arjuna JEE 2024

- Subject Name- Physical Chemistry

- Chapter Name- Atomic Structure

Lecture No.- 07

By- Shivam Mishra Sir

Today's Targets

1. Energy of an e^-
2. Some Definitions
3. Spectrum of H-atom.
4.

Energy of electron in Bohr' Orbit

$$PE = -\frac{K q_1 q_2}{r}$$

$$\boxed{PE = -\frac{K Z e^2}{r}}$$

$$\frac{mv^2}{\cancel{r}} = \frac{K Z e^2}{r^{\cancel{2}}}$$

$$KE = \frac{1}{2} m v^2$$

$$KE = \frac{1}{2} \frac{K Z e^2}{r}$$

$$\boxed{KE = \frac{K Z e^2}{2r}}$$

$$(PE)_{\text{charged particle}} = -\frac{K q_1 q_2}{r}$$

$$\boxed{TE = KE + PE}$$

$$KE = \frac{KZe^2}{2r} \quad \text{— (a)}$$

$$PE = \frac{-KZe^2}{r} \quad \text{(b)}$$

(a+b)

$$TE = \frac{KZe^2}{2r} + \left(\frac{-2KZe^2}{2r}\right)$$

$$TE = \frac{KZe^2 - 2(KZe^2)}{2r} = \frac{-KZe^2}{2r}$$

$$\boxed{TE = \frac{PE}{2} = -KE}$$

→ Yes

→ No

JEE Advanced

$$TE = E_n = -13.6 \cdot \frac{Z^2}{n^2} \text{ eV/atom}$$

$$= -1312 \cdot \frac{Z^2}{n^2} \text{ KJ/mol}$$

$$= -313.6 \frac{Z^2}{n^2} \text{ Kcal/mol.}$$

Q1) Find the energy of 1^{st} & 2^{nd} Orbit of He^{+} ion?

He^{+} $(Z=2)$

(eV/atom)

(a) $E_1 = -13.6 \frac{Z^2}{n^2}$

$= -13.6 \times \frac{(2)^2}{(1)^2} = -13.6 \times 4 = -54.4 \text{ eV}$

(b) $E_2 = -13.6 \frac{Z^2}{n^2} = -13.6 \times \frac{(2)^2}{(2)^2} = -13.6 \text{ eV}$

(Q2) Find the energy of first 4 orbits of H atom? [eV/atom]

