Atomic Structure Overview

Lecture Notes on Atomic Structure and Electromagnetic Theory

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1. Discovery of Electrons

- **Cathode Ray Experiment:**
  - High voltage electric discharge through a gas at low pressure produces cathode rays, which are streams of negatively charged particles called electrons.
  - **Thomson's Experiment:**
    - Determined the charge-to-mass ratio (e/m) of an electron as $1.758820 \times 10^{11}\, C kg^{-1}$.
  - **Millikan's Oil Drop Experiment:**
    - Determined the charge of an electron as $1.6 \times 10^{-19}\, C$.
  - **Calculation of Electron Mass:**
    - $m_e = \frac{e}{\frac{e}{m_e}} = \frac{1.6 \times 10^{-19}}{1.758820 \times 10^{11}} \approx 9.11 \times 10^{-31}\, kg.$

2. Discovery of Protons

- **Goldstein's Experiment (1886):**
  - Using perforated cathodes, Goldstein observed positive rays (canal rays) traveling in the opposite direction to cathode rays.
  - Properties:
    - Travel in straight lines and are positively charged.
    - Charge-to-mass ratio varies with gas.
    - Mass differs for different gases.
    - The smallest positive ion was identified as the proton (hydrogen ion).

3. Discovery of Neutrons

- **Chadwick's Experiment (1932):**
  - Bombarded beryllium with alpha particles and discovered neutrons.
  - Neutrons are neutral particles with a mass slightly greater than that of protons.
  - **Mass Comparisons:**
    - Electron: $9.11 \times 10^{-31}\, kg$
    - Proton: $1.673 \times 10^{-27}\, kg$
    - Neutron: $1.675 \times 10^{-27}\, kg.$

4. Thomson Model

- Describes the atom as a sphere of positive charge with electrons embedded in it, akin to plums in a pudding.

5. Rutherford Model

- **Alpha Particle Scattering Experiment:**
  - Concluded most of the atom is empty space, with a small, dense, positively charged nucleus.
  - The nucleus is very small compared to the atom's total volume (radius of nucleus $10^{-13}\, cm$; atom $10^{-8}\, cm$).
  - **Atomic Model:**
    - Atom consists of a nucleus containing protons and neutrons.
    - Electrons revolve around the nucleus in defined orbits.
    - Atomic Number (Z) = Number of protons.
    - Mass Number (A) = Number of protons + neutrons.
    - Isotopes: Same atomic number, different mass numbers.
    - Isobars: Different atomic numbers, same mass number.
    - Isotones: Same number of neutrons, different atomic numbers.

6. Electromagnetic Theory of Waves

- **Maxwell's Postulates:**
  - Energy is emitted as continuous waves.
  - Radiations are electromagnetic waves oscillating perpendicular to each other and the direction of propagation.
  - **Key Equations:**
    - Velocity (c) = $\nu \times \lambda$
    - Wave number ($\bar{\nu}$) = $\frac{1}{\lambda}$.

7. Electromagnetic Spectrum

- Arranged in increasing order of wavelength:
  - Gamma rays, X-rays, UV rays, Visible light, IR rays, Microwaves, FM/AM Radio waves, Long radio waves.

8. Black Body Radiations

- A perfect black body emits radiations that change color with temperature.

9. Photoelectric Effect

- **Einstein's Explanation:**
  - Electrons are ejected from a metal surface when struck by light of certain frequency (threshold frequency ν_0).
  - **Kinetic Energy:**
    - $E_k = h\nu - h\nu_0$.
  - **Number of Ejected Electrons:**
    - Proportional to the intensity of the incident radiation.

10. Limitations of Electromagnetic Theory of Waves

- Could not explain phenomena like:
  - Interference, diffraction.
  - Black body radiation.
  - Photoelectric effect.

- Line spectra of atoms.

11. Particle Nature of Electromagnetic Radiations

- **Planck's Quantum Theory:**
  - Energy is emitted/absorbed in discrete packets called quanta (photons).
  - Energy (E) = $h\nu$.

12. Explanation of Black Body Radiations and Photoelectric Effect

- **Black Body Radiations:**
  - Emission of photons with varying energy when a black body is heated.
- **Photoelectric Effect:**
  - Emission of electrons from metal when struck by light of sufficient frequency.
  - Excess energy converts to kinetic energy of electrons:
    - $\frac{1}{2}mu^2 = h\nu - h\nu_0$.