PadhoNa

COMPLETE CHAPTER NOTES

Structure of Atom

Theory + Hinglish + Diagrams + Active Recall + Solved Practice

16	135	8
Topics	Solved questions	Recall quizzes

For Class 12, JEE and NEET

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★ Rapid Revision
★ PadhoNa Mega Recall
✓ Detailed Solutions
✓ Recall Answer Key

Yeh Notes Kaise Use Karein

HINGLISH MEIN SAMJHO
Mushkil baat, aasan bhasha mein.

KEY CONCEPT
Must-know idea of the topic.

PRO TIP
Shortcuts and useful extras.

EXAM TRAP
Where students usually lose marks.

1. Padho
Ek topic dhyan se padho, diagram par ruko.

2. Band karo
Page band karke khud se bolo ya likho.

3. Recall karo
Active Recall box bina dekhe solve karo.

4. Practice karo
Practice Zone karo, phir solutions check karo.

01 Discovery of the Electron

Cathode ray tube ka kamaal

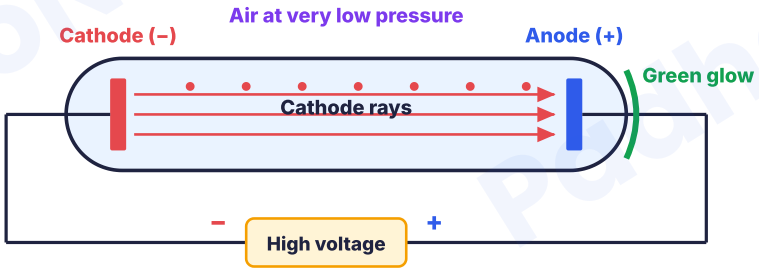
Early Indian and Greek thinkers (around 400 B.C.) held that matter, cut again and again, ends in atoms that can't be divided further. Experiments later showed that atoms are made of smaller particles.

- ✔ Matter is made of molecules, and molecules are made of atoms.
- ✔ Electrons, protons and neutrons are the fundamental particles of an atom.

Particle	Charge	Mass (kg)	Found by
Electron	-1.6×10^{-19} C	9.1×10^{-31}	Crookes, Thomson (1897)
Proton	$+1.6 \times 10^{-19}$ C	1.67×10^{-27}	Goldstein (1886), canal rays
Neutron	0	1.675×10^{-27}	Chadwick (1932)

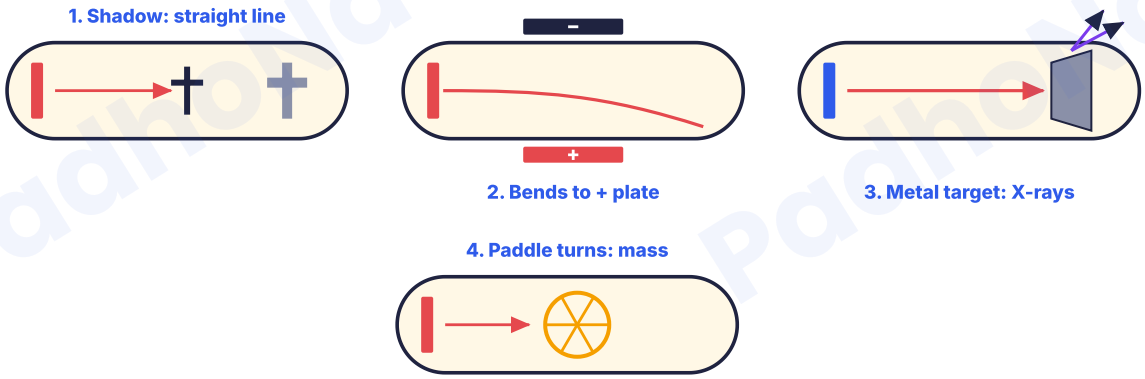
Cathode Ray Experiment

William Crookes (1879) and later J. J. Thomson (1897) passed a high voltage through a gas at very low pressure (about 10^{-4} mm Hg). A stream of negative particles travelled from the cathode and made the far glass glow green.



