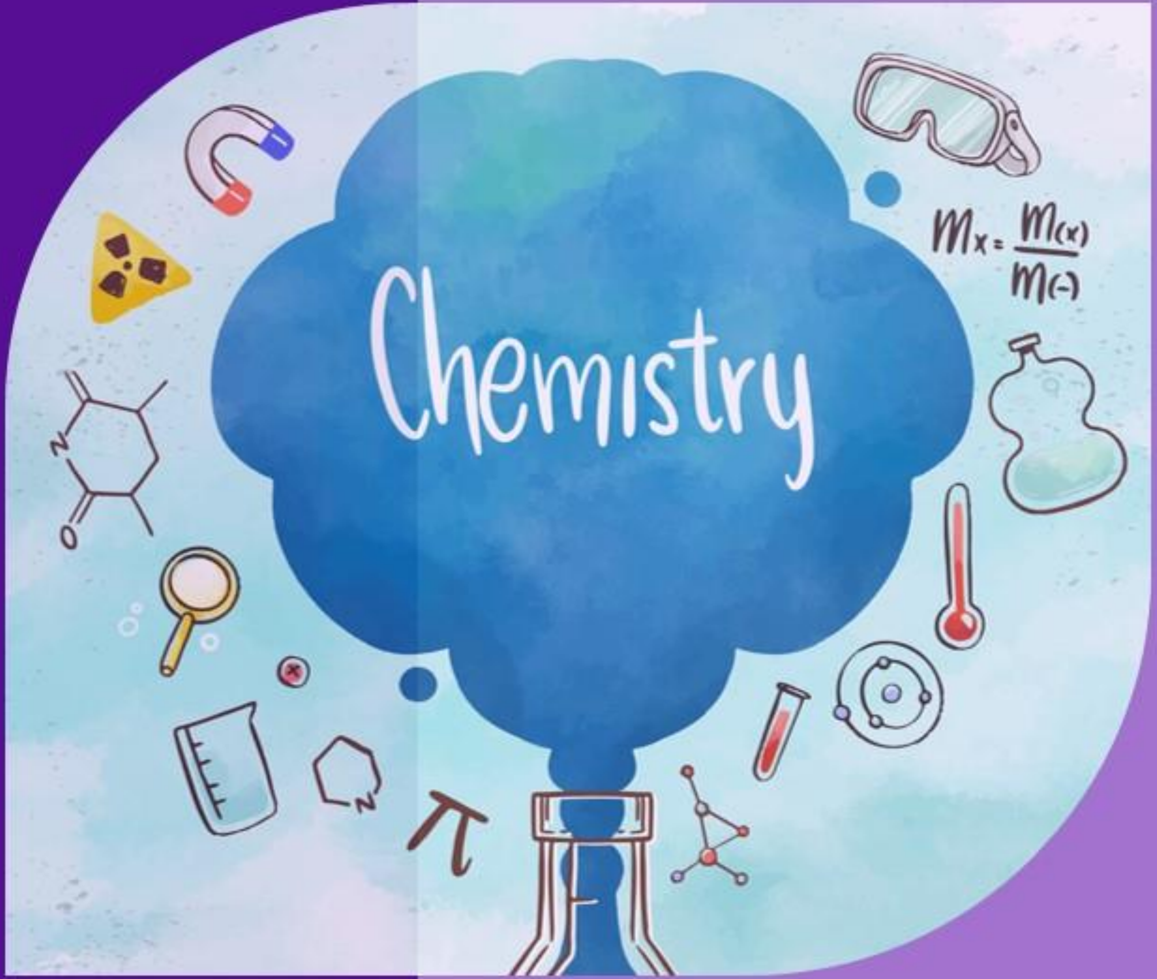
CLASS 11 ACADEMIC PROGRAM 2020

CHEMISTRY

LECTURE : C-04

CHAPTER 2 : QUALITATIVE CHEMISTRY



উদ্ভাস
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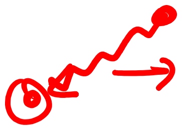
Explanation of the electromagnetic spectrum and the atomic spectrum of hydrogen



radiation
atomic
spectrum

- **Theory and explanation regarding atomic spectrum:**

If an electron jumps from higher energy level to a lower energy level, then it radiates energy. According to the Bohr atomic model, this radiated energy is $\Delta E = hf$. This radiation is atomic spectrum.

