Chapter 19
Atomic Spectra

* $\frac{1}{\lambda_n} = R\left(\frac{1}{p^2} - \frac{1}{n^2}\right)$

  $P = 1, 2, 3 \cdots$

  $n = P+1,\ P+2,\ P+3 \ldots$

  $R = 1.097 \times 10^{7}\ m^{-1}$

For Lyman Series : $P = 1$

For Balmer Series : $P = 2$

For Paschen Series : $P = 3$

For Brackett Series : $P = 4$

* $mvr = \frac{nh}{2\pi}$

  $h = 6.63 \times 10^{-34}\ Js$

* $hf = E_n - E_p$

  E_n : Higher Energy State

  E_p : Lower Energy state

* For electron in circular orbit

  $\frac{mv^2}{r} = \frac{ke^2}{r^2}$

* $r_n = n^2 \times 0.53\ A^{\circ}$

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* $K.E = \frac{1}{2}\frac{ke^2}{r_n}$

$P.E = -\frac{ke^2}{r_n}$

$E_n = -\frac{E_0}{n^2} = \frac{13.6\, eV}{n^2} = -\frac{1312\ kJ/mol}{n^2}$

* For Continuous X-Rays

$\lambda_{min} = \frac{hc}{eV}$

* De-Broglie wavelength

$\lambda = \frac{h}{mv}$

* For Bohr's orbit

$v \propto \frac{1}{\sqrt{r}}$

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* Maximum No. of transitions from n-shell

$$\frac{n(n-1)}{2}$$

e.g

Max. no. of transition from $n=5$

$$\frac{5(5-1)}{2} = \frac{5 \times 4}{2} = 10$$

* Shortest wavelength of Lyman Series is:

91 nm

* Representation:

Neutron → ${}_0n^1$

Proton → ${}_1H^1$

electron → e^{-1}

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TIME FOR:

1. Electrons in excited state $= 10^{-8}$ s
2. Electrons in metastable state $= 10^{-3}$ s

10^{-3} s much longer than 10^{-8} s

EXCITATION POTENTIAL:

The potential difference applied to an electron in its ground state to get an amount of energy equal to excitation energy of electron in the atom.

For Hydrogen Atom:

First Excitation Potential = 10.2 V

Second Excitation Potential = 12.1 V

IONIZATION ENERGY

The ionization energy of the atom is numerically equal to the ground state energy of the atom.

For Hydrogen Atom:

Ionization Energy = 13.6 eV

INNER SHELL TRANSITIONS

K_α → Transition from L-shell to K-shell
K_β → Transition from M-shell to K-shell
K_γ → Transition from N-shell to K-shell

* K-series X-Rays are more energy that L-series.

* Energy Order:

$$K_\gamma > K_\beta > K_\alpha$$

SPECTRUM OF HYDROGEN

1. LYMAN SERIES

UV Region

$$\frac{1}{\lambda} = R\left(\frac{1}{1^2} - \frac{1}{n^2}\right)$$

$$n = 2, 3, 4 \cdots \infty$$

FOR LONGEST WAVELENGTH:

Put $n = 2$

FOR SHORTEST WAVELENGTH:

Put $n = \infty$

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* For every series to find ~~shortest~~ Longest wavelength, put $n = P+1$

Lyman Series :	$P = 1$	UV Region
Balmer Series :	$P = 2$	Visible Region
Paschen Series :	$P = 3$	IR Region
Brackett Series :	$P = 4$	IR Region
Pfund Series :	$P = 5$	IR Region

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CONTINUOUS X-RAYS

→ In a continuous spectrum of X-Rays there exist a minimum wavelength or maximum frequency beyond which no ray is emitted. Their intensities are intermixed such that no definite separating line can be drawn between two wavelengths.

→ This spectrum doesnot depend on nature of target

→ Max. frequency or minimum wavelength of this spectrum depends on the potential difference applied in the X-Ray tube

HOW THEY ARE PRODUCED:

→ When a potential difference V volt is applied in X-Ray tube, the minimum K.E of electrons $\frac{1}{2}mv^2 = eV$. Where 'e' is charge of electron and 'm' is its mass. When this electron strikes the atom of the target, it loses some part of its energy. This energy appears in the form of X-Rays whose energy is hf. It is obvious that hf will be less than eV.

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→ The incident electron before coming to rest collides with many atoms of the target. In this process moving electron is retarded and gets deviated. This event is called Bremsstrahlung. Each retarded electron radiates electromagnetic waves. X-Rays emitted by the target will have continuous range of frequencies upto a maximum frequency f_{max}.

$$f_{max} = \frac{eV}{h} = 0.24 \times 10^{15} V$$

* The minimum wavelength corresponding to maximum frequency is λ_{min}

$$\lambda_{min} = \frac{c}{\nu_{max}} = \frac{hc}{eV} = \frac{12400}{V} A^{\circ}$$

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PRODUCTION OF X-RAYS

→ Highly evacuated tube (Coolidge Tube)

→ contains an anode and a tungsten filament connected to cathode.