How the rays form. Metal cathode gives electrons: M → e^-_M. These break gas molecules: A–A + e^-_M → A + A + e^-_M. They also knock electrons out of gas atoms: A + e^-_M → A^+ + e^-_g + e^-_M. So cathode rays = e^-_M + e^-_g, and A^+ forms anode rays.

Properties of Cathode Rays



#	Observation	Conclusion
1	They cast a shadow	They travel in straight lines
2	They bend toward the + plate	They are negatively charged
3	On hitting heavy metal (W, Mo, Cu)	They produce X-rays
4	They turn a light paddle wheel	Their particles have mass
5	A magnet bends them	They are moving charges
6	They ionise gases	They carry enough energy
7	They pass through thin Al sheets	They are very small
8	They darken photographic plates	They can cause chemical change

Specific charge of electron: $e/m = 1.6 \times 10^{-19} / 9.1 \times 10^{-31} = 1.76 \times 10^{11}$ C/kg (in size)

EXAM TRAP

Specific charge of cathode rays does **not** depend on the gas, the electrode metal or the voltage. It is a universal constant, since these rays are always electrons.

HINGLISH MEIN SAMJHO

Cathode rays matlab electrons ki line. Gas badlo, metal badlo, electron wahi rehta hai, isliye e/m fix hai. Mass electron ka hydrogen atom ka sirf 1/1837 hai.

Practice Zone

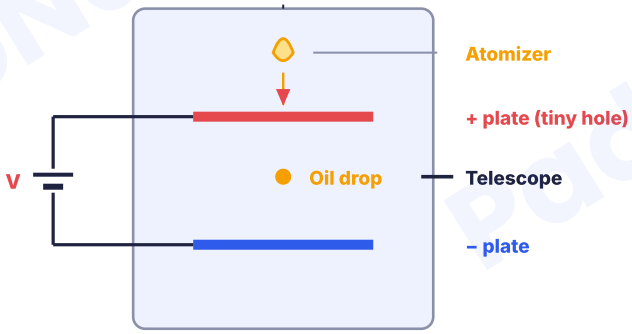
Electrons

1. e/m of cathode rays changes when we change: (A) the gas (B) the electrode metal (C) the voltage (D) none of these
2. (i) How many electrons together weigh 1 kg? (ii) Find the mass and charge of 2 moles of electrons.

02 Millikan, Proton, Neutron

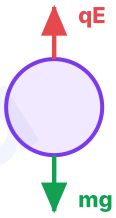
Charge ki keemat aur baaki kan

Millikan's Oil Drop Experiment



- An atomiser makes tiny oil drops. One falls through a tiny hole in the upper plate.
- X-rays or an electron beam ionise the air, and the drops pick up electrons.
- The voltage is set so that the drop hangs still.

- Charges found were always whole multiples of one value: q = ne, with e = 1.6×10^{-19} C.



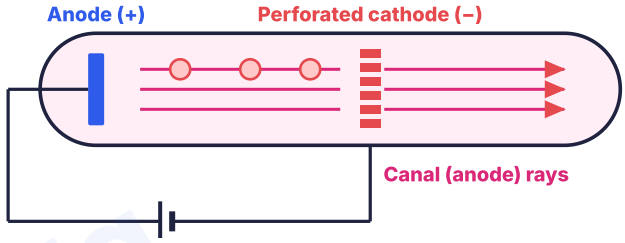
Balance: mg = qE

q = mg/E = ne

$$m_e = e/(e/m) = 1.602176 \times 10^{-19} / 1.758820 \times 10^{11} = 9.1094 \times 10^{-31} \text{ kg}$$

Positive Rays: Discovery of the Proton

E. Goldstein (1886) used a perforated cathode. Along with cathode rays, a new beam moved from the anode side toward the cathode and through its holes. These are **canal rays** or **anode rays**.



- They form in the gas between the electrodes, not from the anode surface.
- e/m is smaller than for electrons.
- e/m depends on the gas. It is largest for hydrogen, whose positive ion is the lightest. That ion is the **proton**.
- They ionise gases and can cause physical and chemical changes.

Discovery of the Neutron

Chadwick (1932) hit thin beryllium with α particles. Neutral particles slightly heavier than protons came out.

$$^{9}_{4}\text{Be} + ^{4}_{2}\text{He} \rightarrow ^{12}_{6}\text{C} + ^{1}_{0}\text{n}$$

HINGLISH MEIN SAMJHO

Anode rays anode se nahi nikalti, tube ki gas se banti hain. Isliye gas badli toh e/m badla. Sabse halka ion H^+, toh e/m sabse zyada.