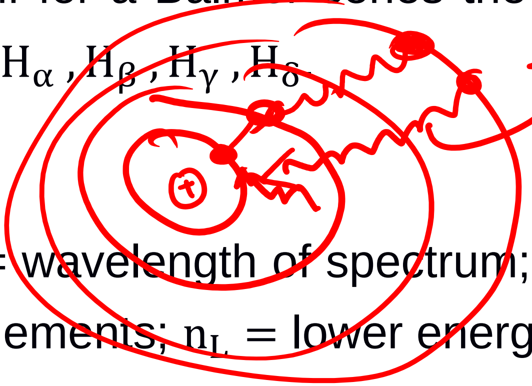
It can be seen from experimentation that different elements have different spectral energy, i.e. as the wavelength and frequency of the spectra are different, so are the colors. This difference mainly depends upon the change of orbital destination of electron.

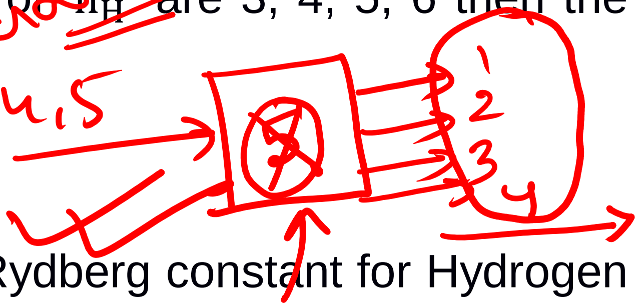
6 → 3
5 → 2

Lymen, Balmer and other scientists discovered different series at different times and expressed them using different formulas. But at present, a single easy equation is used to express the wave number or wavelength of different atomic spectrum. It is to be noted that, if for a Balmer series the values of n_H are 3, 4, 5, 6 then the obtained spectrum are respectively expressed by $H_\alpha, H_\beta, H_\gamma, H_\delta$.

radiate
1, 2, 3, 4, 5

The equation is, $\bar{\nu} = \frac{1}{\lambda} = R_H\left(\frac{1}{n_L^2} - \frac{1}{n_H^2}\right)z^2$ ✓





Here, $\bar{\nu}$ = the number of waves per unit length; λ = wavelength of spectrum; R_H = Rydberg constant for Hydrogen atom, $R_H = 109678\text{cm}^{-1}$, z = Atomic number of elements; n_L = lower energy shell; n_H = higher energy shell.

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Explanation of the electromagnetic spectrum and the atomic spectrum of hydrogen

$\boxed{MKS}$ / $\boxed{SI}$ //

$$r_n = \frac{n^2h^2\epsilon_0}{\pi m e^2 Z} \; ; \; V_n = \frac{Ze^2}{2nh\epsilon_0} \; ; \; E_n = \frac{-Z^2me^4}{8n^2h^2\epsilon_0^2}$$

radius

velocity

energy

✓ ϵ_0 = permittivity of free space $= 8.854\times10^{-12}$ F/m

↳ epsilon not

✓ h = Plank's Constant $= 6.626\times10^{-34}$ Js

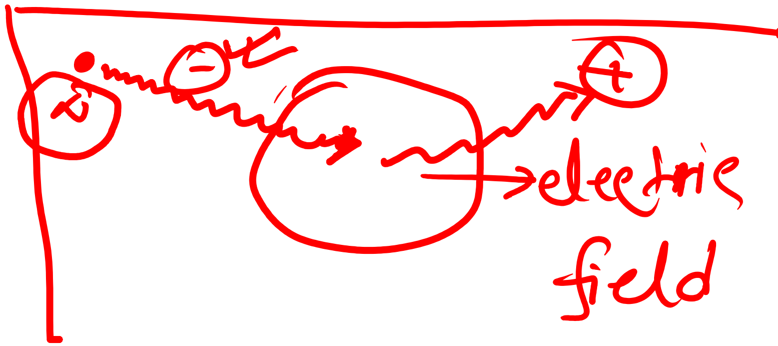
✓ m = mass of electron $= 9.11\times10^{-31}$ kg