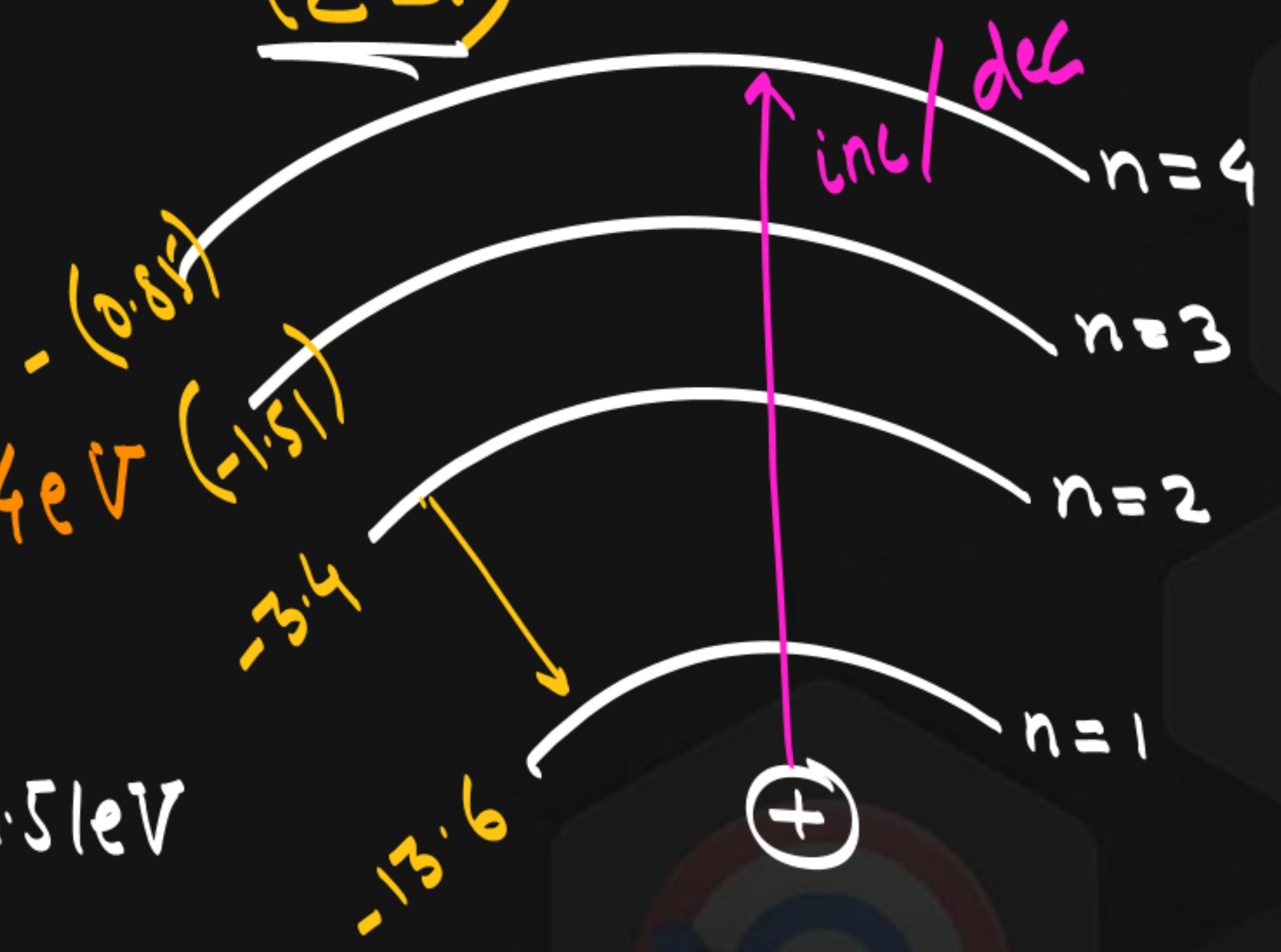
$(Z=1)$

$$E_1 = -13.6 \times \frac{Z^2}{n^2} = -13.6 \times \frac{1^2}{1^2} = -13.6\,eV$$

$$E_2 = -13.6 \times \frac{Z^2}{n^2} = -13.6 \times \frac{(1)^2}{(2)^2} = -\frac{13.6}{4} = -3.4\,eV$$

$$E_3 = -13.6 \times \frac{Z^2}{n^2} = -13.6 \times \frac{1^2}{3^2} = -\frac{13.6}{9} = -1.51\,eV$$