Practice Zone

Particles

3. Oil drops carry 6, 15, 9, 21 and 12×10^{-18} units. What is the largest value of the unit charge that fits? (A) 6×10^{-18} (B) 3×10^{-18} (C) 9×10^{-18} (D) 1.5×10^{-17}
4. A drop of mass 3.2×10^{-15} kg hangs in a field of 10^5 V/m. Take g = 10 m/s². How many extra electrons does it carry?
5. Which statement is wrong? (A) Cathode rays leave the cathode surface. (B) Anode rays are heavier than cathode rays. (C) Anode rays come from the anode surface. (D) Cathode rays move straight.
6. e/m is largest for: (A) He^{2+} (B) D^+ (C) H^+ (D) He^+
7. The e/m of anode rays depends on: (A) anode metal (B) cathode metal (C) gas in the tube (D) applied voltage

8 Two particles have charges 2 : 3 and masses 5 : 6. Find the ratio of specific charges.

PadhoNa
Active Recall 1

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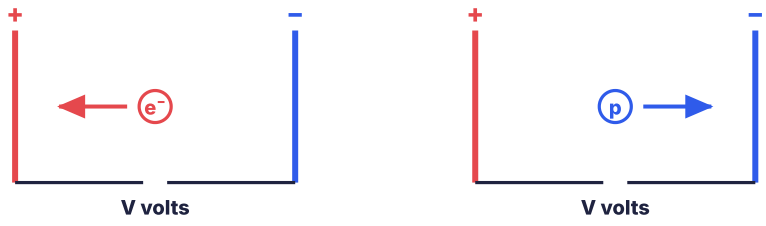
1. e/m of electron?
2. Charge unit from oil drop?
3. Who found the neutron?
4. Which ion is the proton?
5. Paddle wheel shows?
6. Anode rays form where?

Answers: Recall Answer Key (last section). Score likho: ___ / 6

03 Charge, Potential, Closest Approach

qV aur KE ka khel

- **Quantised:** Q = ne.
- **Two types:** positive and negative.
- **Force:** $F = kq_1q_2/r^2$, $k = 9 \times 10^9$ N m²/C². Unlike charges attract, like charges repel.
- **Potential energy:** $|PE| = kq_1q_2/r$. Repulsion gives + PE, attraction gives − PE.
- **Accelerated charge:** $qV = \frac{1}{2}mv^2$.



$v = \sqrt{(2qV/m)}$ | $1\ eV = 1.6 \times 10^{-19}$ J

One electron volt is the energy an electron gains when accelerated from rest through 1 V. A free positive charge moves from high to low potential; a free negative charge moves from low to high.

EXAM TRAP

Convert mass to kg. Remember: $m_e = 9.1 \times 10^{-31}$ kg, $m_p \approx 1.67 \times 10^{-27}$ kg $\approx 1836\ m_e$.

Closest Distance of Approach



All KE becomes PE at A

α: $\frac{1}{2}mv_o^2 = k(2e)(Ze)/R_o$, so $R_o = 4kZe^2/mv_o^2$ | Proton: $R_o = 2kZe^2/mv_o^2$

HINGLISH MEIN SAMJHO

Volt se energy, energy se speed. α ko nucleus ki taraf bhejo, sari KE PE ban jaati hai jahan woh rukta hai. Wahi closest distance.

Practice Zone

Charge and speed

9. True or false: a body can carry (i) 30 e (ii) 2.5 moles of electrons' charge (iii) 7.5 e.
10. A proton and an α particle cross the same voltage from rest. Find v_p/v_α. Also find the ratio of voltages needed for equal speed.
11. A particle of mass 2.5×10^{-20} g and charge 4e crosses 10 V from rest. Find v.
12. A charged particle of mass 1.6×10^{-23} g has KE 50 eV. Find v.
13. Find the speed of an electron accelerated from rest through 80 V.
14. An electron moves at 5.30×10^6 m/s. Find its stopping potential.
15. Find R_o for an α particle of speed v aimed at a gold nucleus (Z = 79), mass m_α.
16. An 8 MeV α particle is aimed head-on at a gold nucleus. Find R_o.