✓ e = charge of electron $= -1.6\times10^{-19}$ C

✓ n = orbit number

✓ Z = atomic number

unit (SI)



Explanation of the electromagnetic spectrum and the atomic spectrum of hydrogen

$$E_n = \frac{-z^2 m e^4}{8 h^2 n^2 \epsilon_0^2}; \quad E_{n_L} = \frac{-z^2 m e^4}{8 h^2 n_L^2 \epsilon_0^2}; \quad E_{n_H} = \frac{-z^2 m e^4}{8 h^2 n_H^2 \epsilon_0^2}$$

n_L = Lower orbit

n_H = Higher orbit

$n_H \rightarrow n_L \rightarrow$ radiation

$\therefore E_{n_H} - E_{n_L} = \Delta E$ = radiated / emitted energy

$$= \ominus \frac{z^2 m e^4}{8 h^2 n_H^2 \epsilon_0^2} \ominus \left(\ominus \frac{z^2 m e^4}{8 h^2 n_L^2 \epsilon_0^2} \right) = - \frac{z^2 m e^4}{8 h^2 n_H^2 \epsilon_0^2} \oplus \frac{z^2 m e^4}{8 h^2 n_L^2 \epsilon_0^2}$$

$$= \oplus \frac{z^2 m e^4}{8 h^2 n_L^2 \epsilon_0^2} - \frac{z^2 m e^4}{8 h^2 n_H^2 \epsilon_0^2} = \frac{m e^4 z^2}{8 h^2 \epsilon_0^2} \left(\frac{1}{n_L^2} - \frac{1}{n_H^2} \right)$$

Explanation of the electromagnetic spectrum and the atomic spectrum of hydrogen

$$\Delta E = \frac{me^4 Z^2}{8h^2\epsilon_0^2}\left(\frac{1}{n_L^2}-\frac{1}{n_H^2}\right) = \frac{me^4}{8h^2\epsilon_0^2}\left(\frac{1}{n_L^2}-\frac{1}{n_H^2}\right)Z^2$$

$$\downarrow$$

$$\frac{hc}{\lambda} = \frac{me^4}{8h^2\epsilon_0^2}\left(\frac{1}{n_L^2}-\frac{1}{n_H^2}\right)Z^2$$

$$\Delta E = \frac{hc}{\lambda}$$

$$\Rightarrow \frac{1}{\lambda} = \underbrace{\frac{me^4}{8h^2\epsilon_0^2 \times hc}}_{\text{Rydberg } (R_H)}\left(\frac{1}{n_L^2}-\frac{1}{n_H^2}\right)Z^2$$

$$\text{Rydberg constant} = \frac{me^2}{8h^2\epsilon_0^2} \times \frac{e^2}{hc} = 1{\cdot}097\times10^{7}\ m^{-1}$$

$$= \frac{(9{\cdot}11\times10^{-31})(-1{\cdot}6\times10^{-19})^2}{8\times(6{\cdot}626\times10^{-34})^2\times(8{\cdot}854\times10^{-12})^2} \times \frac{(-1{\cdot}6\times10^{-19})^2}{(6{\cdot}626\times10^{-34})(3\times10^{8})}$$

Explanation of the electromagnetic spectrum and the atomic spectrum of hydrogen

$$\underbrace{\frac{1}{\lambda}}_{\downarrow\ \boxed{m^{-1}}} \boxed{=} \underbrace{R_H}_{\downarrow\ \boxed{m^{-1}}} \underbrace{\left(\frac{1}{n_L^2} - \frac{1}{n_H^2}\right)}_{\downarrow\ \text{no unit}} \underbrace{Z^2}_{\downarrow\ \text{no unit}}$$

⊛⊛⊛ $$\left.\begin{aligned} R_H &= 1.097 \times 10^7 \ m^{-1} \\ &= 10.97 \times 10^6 \ m^{-1} \end{aligned}\right\}$$

$\underline{\underline{f = \text{frequency}}}$

$\underline{= \nu}$

$$\underline{\bar{\nu}} = \text{wave number} = \frac{1}{\lambda} = \textcircled{m^{-1}} \text{ unit}$$

Poll Question- 1

- If the wavelength of the wave is 500 cm then what is the number of wave?

