

REVIEW QUESTIONS

Chapter 7

1. Calculate the wavelength and energy of a photon of radiation with frequency of $2.85 \times 10^{12} \text{ s}^{-1}$.

$$\lambda = \frac{c}{\nu} = \frac{3.00 \times 10^8 \text{ m/s}}{2.85 \times 10^{12} \text{ s}^{-1}} = 1.05 \times 10^{-4} \text{ m}$$

$$E = h\nu = (6.634 \times 10^{-34} \text{ J}\cdot\text{s})(2.85 \times 10^{12} \text{ s}^{-1}) = 1.89 \times 10^{-21} \text{ J}$$

2. What is the wavelength of radiation with energy of $8.23 \times 10^{-19} \text{ J}$? In what region of the electromagnetic spectrum would this radiation be found?

$$\nu = \frac{E}{h} = \frac{8.23 \times 10^{-19} \text{ J}}{6.634 \times 10^{-34} \text{ J}\cdot\text{s}} = 1.24 \times 10^{15} \text{ s}^{-1}$$

$$\lambda = \frac{c}{\nu} = \frac{3.00 \times 10^8 \text{ m/s}}{1.24 \times 10^{15} \text{ s}^{-1}} = 2.42 \times 10^{-7} \text{ m} = 242 \text{ nm (UV)}$$

3. For each of the following transitions in the hydrogen atom, calculate the energy, wavelength and frequency of the associated radiation and determine whether radiation is absorbed or emitted during the transition.

- a) from $n=5$ to $n=1$

$$\frac{1}{\lambda} = 1.097 \times 10^7 \left(\frac{1}{n_1^2} - \frac{1}{n_2^2} \right) \text{ m}^{-1} = 1.097 \times 10^7 \left(\frac{1}{1} - \frac{1}{25} \right)$$

$$\lambda = 9.50 \times 10^{-8} \text{ m}$$

$$\nu = \frac{c}{\lambda} = \frac{3.00 \times 10^8 \text{ m/s}}{9.50 \times 10^{-8} \text{ m}} = 3.16 \times 10^{15} \text{ s}^{-1}$$

$$E = h\nu = (6.634 \times 10^{-34} \text{ J}\cdot\text{s})(3.16 \times 10^{15} \text{ s}^{-1}) = 2.10 \times 10^{-18} \text{ J}$$

Energy is emitted by this transition

- b) from $n=2$ to $n=7$

$$\frac{1}{\lambda} = 1.097 \times 10^7 \left(\frac{1}{n_1^2} - \frac{1}{n_2^2} \right) \text{ m}^{-1} = 1.097 \times 10^7 \left(\frac{1}{4} - \frac{1}{49} \right)$$

$$\lambda = 3.97 \times 10^{-7} \text{ m}$$

$$\nu = \frac{c}{\lambda} = \frac{3.00 \times 10^8 \text{ m/s}}{3.97 \times 10^{-7} \text{ m}} = 7.56 \times 10^{14} \text{ s}^{-1}$$

$$E = h\nu = (6.634 \times 10^{-34} \text{ J}\cdot\text{s})(7.56 \times 10^{14} \text{ s}^{-1}) = 5.02 \times 10^{-19} \text{ J}$$

Energy is absorbed by this transition

4. Use the diagrams below to determine the wavelength and frequency of each wave shown. (Assume the same time and distance scale for both waves)

For wave (a)

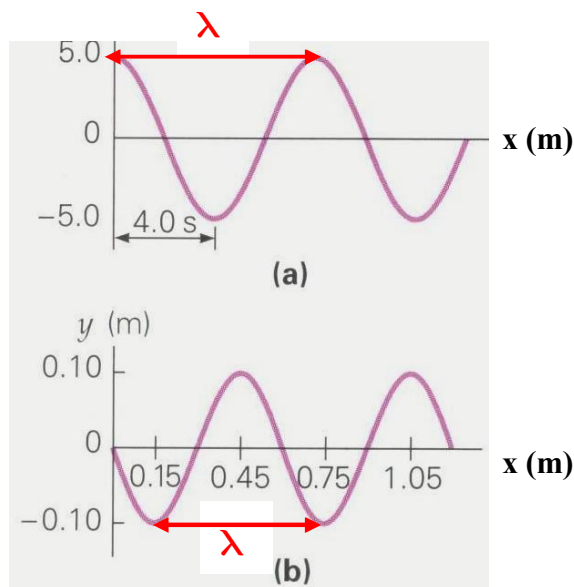
$$\lambda = 0.75 \text{ m}$$

$$v = \frac{1 \text{ wave}}{8.0 \text{ s}} = 0.125 \text{ s}^{-1}$$

For wave (b)

$$\lambda = 0.60 \text{ m}$$

$$v = \frac{1 \text{ wave}}{6.0 \text{ s}} = 0.166 \text{ s}^{-1}$$



5. The energy needed to remove an electron completely from an atom is called its *ionization energy*. In terms of Bohr's model, ionization can be considered a process in which the electron moves to an "orbit" of infinite radius. The ionization of a ground-state hydrogen atom can therefore be calculated by assuming that the electron undergoes a transition from $n_i=1$ state to $n_f=\infty$ state. Calculate this energy in kJ/mol.