PadhoNa Test Series

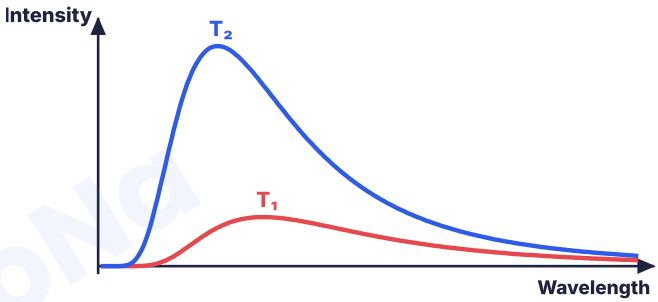
Yeh basics har numerical mein kaam aate hain.
PadhoNa Test Series mein unit conversion ki galtiyan pakdo.

04 Black Body and Photons

E = hν

Diffraction and interference fit the wave picture of light. Two things did not: **black body radiation** and the **photoelectric effect**.

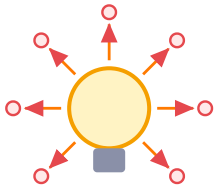
A **black body** is an ideal body that absorbs and emits all frequencies. Its emission curve depends only on temperature. Planck explained it: atoms emit or absorb energy in small packets (quanta), not continuously.



$T_2 > T_1$: the peak rises and moves to shorter λ

$E = h\nu = hc/\lambda$ | $c = \nu\lambda$ | Wavenumber $\bar{\nu} = 1/\lambda$ | $h = 6.626 \times 10^{-34}$ J s

λ (Å) = 12400 / E (eV) | λ (nm) = 1240 / E (eV)



n photons per second

$P = n \times hc/\lambda$

$n = P\lambda/hc$

$n \times hc/\lambda$ = total energy | Per mole: multiply by N_A

HINGLISH MEIN SAMJHO

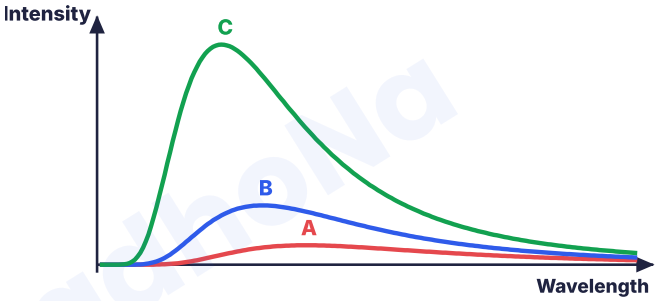
Roshni packets mein aati hai, jaise rupaye ke sikke: aadha sikka nahi hota. Kam wavelength matlab bada sikka. Exam mein 12400/E wala shortcut lagao.

Practice Zone

Black body

17 How many statements are wrong? (1) A black body absorbs all radiation. (2) Its spectrum depends only on temperature. (3) At a given T, the curve shows a maximum. (4) The peak shifts to lower frequency as T rises.

18 Curves are drawn for three temperatures. How many are correct? (1) $T_C > T_B > T_A$ (2) The peak moves to shorter λ as T rises (3) Continuous energy theory explains the curve (4) Quantised energy explains the curve



Practice Zone

Photons

19 Find λ of a 4 eV photon in Å, by two methods.

20 A 60 W lamp gives monochromatic light of 500 nm. Find photons per second.

21 Cl_2 bond energy is 243 kJ/mol. Find the wavenumber of a photon that just breaks a bond.

22 Find the energy of one mole of photons of 400 nm. ($h = 6.63 \times 10^{-34}$, $N_A = 6.02 \times 10^{23}$) (A) 199 (B) 249 (C) 299 (D) 349 kJ/mol

23 Find the energy of 50 photons of wavelength 2480 Å.

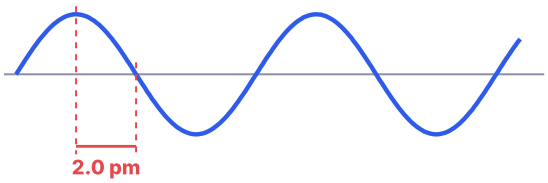
24 Lamps A and B give light of 6000 Å and 4000 Å, with equal photon rates. A is 40 W. Find the wattage of B.