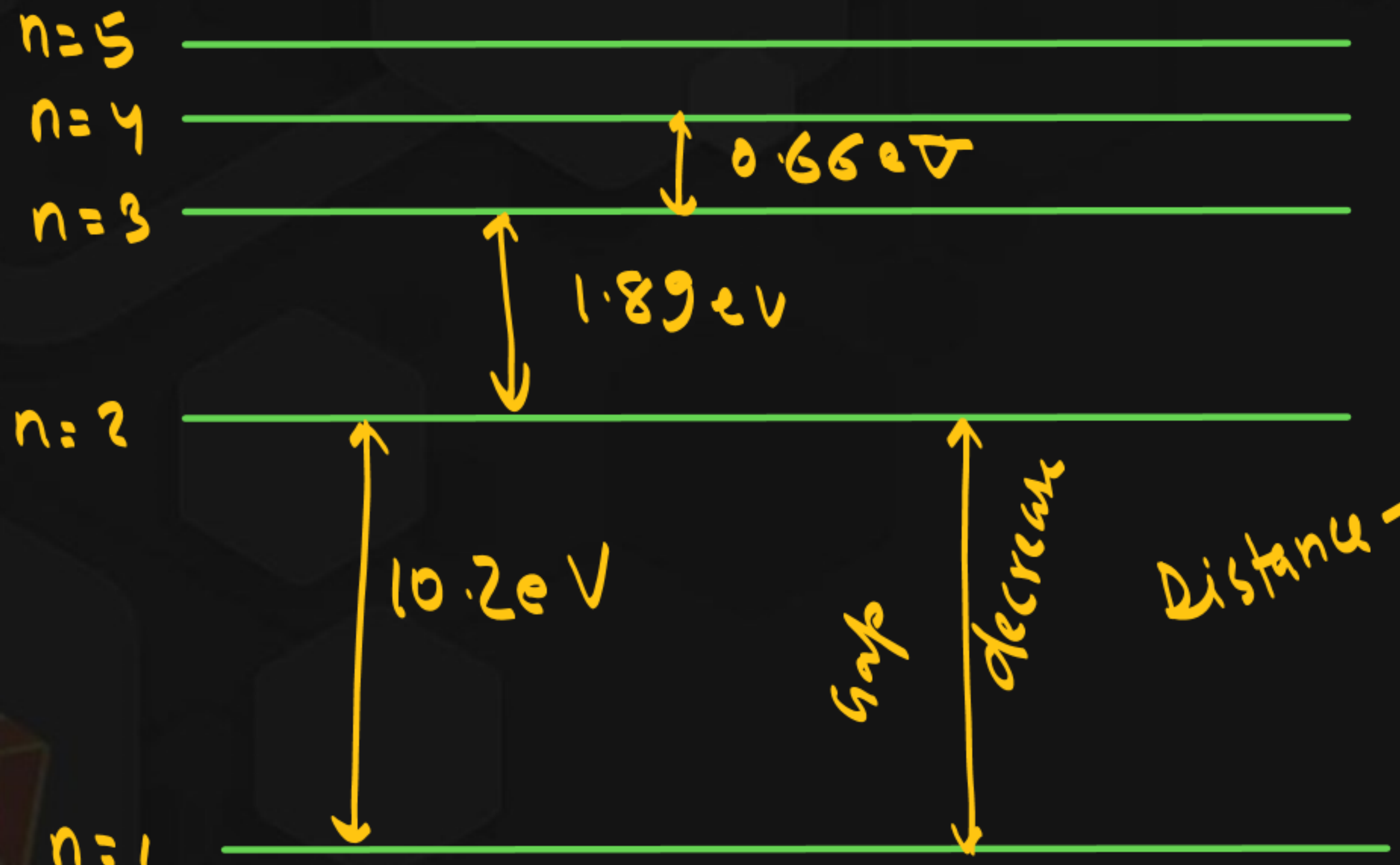
$$E_4 = -13.6 \times \frac{Z^2}{n^2} = -13.6 \times \frac{1^2}{4^2} = -0.85\,eV$$



