie above the second excited state by the photon energy

$$E_{52} = hf = \frac{hc}{\lambda} = \frac{(6.626 \times 10^{-34}\ \text{J} \cdot \text{s})(3.00 \times 10^{8}\ \text{m/s})}{520 \times 10^{-9}\ \text{m}}$$
$$= 3.82 \times 10^{-19}\ \text{J}$$

The sixth excited state exceeds the second in energy by

$$E_{62} = \frac{(6.626 \times 10^{-34}\ \text{J} \cdot \text{s})(3.00 \times 10^{8}\ \text{m/s})}{410 \times 10^{-9}\ \text{m}} = 4.85 \times 10^{-19}\ \text{J}$$

Then the sixth excited state is above the fifth by

$$(4.85 - 3.82) \times 10^{-19}\ \text{J} = 1.03 \times 10^{-19}\ \text{J}$$