[✓ (a) 1/500]

(b) 1/250

(c)1/200

no unit shown

λ = wavelength

$\bar{\nu} = \frac{1}{\lambda}$ = wave number

$\bar{\nu} = \frac{1}{500}$

$\boxed{\nu = \text{frequency} = f}$

Spectral regions

Name of series	n_L	n_H	Region of radiation
Lymen Series ✓	1	2, 3, 4, ...	→ Ultraviolet region
Balmer Series ✓	2	3, 4, 5, ...	→ ✓✓ Visible region
Paschen Series ✓	3	4, 5, 6, ...	→ Infrared region
Brackett Series ✓	4	5, 6, 7, ...	→ Infrared region
Pfund Series ✓	5	6, 7, 8, ...	→ Infrared region
Humphreys	6	7, 8 - - - -	〃

Visible Range

UV ← V - - - - R → IR

Visible light and spectrum

Chart-01	Chart-02
Wavelength of different types of electromagnetic radiation	The wavelength of different colors in the visible light are as follows
Cosmic ray: < 0.0005 Å	Violet : 380 – 424 nm
Gamma ray (γ-ray) : < 0.005 - 1.5 Å	Indigo : 425 – 450 nm
X-ray : < 0.1 - 100 Å	Blue : 451 – 500 nm
Ultraviolet ray (UV) : < 3800 Å	Green : 501 – 575 nm
Visible light : 3800 Å - 7000 Å	Yellow : 576 – 590 nm
Infrared (IR) > 7000 Å	Orange : 591 – 647 nm
Radio and television wave length: > 2.2 × 10^6 Å	Red : 648 – 700 nm

$1\,\text{Å} = 10^{-10}\,m$ | $1\,nm = 10^{-9}\,m$

Poll Question- 2

- If electron jumps from Lymen series to 5th shell which of the following are the values of nL and nH?

$n_L=1$

$n_H=5$

Lower orbit / shell

higher orbit / shell

[✓ (a) $nL = 1\ and\ nH = 5$]

(b) $nL = 2\ and\ nH = 5$

(c) $nL = 5\ and\ nH = 1$

(d) $nL = 2\ and\ nH = 2$

Mathematical problem

- ☐ What would be the wavelength and color of the spectral line created when electron goes from 4th shell to 2nd shell of a hydrogen atom? [BUET'06-07, 14-15]

$Z = 1$

$n_L = 2$

$n_H = 4$

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

$$\bar{\nu} = \frac{1}{\lambda} = R_H \left(\frac{1}{n_L^2} - \frac{1}{n_H^2} \right) Z^2$$

$$= (1.097 \times 10^7) \left(\frac{1}{2^2} - \frac{1}{4^2} \right) (1)^2$$

$$= 2056875 \, m^{-1} \text{ (wave number)}$$

$$\Rightarrow \bar{\nu}$$

(ii) $$\lambda = \frac{1}{\bar{\nu}} = 4.86 \times 10^{-7} \, m = 4.86 \times 10^{-7} \times 10^{9} \, nm = 486 \, nm \; \boxed{\text{Blue}}$$

nm is for ranging

⊛ An electron moves from 6th shell to 3rd shell of an hydrogen atom. What will be its wave number & energy?

Soln:

$Z=1$; $n_L=3$; $n_H=6$

$\bar{\nu} = \frac{1}{\lambda} = R_H\left(\frac{1}{n_L^2}-\frac{1}{n_H^2}\right)Z^2$

$\therefore \bar{\nu} = (1.097\times10^7)\left(\frac{1}{3^2}-\frac{1}{6^2}\right)(1)^2 = 914166.6667\ m^{-1}$ (Ans)

$\Delta E = \frac{hc}{\lambda} = hc.\bar{\nu} = (6.626\times10^{-34})\times(3\times10^8)\times(914166.6667)$

$= 1.82\times10^{-19}$ J

n
1 → L
2 → B
3 → P
4 → B
5 → Pf
6 → H

not visible

2nd shell 6th shell

* An electron moves from Humphreys shell to Balmer shell of an hydrogen atom. $\rightarrow Z = 1$ what is its color & its energy?