$E_2 - E_1 = 10.2\,eV$

$E_3 - E_2 = 1.89\,eV$

$E_4 - E_3 = 0.66\,eV$



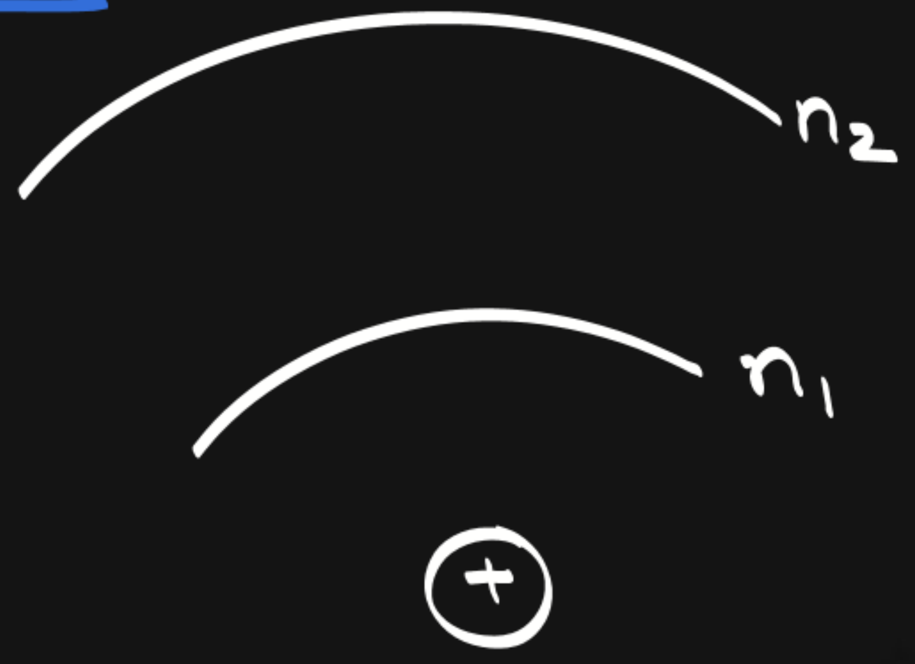
Distance → Energy

H. atom

CKL

→ Energy difference b/w 2 orbits

$$E_{n_1} = -13.6 \times \frac{Z^2}{n_1^2} \quad -\text{(I)}$$



$$E_{n_2} = -13.6 \times \frac{Z^2}{n_2^2} \quad -\text{(II)}$$

$$\Delta E_n = E_{n_2} - E_{n_1} = -\frac{13.6 \times Z^2}{n_2^2} - \left(-\frac{13.6 \times Z^2}{n_1^2}\right)$$

$\underline{\Delta E_n}$

$$= 13.6 \times Z^2 \left\{ -\frac{1}{n_2^2} + \frac{1}{n_1^2} \right\} = 13.6\, Z^2 \left\{ \frac{1}{n_1^2} - \frac{1}{n_2^2} \right\}$$

(A) Frequency and Time Period of revolution

Frequency :→ No. of revolution made by e^- per sec.

Aisa hota hai →

$$\boxed{\nu = \frac{v}{2\pi r}}$$

$$\nu = \frac{v_0 \times \frac{Z}{n}}{2\pi r_0 \times \frac{n^2}{Z}}$$

$$\boxed{\nu = \frac{v_0}{2\pi r_0} \times \frac{Z^2}{n^3}}$$

JM-2020

$$\boxed{\nu \propto \frac{Z^2}{n^3}}$$

$$v_n = \underbrace{2.188 \times 10^6}_{v_0} \times \frac{Z}{n} \text{ m/s}$$

$$\boxed{v_n = v_0 \times \frac{Z}{n} \text{ m/s}}$$

$$r_n = 0.529 \times \frac{n^2}{Z} \text{ Å}$$

$$\boxed{r_n = r_0 \times \frac{n^2}{Z} \text{ Å}}$$

Time period :→ Time required for 1 revolution.

Circular Motion

$$\boxed{T = \frac{1}{\nu}}$$

$$\boxed{T = \frac{2\pi r}{v}}$$

$$\boxed{T \propto \frac{n^3}{Z^2}}$$

Heluwa

(Q) Find the ratio Time period of an e^- for 2^{nd} orbit of He^+ to 4^{th} orbit of Li^{+2} ?