$$\frac{1}{\lambda} = 1.097 \times 10^7 \left(\frac{1}{n_1^2} - \frac{1}{n_2^2} \right) \text{ m}^{-1} = 1.097 \times 10^7 \left(\frac{1}{1} - \frac{1}{\infty} \right) \quad \frac{1}{\infty} = 0$$

$$\lambda = 9.12 \times 10^{-8} \text{ m}$$

$$v = \frac{c}{\lambda} = \frac{3.00 \times 10^8 \text{ m/s}}{9.12 \times 10^{-8} \text{ m}} = 3.29 \times 10^{15} \text{ s}^{-1}$$

$$E = h\nu = (6.634 \times 10^{-34} \text{ J}\cdot\text{s})(3.29 \times 10^{15} \text{ s}^{-1}) = 2.18 \times 10^{-18} \text{ J}$$

$$E = \frac{2.18 \times 10^{-18} \text{ J}}{1 \text{ atom}} \times \frac{6.02 \times 10^{23} \text{ atoms}}{1 \text{ mol}} \times \frac{1 \text{ kJ}}{10^3 \text{ J}} = 1.31 \times 10^3 \text{ kJ/mol}$$

6. Determine if each set of quantum numbers below is permissible or not. If yes, write the orbital designation for each.

- a) $n=2$ $l=1$ $m_l=+1$ **Yes** **2p**
- b) $n=1$ $l=0$ $m_l=-1$ **No (m_l cannot be greater than l)**
- c) $n=4$ $l=2$ $m_l=+1$ **Yes** **4d**
- d) $n=3$ $l=3$ $m_l=0$ **No (l values cannot exceed $n-1$)**

7. Write the quantum numbers associated with each of the following orbitals:

- a) 4p $n=4$ $l=1$ $m_l=+1, 0$ or -1
- b) 3d $n=3$ $l=2$ $m_l=+2, +1, 0, -1$ or -2
- c) 7s $n=7$ $l=0$ $m_l=0$
- d) 5f $n=5$ $l=3$ $m_l=+3, +2, +1, 0, -1, -2$ or -3

8. The quantum numbers listed below are for four different orbitals. List them in order of increasing energy. Indicate whether any two have the same energy.

- a) $n=4$ $l=0$ $m_l=0$ **4s**
- b) $n=3$ $l=2$ $m_l=+1$ **3d**
- c) $n=3$ $l=1$ $m_l=-1$ **3p**
- d) $n=3$ $l=2$ $m_l=0$ **3d**

$$\mathbf{c < a < b = d}$$

9. Rank the following orbitals in increasing order of energy:

$$4d \qquad 3p \qquad 6s \qquad 5p \qquad 4f$$

$$3p < 4d < 5p < 6s < 4f$$

10. How many orbitals are possible with each of the following designations:

a) 2p 3

b) 5s 1

c) 3d 5

d) 4f 7

11. When a compound containing cesium is heated in a Bunsen burner flame, photons with energy of $4.30 \times 10^{-19} \text{ J}$ are emitted. What color is the cesium flame?

$$\nu = \frac{E}{h} = \frac{4.30 \times 10^{-19} \text{ J}}{6.634 \times 10^{-34} \text{ J}\cdot\text{s}} = 6.48 \times 10^{14} \text{ s}^{-1}$$

$$\lambda = \frac{c}{\nu} = \frac{3.00 \times 10^8 \text{ m/s}}{6.48 \times 10^{14} \text{ s}^{-1}} = 4.63 \times 10^{-7} \text{ m} = 463 \text{ nm (Blue-green color)}$$

12. The He^+ ion contains one electron and is therefore a hydrogen-like ion. Calculate the wavelength of the first four electron transitions ($6 \rightarrow 2$, $5 \rightarrow 2$, $4 \rightarrow 2$ and $3 \rightarrow 2$) for this ion and compare with the same transitions in the H atom. Comment on the differences. (R_{H} for $\text{He}^+ = 8.72 \times 10^{-18} \text{ J}$)

$$\frac{1}{\lambda} = \frac{R_{\text{H}}}{hc} \left(\frac{1}{n_1^2} - \frac{1}{n_2^2} \right) = 4.38 \times 10^7 \left(\frac{1}{n_1^2} - \frac{1}{n_2^2} \right) \text{ m}^{-1}$$

$$\frac{R_{\text{H}}}{hc} = \frac{8.72 \times 10^{-18} \text{ J}}{(6.634 \times 10^{-34} \text{ J}\cdot\text{s})(3.00 \times 10^8 \text{ m/s})} = 4.38 \times 10^7 \text{ m}^{-1}$$

For transition $6 \rightarrow 2$ $\lambda = 1.03 \times 10^{-7} \text{ m} = 103 \text{ nm (H= 411 nm)}$

For transition $5 \rightarrow 2$ $\lambda = 1.09 \times 10^{-7} \text{ m} = 109 \text{ nm (H= 434 nm)}$

For transition $4 \rightarrow 2$ $\lambda = 1.22 \times 10^{-7} \text{ m} = 122 \text{ nm (H= 487 nm)}$

For transition $3 \rightarrow 2$ $\lambda = 1.64 \times 10^{-7} \text{ m} = 164 \text{ nm (H= 657 nm)}$

All H transitions are in the visible region, while He^+ transitions are in the UV region