25 How many photons per second does a 10 mW laser give at 496 nm?

26 One quantum splits one molecule of a gas, and light of 4960 Å is absorbed. Find the energy per mole.

27 A light sensor needs 3.0×10^{-14} J in total, at 660 nm. Find the least number of photons. ($h = 6.6 \times 10^{-34}$)

28 Find v of this electromagnetic wave.



29 Find the wavenumber of 6250 Å in cm^{-1}.

PadhoNa

Active Recall 2

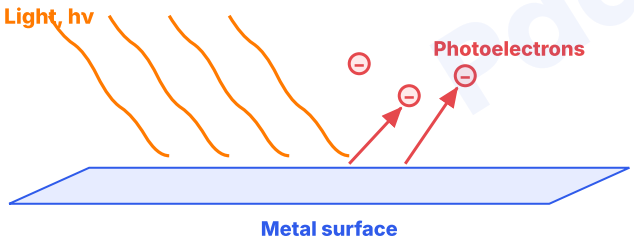
Page cover karo. 2 minute ka timer lagao. Pehle dimaag se likho, phir check karo.

1. E of a photon?
2. Shortcut for λ (Å)?
3. Black body curve depends on?
4. Peak moves how with T?
5. Per mole?

Answers: Recall Answer Key (last section). Score likho: ___ / 5

05 Photoelectric Effect

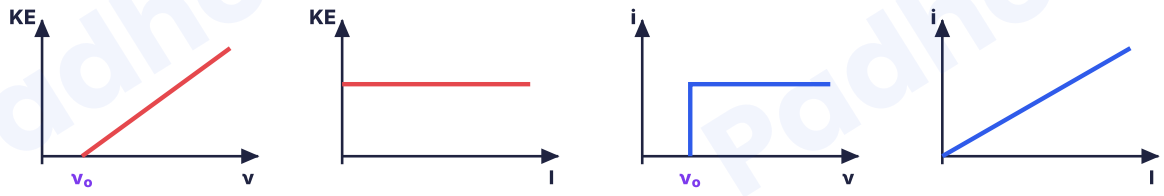
Roshni se electron



Light on metals such as K, Rb, Cs ejects electrons. **Work function** is the least energy needed to pull an electron off the surface.

- There is no time lag.
- Number of electrons ∝ intensity.
- Each metal has a threshold frequency ν_o. Below it, no emission, however bright the light.
- Above ν_o, KE rises linearly with frequency.

$h\nu = h\nu_o + KE_{max}$ | $W = h\nu_o = hc/\lambda_o$ | $KE_{max} = eV_o$ (V_o = stopping potential)



EXAM TRAP

KE rises **linearly** with frequency, but it is not directly proportional, since the line starts at ν_o. Brighter light gives more electrons, not faster ones.

HINGLISH MEIN SAMJHO

Photon ki sankhya badhi (intensity) toh electron ki sankhya badhi (current). Photon ki energy badhi (frequency) toh electron ki KE badhi.

Practice Zone

Photoelectric

30 $\nu_o = 5 \times 10^{14}\ s^{-1}$, $\nu = 1.2 \times 10^{15}\ s^{-1}$. Find KE.

31 $\nu_o = 1.5 \times 10^{15}\ s^{-1}$, $h = 6.6 \times 10^{-34}$. Find the least photon energy.

32 λ gives KE_{max} 2 eV, and $\lambda/2$ gives 6 eV on the same metal. Find W.

33 Momentum of the fastest electron is p at wavelength λ. Find λ' for 2p, with KE much greater than W.

34 Threshold λ_o, light of λ. Find the electron speed.

35 Work functions in eV: Li 2.4, Na 2.3, K 2.2, Mg 3.7, Cu 4.8, Ag 4.3. How many show the effect at 300 nm?

36 $W = 4.97 \times 10^{-19}$ J. Find λ_o. ($h = 6.63 \times 10^{-34}$)

37 $W = 3.6 \times 10^{-19}$ J, photons of 400 nm. Find KE and V_o.