*Soln: $n_L = 2$; $n_H = 6$; $Z = 1$; $R_H = 1.097 \times 10^{7} m^{-1}$

$$\bar{\nu} = \frac{1}{\lambda} = R_H\left(\frac{1}{n_L^2} - \frac{1}{n_H^2}\right)Z^2 = (1.097\times10^{7})\left(\frac{1}{2^2} - \frac{1}{6^2}\right)(1)^2$$

$$= 2437777.778\ m^{-1} \ ; \ \lambda = \frac{1}{\bar{\nu}} = 4.1021\times10^{-7} m$$

$$= 410\ nm$$

(violet)

$$\Delta E = \frac{hc}{\lambda} = hc \cdot \frac{1}{\lambda} = hc \cdot \bar{\nu} = 4.8458 \times 10^{-19} J$$

Mathematical problem

❑ *H*- What is the maximum wave number for Balmer series?

→ দ্বিতীয়

$\rightarrow Z=1 ; R_H = 1.097 \times 10^7 m^{-1}$

$n_L = 2$

$\bar{\nu}_{max} \rightarrow E_{max} ; n_H = \infty$

$$\bar{\nu} = R_H\left(\frac{1}{n_L^2} - \frac{1}{n_H^2}\right)Z^2$$

$$\left[\frac{1}{\infty^2} = \frac{1}{\infty} = 0\right]$$

$$\bar{\nu}_{max} = (1.097 \times 10^7)\left(\frac{1}{2^2} - \frac{1}{\infty^2}\right)(1)^2$$

$$= 2742500 \ m^{-1}$$

Concept

$E = \frac{hc}{\lambda}$ | $E \propto \frac{1}{\lambda}$; $E \propto f \propto \nu$

$E = hf = h\nu$

$E \propto \bar{\nu}$

$E = hc\bar{\nu}$

$[f = \nu]$

E = energy

λ = wavelength

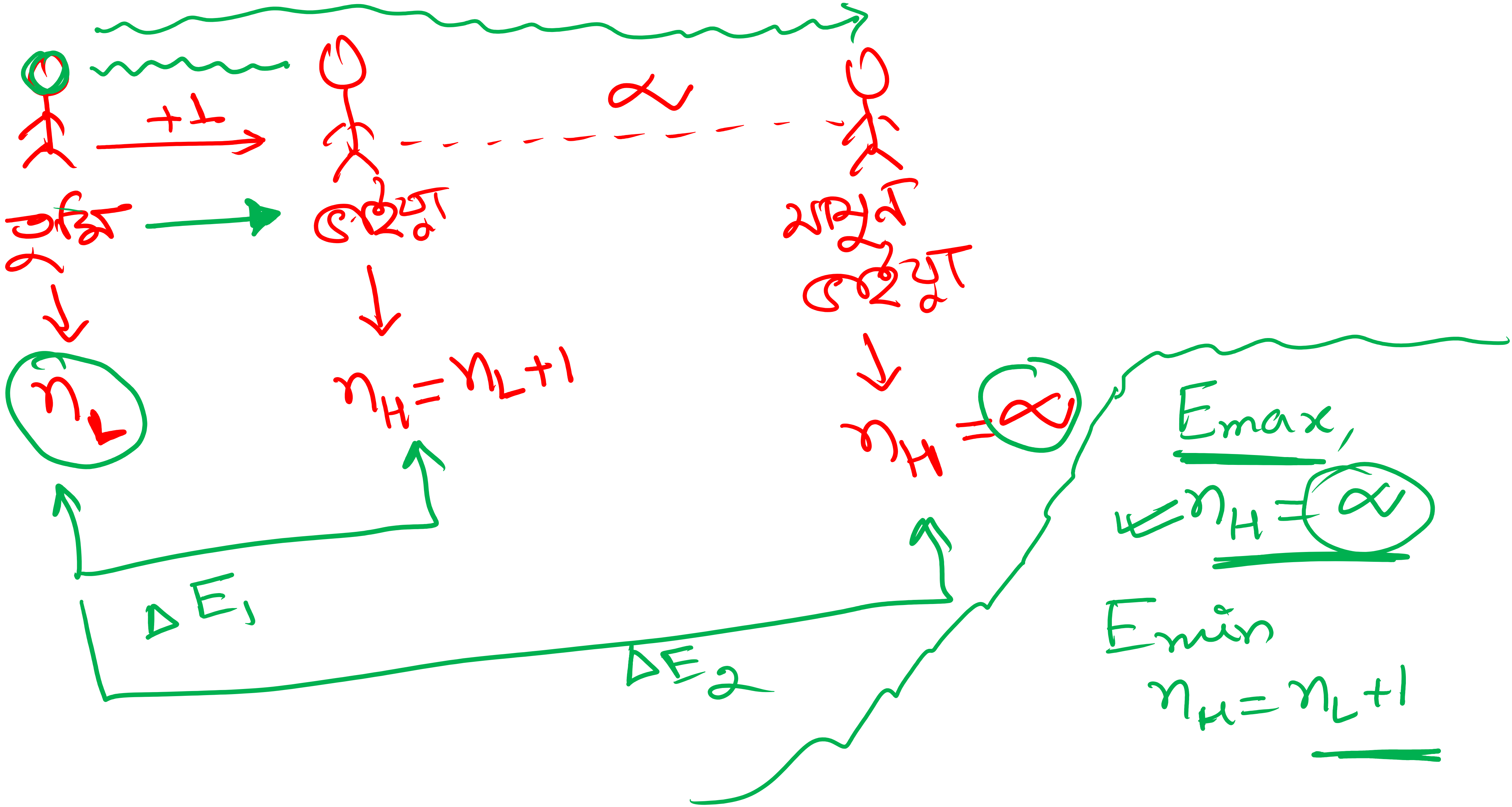
$E_{max} \rightarrow f_{max} \rightarrow \nu_{max} \rightarrow \bar{\nu}_{max} \rightarrow \lambda_{min}$