He^+ $[Z_1 = 2]$ $[n_1 = 2]$

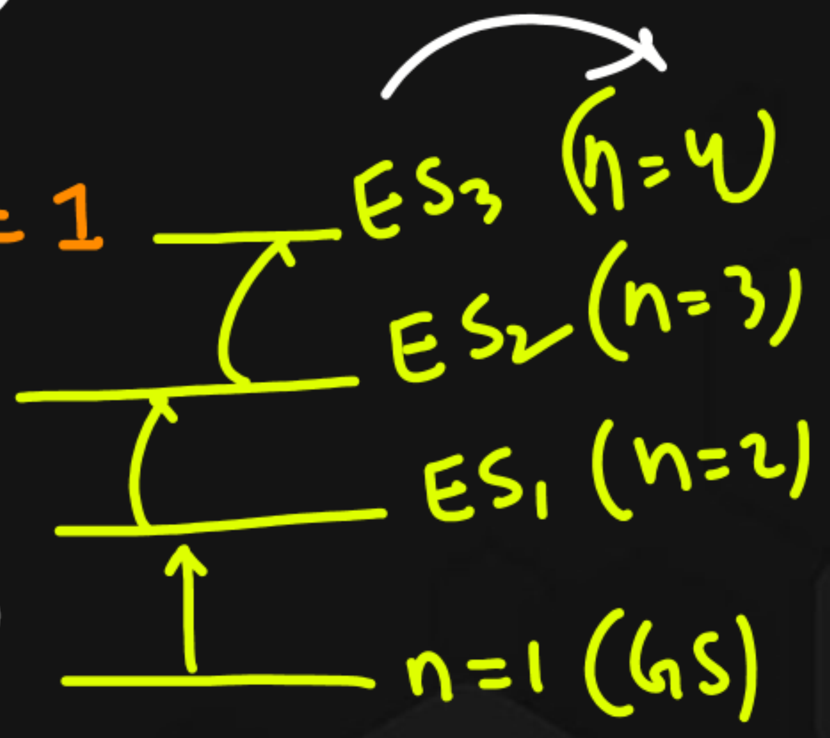
Li^{+2} $[Z_2 = 3]$ $[n_2 = 4]$

$$\frac{T_{He^+}}{T_{Li^{+2}}} = \frac{n_1^3 \times Z_2^2}{Z_1^2 \times n_2^3} = \frac{(2)^3 \times 3^2}{2^2 \times (4)^3} = \frac{2 \times 9}{64} = \frac{9}{32}$$

Few Imp Definitions (Single e^- species)

(a) Ground State → $n = 1$ (First orbit)

(b) Excited State → Orbit other than $n = 1$
ie $n = 2, 3, \ldots$



(Q) Which of the following value of n corresponds to 6^{th} excited state?

(A) 6 (B) 5 (C) 7 (d) 9

(c) Ionisation Energy (IE)

The energy required to move an e^- from (G S) $n=1$ to $n=\infty$.

$n_1 = 1$, $n_2 = \infty$

$$\Delta E = IE = 13.6 \times Z^2 \left\{ \frac{1}{n_1^2} - \frac{1}{n_2^2} \right\}$$

$$= 13.6 \times Z^2 \left\{ \frac{1}{1^2} - \frac{1}{\infty^2} \right\} \quad \left[\frac{1}{\infty} \to 0 \right]$$

$$\boxed{IE = 13.6 \times Z^2 \, eV}$$

(Q) Find I E of

(1) H- atom $= 13.6\,Z^2 = 13.6\text{ eV}$

$$\Delta E_n = 13.6\,Z^2\left\{\frac{1}{n_1^2} - \frac{1}{n_2^2}\right\}$$

(2) He^+ $(Z=2)$ $= 13.6 \times (2)^2 = 54.4\text{ eV}$

(3) Li^{+2} $(Z=3)$ $= 13.6 \times (3)^2 = 122.4\text{ eV}$

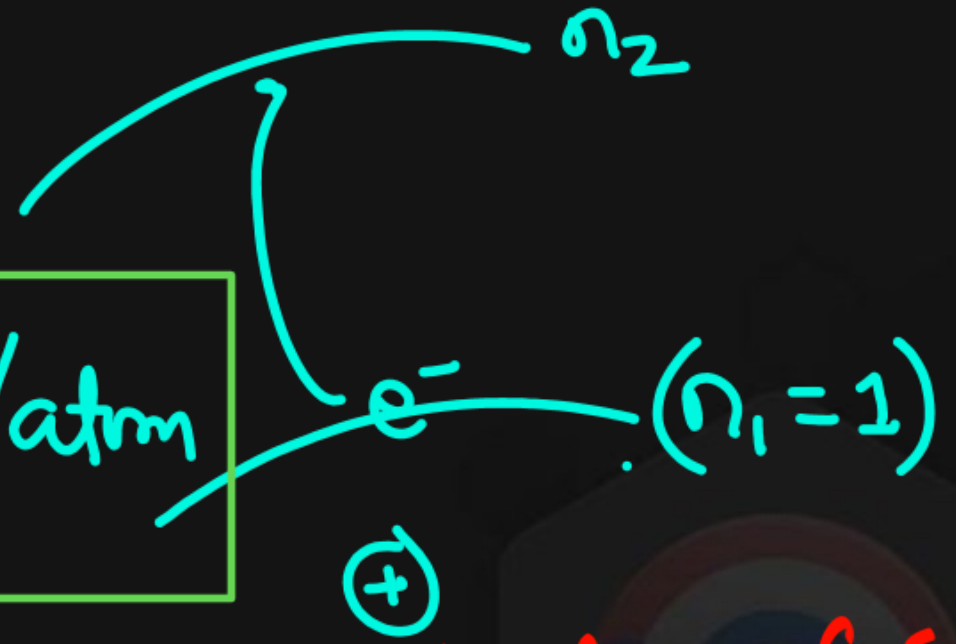
(1) Excitation Energy (EE)