→ Electrons are emitted from the filament by thermionic emission

* ANODE : Copper Block

The anode is copper block inclined to the electron stream and having a small target of tungsten, or another metal (such as platinum) on which electrons are focused by the concave cathode.

→ The tube has a lead shield with a small window to allow the passage of X-Rays beam

→ Voltage : High DC voltage of order of 50,000V

→ A small part of K.E of the incident electron is converted into X-Rays, the rest is converted into heat. The target becomes very hot and must, therefore have a high melting point.

The heat generated in target is dissipated through copper rod

Sometimes the anode is cooled by water flowing behind the anode.

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* Hard X-Rays :
  Large penetrating capacity

* Soft X-Rays:
  Small penetrating capacity

* Intensity of X-Rays beam depend on:
  No. of electrons striking the target per second

* Wavelength of X-Rays Depend on:
  Voltage across the tube

* Penetration Power of X-Rays depend on:
  1. Accelerating Voltage
  2. Intensity of beam

LASER

* Stand For:

Light Amplification by Stimulated Emission of Radiation

* Characteristics Of Laser:

1. Monochromatic
2. Unidirectional
3. Coherent
4. Sharply focused
5. Highly polarized
6. Affect photographic plate
7. Show Reflection, refraction, diffraction

* BASIC TERMS:

1. Metastable State:

It is a high energy state in which electrons can stay for a long time

2. Optical Pumping:

It is the process of providing energy to initiate and maintain the process

3. POPULATION INVERSION:

The situation in which number of excited atoms exceeds the number of atoms in ground state

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4. Stimulated Emission:

Stimulated emission is the process by which an incoming photon of a specific frequency can interact with an excited atomic electron, causing it to drop to a lower energy level.

5. Coherence:

It means that stimulated photons have same frequency and wavelength

HELIUM- NEON LASER

→ Gas Laser
→ 85% Helium and 15% Neon Gas
→ Active Medium: Neon

* METASTABLE STATES:

Nearly Identical

Helium = 20.61 eV

Neon = 20.66 eV

* CONSTRUCTION

1. Pump Source (High Voltage Power Supply)
2. Gain Medium (He and Neon)
3. Resonating Cavity

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* Energy is supplied to the Gain medium to achieve population inversion.

* In He-Ne laser, neon atoms are the active centres and have energy levels suitable for laser transitions while helium atoms help in exciting neon atoms.

* TWO MIRRORS:
  1. Partially silvered → Output coupler
  2. Fully silvered → Fully Reflecting mirror

→ The metastable state of helium atoms cannot return to ground state by spontaneous emission. However, they can return to ground state by transferring their energy to the lower energy state electrons of neon atoms. Thus, helium atoms help neon atoms in achieving population inversion. Millions of ground state electrons of neon atoms are excited to metastable state.

After some period, the metastable state electrons of the neon atoms will spontaneously fall into the next lower energy states by releasing photons of red light. This is called spontaneous emission.

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* When light enters a different medium, its frequency remains the same. Hence, its energy remains the same throughout the entire process.

* The frequency of emitted radiations or photons from an atom is equal to the frequency with which the electron bounces back and forth between the higher and the lower energy state.

* When hydrogen gas is placed in a discharge tube, and a discharge is caused in it by means of high voltage across the tube, the gas becomes luminous and gives off a bluish-red light

* RYDBERG'S CONSTANT:

$$R_H = \frac{E_0}{hc} = 1.0974 \times 10^7 \, m^{-1}$$

* The image of a CT scan is called a Tomogram.

PROPERTIES OF X-RAYS

1. They are not refracted as they pass from one medium to another.
2. Cast shadows of obstacles placed in their path
3. Can be diffracted
4. cause fluorescence in many substances
5. effect photographic plates
6. can penetrate solid substances which are opaque to ordinary visible light.
7. When they pass through a solid, liquid or gas, they ionize the atoms

* Velocity of electron in n^{th} Bohr's orbit for hydrogen atom:

$$V_n = \frac{2.2 \times 10^6}{n}$$

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MCQ : The total energy of electron in state $n=\infty$ is :

Ans : Zero

Sol:

$$E_n = -\frac{E_o}{n^2} = -\frac{E_o}{\infty^2} = 0$$

* The outer orbit electron has greater energy than inner orbits

MCQ 2016+2018 : The ground state energy of hydrogen is 13.6 eV. The energy needed to ionize H-atom from its second excited state is?

Ans : 1.51 eV

Sol.

Second Excited state refers to $n=3$ and energy of electron in this state is

$$E_2 = -\frac{E_o}{3^2} = -1.51\ eV$$

Hence in order to ionize the hydrogen atom 1.51 eV is needed