$E_{min} \rightarrow f_{min} \rightarrow \nu_{min} \rightarrow \bar{\nu}_{min} \rightarrow \lambda_{max}$

$\bar{\nu}$ = wave number

$f = \nu$ = frequency

Concept


+1
∝
তুমি
ভেহুয়া
মামুর ভেহুয়া
n_L
$n_H = n_L + 1$
$n_H = \infty$
ΔE_1
ΔE_2
E_{max},
$\Leftarrow n_H = \infty$
E_{min}
$n_H = n_L + 1$

H → Paschen series's   maximum $\lambda = ?$

H ↓ $Z = 1$

Paschen series's ↓ $n_L = 3$

$n_H = 3+1 = 4$

$\lambda_{max} \{ E_{min}$ ↓ $n_H = n_L + 1$

$$\therefore \bar{\nu} = \frac{1}{\lambda} = R_H \left(\frac{1}{n_L^2} - \frac{1}{n_H^2} \right) Z^2$$

$$\bar{\nu} = (1.097 \times 10^7) \left(\frac{1}{3^2} - \frac{1}{4^2} \right) (1)^2 = 533263.8889 \ m^{-1}$$

$$\therefore \lambda = \frac{1}{\bar{\nu}} = 1.875 \times 10^{-6} \ m$$

(Ans)

S-1

n_L

lower orbit

$\boxed{n_H = n_L + 1}$

higher

$\boxed{\Delta E_1}$

S-2

n_L

$\boxed{n_H = \infty}$

$\boxed{\Delta E_2}$

$E_2 >> E_1$

for, E_{max},

$n_H = \infty$

E_{min}

$n_H = n_L + 1$

$E \propto f \propto \nu \propto \bar{\nu}$

$E \propto \frac{1}{\lambda}$

$z=1$ (*) H – Pfund →5th shell series's maximum and minimum wavelength.

