Atomic Structure

Bohr's Atomic Model

Introduction

- Proposed by Niels Bohr in 1913.
- Built upon Rutherford's model, addressing its limitations by introducing quantized orbits.
- Explains stability of atoms and emission spectra.

Postulates of Bohr's Model

1. **Quantized Orbits:**
   - Electrons revolve around the nucleus in specific circular orbits without radiating energy.
   - These orbits are called stationary states or energy levels.
2. **Quantized Angular Momentum:**
   - Angular momentum (L) of an electron in an orbit is quantized and given by:

$$L = n\frac{h}{2\pi}$$

   where n is the principal quantum number (1, 2, 3, …), and h is Planck's constant.
3. **Energy Levels:**
   - Each orbit corresponds to a definite energy level. Energy is only emitted or absorbed when an electron transitions between these levels.
4. **Radiation of Energy:**
   - When an electron jumps from a higher energy orbit (n_2) to a lower energy orbit (n_1), energy is emitted in the form of a photon. The energy of the photon is given by:

$$E = h\nu = E_{n_2} - E_{n_1}$$

   where ν is the frequency of the emitted radiation.

Hydrogen Spectrum

Emission Spectrum of Hydrogen

- When an electron transitions between energy levels, it emits or absorbs light at specific wavelengths, resulting in a series of spectral lines.

Series of Spectral Lines

1. **Lyman Series:**
   - Transitions to $n = 1$.

- ○ Falls in the ultraviolet region.
- ○ Wavelengths: $\lambda = \dfrac{1}{R_H\left(1-\frac{1}{n^2}\right)}$ for $n > 1$.

2. **Balmer Series:**
   - ○ Transitions to $n = 2$.
   - ○ Visible region.
   - ○ Wavelengths: $\lambda = \dfrac{1}{R_H\left(\frac{1}{2^2}-\frac{1}{n^2}\right)}$ for $n > 2$.

3. **Paschen Series:**
   - ○ Transitions to $n = 3$.
   - ○ Infrared region.
   - ○ Wavelengths: $\lambda = \dfrac{1}{R_H\left(\frac{1}{3^2}-\frac{1}{n^2}\right)}$ for $n > 3$.

4. **Brackett Series:**
   - ○ Transitions to $n = 4$.
   - ○ Infrared region.
   - ○ Wavelengths: $\lambda = \dfrac{1}{R_H\left(\frac{1}{4^2}-\frac{1}{n^2}\right)}$ for $n > 4$.

5. **Pfund Series:**
   - ○ Transitions to $n = 5$.
   - ○ Infrared region.
   - ○ Wavelengths: $\lambda = \dfrac{1}{R_H\left(\frac{1}{5^2}-\frac{1}{n^2}\right)}$ for $n > 5$.

Energy of Electron in Bohr's Model

Energy Levels

- The energy of an electron in the nth orbit of a hydrogen atom is given by:

$$E_n = -\frac{13.6\ \text{eV}}{n^2}$$

  where 13.6 eV is the ionization energy of hydrogen.

Energy Difference

- The energy difference between two levels n_1 and n_2 is:

$$\Delta E = E_{n_2} - E_{n_1} = 13.6\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)\ \text{eV}$$

Rydberg Constant

- The Rydberg formula for the wavelength of spectral lines in hydrogen is given by:

$$\frac{1}{\lambda} = R_H\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

  where:
  - ○ λ is the wavelength.
  - ○ R_H is the Rydberg constant $(R_H = 1.097 \times 10^7\ \text{m}^{-1})$.

      ○ n_1 and n_2 are integers with $n_2 > n_1$.

Example Problems

Example 1: Wavelength of the Balmer Series

Calculate the wavelength of the first line in the Balmer series ($n_2 = 3$ to $n_1 = 2$).

$$\frac{1}{\lambda} = R_H \left(\frac{1}{2^2} - \frac{1}{3^2} \right)$$

$$\frac{1}{\lambda} = 1.097 \times 10^7 \left(\frac{1}{4} - \frac{1}{9} \right)$$

$$\frac{1}{\lambda} = 1.097 \times 10^7 \left(\frac{9 - 4}{36} \right)$$

$$\frac{1}{\lambda} = 1.097 \times 10^7 \times \frac{5}{36}$$

$$\lambda = \frac{36}{1.097 \times 10^7 \times 5}$$

$$\lambda \approx 656 \text{ nm}$$

Example 2: Energy Difference Between Two Levels

Calculate the energy difference between $n = 2$ and $n = 4$ in a hydrogen atom.

$$\Delta E = 13.6 \left(\frac{1}{2^2} - \frac{1}{4^2} \right)$$

$$\Delta E = 13.6 \left(\frac{1}{4} - \frac{1}{16} \right)$$

$$\Delta E = 13.6 \left(\frac{4 - 1}{16} \right)$$

$$\Delta E = 13.6 \times \frac{3}{16}$$

$$\Delta E = 2.55 \text{ eV}$$

Example 3: Radius of the Third Orbit

Calculate the radius of the third orbit ($n = 3$) in a hydrogen atom.
The radius of the nth orbit is given by:

$$r_n = n^2 \times r_1$$

where $r_1 = 0.529$ Å is the Bohr radius.

$$r_3 = 3^2 \times 0.529 \text{ Å}$$

$$r_3 = 9 \times 0.529 \text{ Å}$$

$$r_3 = 4.761 \text{ Å}$$

These notes and example problems should provide a comprehensive overview of Bohr's atomic model, the hydrogen spectrum, the energy of electrons, and the Rydberg constant.