$\left(\frac{1}{1}-\frac{1}{49}=\frac{49-1}{49}=\frac{48}{49}\right)$

Energy required to move an e^- from (GS) $n_1=1$ to any excited state (n_2).

$$\Delta E_n = EE = 13.6 \times Z^2 \left\{\frac{1}{n_1^2}-\frac{1}{n_2^2}\right\}$$

$$\boxed{EE = 13.6 \times Z^2 \left\{1-\frac{1}{n_2^2}\right\} eV/atm}$$



(Q) Find the excitation for He^+ ion if e^- transits from GS to 6th Excited State?

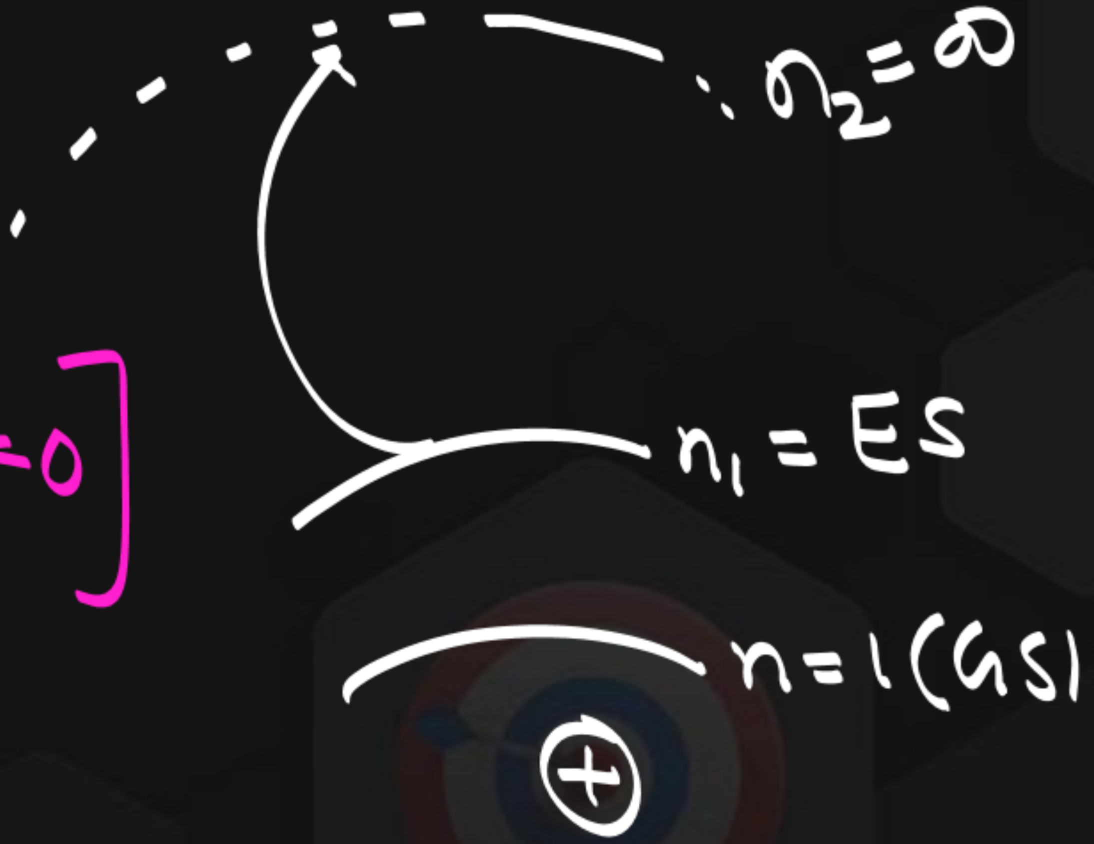
$Z=2$, $n_1=1$, $n_2=7$

$$\Delta E = +13.6 \times (2)^2 \left\{\frac{1}{1}-\frac{1}{49}\right\} = 13.6 \times 4 \times \left\{\frac{48}{49}\right\} \simeq 53.3\,eV$$

(E) Seperation Energy or Binding Energy [SE/BE]

The energy required to move an e^- from n_1 (any excited state) to $n_2 = \infty$.