for, λ_{max}, → E_{min}

$n_H = n_L + 1 = 5+1 = 6$

$n_L = 5$; $z=1$

$$\bar{\nu} = \frac{1}{\lambda} = R_H\left(\frac{1}{n_L^2} - \frac{1}{n_H^2}\right) z^2$$

$$= (1.097 \times 10^7)\left(\frac{1}{5^2} - \frac{1}{6^2}\right)(1)^2$$

$$= 134077.7778 \ m^{-1}$$

$$\lambda_{max} = \frac{1}{\bar{\nu}} = 7.45835 \times 10^{-6} \ m$$

for, λ_{min} → E_{max} → $n_H = \alpha$

$n_L = 5$

$z=1$

$$\bar{\nu} = \frac{1}{\lambda} = R_H\left(\frac{1}{n_L^2} - \frac{1}{n_H^2}\right) z^2$$

$$= (1.097 \times 10^7)\left(\frac{1}{5^2} - \frac{1}{\alpha^2}\right)(1)^2$$

$$= 438800 \ m^{-1}$$

$$\lambda_{min} = \frac{1}{\bar{\nu}} = 2.2789 \times 10^{-6} \ m$$

Element identification using line spectra

$$\bar{\nu} = \frac{1}{\lambda} = R_H\left(\frac{1}{n_L^2} - \frac{1}{n_H^2}\right)z^2$$

* * *

Z=1 → Hydrogen

Z=11 → Na

Z=20 → Ca

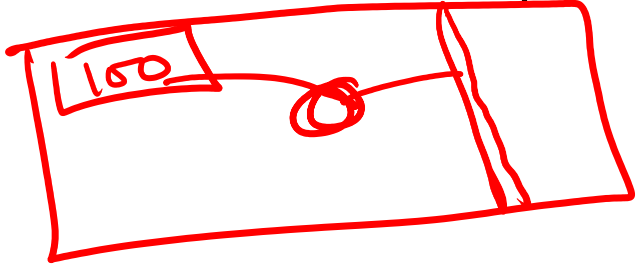
Z=17 → Cl

Use of UV-Ray detection in counterfeit money / passport

D S

Wavelength of UV ray is from $\lambda = 10\text{nm}$ to $380\,\text{nm}$. But UV ray with wavelength $230\text{nm} - 375\text{nm}$ is used as optical sensor true-false currency in note detection machine. Special chemical substance named optical sensor phosphor is used as security device in currency note. Electron of phosphor molecule being excited by low wavelength or high frequency UV ray is transferred to higher energy level. At next moment the excited electron of phosphor molecule returns back to stable state from excited state and the absorbed energy is radiated as visible light of definite frequency. As the radiation is with color so it is called fluorescence. Depending on this principle UV ray is used to detect fake note/passport.

U P



phosphor + UV

energy absorb
immediately visible
area - light ray
emit করে.

Poll question -3

- What is used for detection in counterfeit money / passport:

  (a) Phosphor

  (b) IR

Medical use of IR rays & Principles of MRI examination in diagnosis

Infra Red

i) blood Pressure

ii) acne

iii) Pyorrhea

iv) asthma

v) vein blockade

Magnetic Resonance Imaging

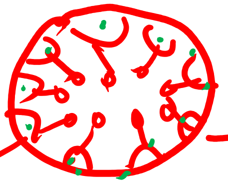
NMR → Nuclear Magnetic Resonance

Magnetic Field (0.5-4T) → ideal

70% H_2O

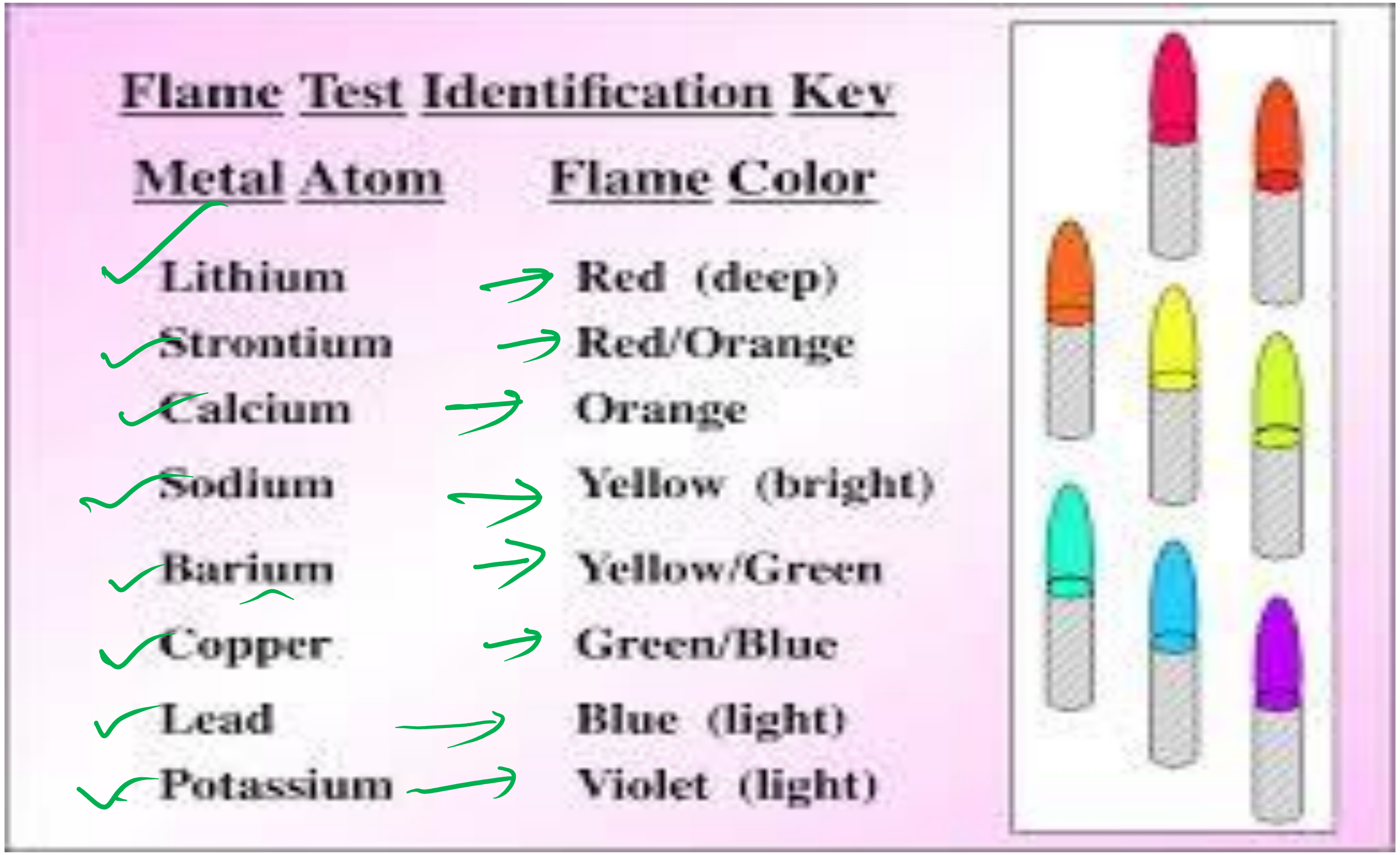
H^+

MRI



nerve → diagonosis

Metal ion detection with the help of flame test



Flame Test Identification Key

Metal Atom	Flame Color
✓ Lithium	Red (deep)
✓ Strontium	Red/Orange
✓ Calcium	Orange
✓ Sodium	Yellow (bright)
✓ Barium	Yellow/Green
✓ Copper	Green/Blue
✓ Lead	Blue (light)
✓ Potassium	Violet (light)

heat

Use of acid in metal ion detection with flame test

HCl → Cl^- ion is most volatile (sublimate) s ⇄ g

↳ its emission spectrum is in IR region.

HCl +Na → NaCl

HCl +Mg → $MgCl_2$

$$NaCl \xrightarrow{\Delta}$$

Na^+(spectrum) visible

Cl^-(spectrum) not visible

$$MgCl_2 \xrightarrow{\Delta} Mg^{2+} + 2Cl^-$$

NaCl → Na✓ Cl✗

$NaNO_3$ → Na✓ NO_3✓ mixture

Na_2CO_3 → Na✓ CO_3✓

Poll Question -4

- Which acid is used in flame test?

(a) HCl

(b) HNO3

(c) H2CO3

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স্বপ্ন জয় তোমারই হবে।