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Atomic Structure
Content By Chandra Shekhar

1. RUTHERFORD'S NUCLEAR MODEL

- Conducted α-particle scattering experiment using a thin gold foil.
- Concluded that atoms consist of a small, dense, positively charged nucleus where most mass is concentrated.
- Protons and neutrons (collectively nucleons) reside in the nucleus.

Limitations:

- Fails to explain stability of atoms — electrons should spiral into the nucleus due to radiated energy.
- Could not justify line spectra observed in hydrogen atom.

2. PLANCK'S QUANTUM THEORY

- Energy is quantized and emitted/absorbed in discrete units (quanta).
- Energy of radiation is given by: $E = h\nu = \dfrac{hc}{\lambda}$

  Where: $h = 6.626 \times 10^{-34}$ Js (Planck's constant)

3. PHOTOELECTRIC EFFECT (EINSTEIN)

- $K.E._{max} = h\nu - h\nu_0 = \dfrac{hc}{\lambda} - \dfrac{hc}{\lambda_0}$
- Demonstrates particle nature of light; requires threshold frequency (ν_0) for electron ejection.

4. BOHR'S ATOMIC MODEL

Key Postulates:

1) Electrons revolve in discrete circular orbits without emitting energy.

2) Angular momentum is quantized: $mvr = \dfrac{nh}{2\pi}$, $n = 1, 2, 3, ...$

3) Energy emitted/absorbed during transition between levels: $\Delta E = h\nu$

Important Derivations (for Hydrogen-like atoms):

- Radius: $r_n = \dfrac{n^2 h^2}{4\pi^2 k Z e^2 m} = 0.529 \dfrac{n^2}{Z}$ Å
- Velocity: $v_n = \dfrac{Ze^2}{2\epsilon_0 nh}$
- Energy: $E_n = -\dfrac{13.6 Z^2}{n^2}$ eV
- Transition energy: $\Delta E = 13.6 Z^2 \left(\dfrac{1}{n_1^2} - \dfrac{1}{n_2^2} \right)$

5. SPECTRAL SERIES OF HYDROGEN

S.No.	Spectral Series	Region	Transition
1	Lyman series	Ultraviolet	$n_1 = 1, n_2 = 2, 3, 4, \ldots, \infty$
2	Balmer series	Visible	$n_1 = 2, n_2 = 3, 4, 5, \ldots, \infty$
3	Paschen series	Infrared	$n_1 = 3, n_2 = 4, 5, 6, \ldots, \infty$
4	Brackett series	Infrared	$n_1 = 4, n_2 = 5, 6, 7, \ldots, \infty$
5	Pfund series	Infrared	$n_1 = 5, n_2 = 6, 7, 8, \ldots, \infty$

6. DUAL NATURE OF MATTER (DE BROGLIE)

- Wave-particle duality: Matter can behave as both particle and wave.
- Wavelength: $\lambda = \dfrac{h}{mv}$
- Verified by electron diffraction experiments.

7. HEISENBERG'S UNCERTAINTY PRINCIPLE

- States that position and momentum cannot be known simultaneously with full precision.

- $\Delta x \cdot \Delta p \geq \dfrac{h}{4\pi}$
- Also: $\Delta E \cdot \Delta t \geq \dfrac{h}{4\pi}$

8. SCHRÖDINGER WAVE EQUATION

- Time-independent 3D form:

$$-\dfrac{h^2}{8\pi^2 m} \nabla^2 \Psi + V\Psi = E\Psi$$

- Ψ is the wave function — Ψ^2 gives probability density of finding the electron.

9. Quantum Numbers

- **Principal** (n): Size and energy level of orbital.
- **Azimuthal** (l): Shape of orbital ($l = 0$ to $n - 1$): s, p, d, f
- **Magnetic** (m): Orientation ($-l$ to $+l$)
- **Spin** (s): Direction of spin ($+\frac{1}{2}, -\frac{1}{2}$)

10. Rules for Filling Electrons

- **Aufbau Principle**: Electrons fill orbitals in increasing energy order.
- **(n + l) Rule**: Lower ($n + l$) means lower energy. If equal, lower n fills first.
- **Pauli Exclusion Principle**: No two electrons can have the same four quantum numbers.
- **Hund's Rule**: Electrons occupy degenerate orbitals singly first with parallel spins.