$n_2 = \infty$



$$SE = \Delta E_n = 13.6 \times Z^2 \left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$$

$$SE = 13.6 \times Z^2 \left(\frac{1}{n_1^2} - 0\right) \quad \left[\frac{1}{\infty^2} = 0\right]$$

$$\boxed{SE = 13.6 \times \frac{Z^2}{n_1^2}}$$

(Q) Find SE for $\underline{3^{rd}\ ES}$ of He^+? $(Z=2)$

$\underline{n_1 = 4}$

$$SE = 13.6 \times \frac{2^2}{4^2} = 3.4\ eV/atom$$

If the total energy of an electron is -1.51 eV in hydrogen atom then find out K.E, P.E, orbit's radius and velocity of the electron in that orbit.

H·W

Calculate the ratio OF energies of He^+ for 1^{st} & 2^{nd} excited state.

H.W

The ionisation energy of a hydrogen atom is 13.6 ev. The energy of the ground level in doubly ionised lithium is

(a) -28.7 eV (b) -54.4 eV (c) -122.4 eV (d) -13.6 eV

H.W

2^{nd} separation energy of an electron in H atom

(a) 27.2 eV (b) 1.51 eV (c) 3.4 eV (d) 13.6 eV

H.W

Spectrum of H-atom

O
Y
B

Spectrum

- **Continuous spectrum**
  - One colour overlaps other
  - eg → Rainbow, white light from prism.
- **Non-Continuous/Discrete Spectrum**
  - **Absorption**
    (e^- higher orbit)
    (Light absorb)
    - Line Spectrum — Atom
    - Band Spectrum — Molecule
  - **Emission**
    Emit
    e^- comes back to lower orbit
    - Line Spectrum — Atom
    - Band Spectrum — Molecule

Our Syllabus → Line Spectrum (Emission)

Our Syllabus (JA)

Line emission Spectrum ✓

RYDBERG FORMULA

H·W

$$\bar{v} = \frac{1}{\lambda} = RZ^2\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$$

R = Rydberg constant = 109678 cm^{-1} = 109700 cm^{-1} 10970000 m^{-1} = $1.1 \times 10^7\ m^{-1}$

$$\frac{1}{R} = 9.12 \times 10^{-6}\ cm = 912\ \text{Å}$$

Where $\frac{2\pi^2 mk^2 e^2}{ch^3}$ is a constant which is equal to Rydberg constant (R).

$$\frac{1}{\lambda} = RZ^2\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$$

$\boxed{TE = -KE = \frac{PE}{2}}$ $E_n = -13.6 \times \frac{Z^2}{n^2}$ eV/atom

$\nu \propto \frac{Z^2}{n^3}$ | $T = \frac{1}{\nu} \propto \frac{n^3}{Z^2}$

- GS $(n = 1)$
- ES $(n = 2, 3, 4)$
- IE $(n_1 = 1 \text{ to } n = \infty)$ $IE = 13.6 \times Z^2$
- EE $(n_1 = 1 \text{ to } n_2)$ $EE = 13.6 \times Z^2 \left(1 - \frac{1}{n^2}\right)$
- SE $(n_1 = ES \text{ to } n_2 = \infty)$ $SE = 13.6 \times \frac{Z^2}{n_1^2}$

$\Delta E = 136 \times Z^2 \left\{\frac{1}{n_1^2} - \frac{1}{n_2^2}\right\}$

Spectrum → Emission ✓

Homework

DPP → 04

Module

Read Spectrum from NCERT/Module

Ex-4 → 9, 11, 29, 87 to 90


thank you