38 Light doubles in intensity, at the same ν. What happens to current and KE_{max}?

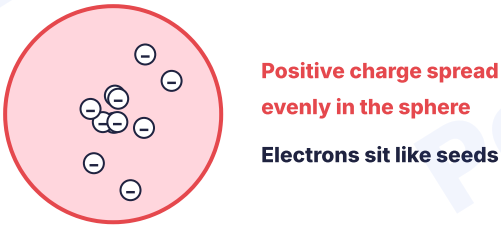
PadhoNa Test Series

Photoelectric ke graph bhi poochhe jaate hain.
PadhoNa Test Series mein graph aur numerical dono practice karo.

06 Thomson and Rutherford Models

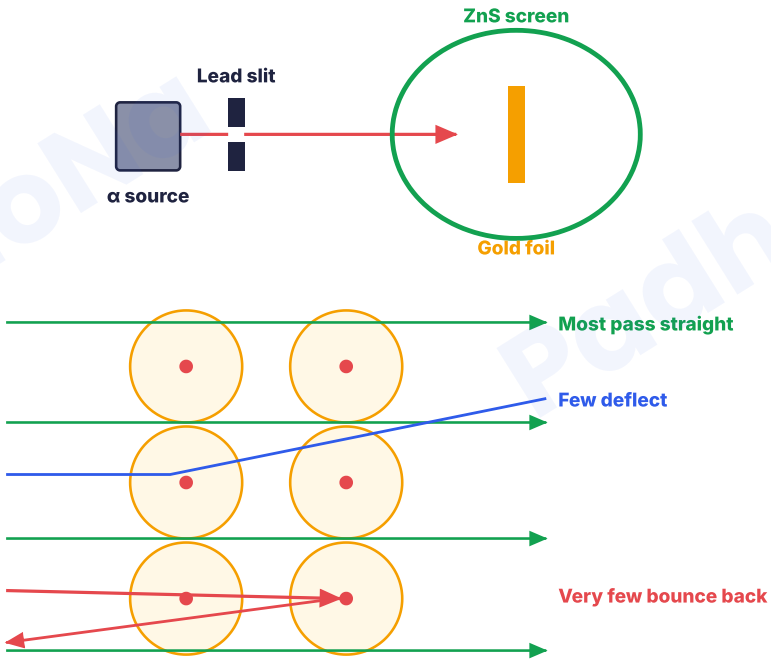
Tarbooz se nucleus tak

Thomson Model (1898)



Also called the plum pudding, raisin pudding or watermelon model. Mass is spread evenly over the atom. It explains neutrality, but not the scattering results below.

Rutherford's α Scattering



- Most α particles passed undeflected: an atom is mostly empty.
- A small fraction deflected: the positive charge is concentrated.
- Very few bounced back, nearly 180°: a tiny, heavy nucleus.

Drawbacks

- An accelerated charge radiates energy (Maxwell). The electron should spiral into the nucleus.
- It can't explain the line spectrum of hydrogen.

HINGLISH MEIN SAMJHO

Thomson: atom tarbooz jaisa. Rutherford: atom khaali maidan, beech mein chhota bhaari nucleus. Par electron ghoomte ghoomte gir kyun nahi jaata? Yahi Bohr ne solve kiya.

Practice Zone

Models

39 The beam in the scattering experiment was: (A) β particles (B) γ rays (C) helium atoms (D) helium nuclei

40 Rutherford's scattering experiment showed that: (A) mass and energy are related (B) electrons occupy space around a nucleus (C) neutrons lie deep in the nucleus (D) impact point can be fixed exactly

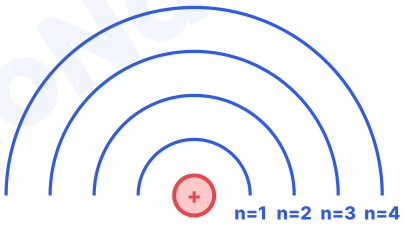
41 The scattering results relate most to the size of the: (A) nucleus (B) atom (C) electron (D) neutron

42 Rutherford's scattering experiment first showed that an atom has: (A) electrons (B) protons (C) a nucleus (D) neutrons

07 Bohr's Model

r, v, E, T, f, a

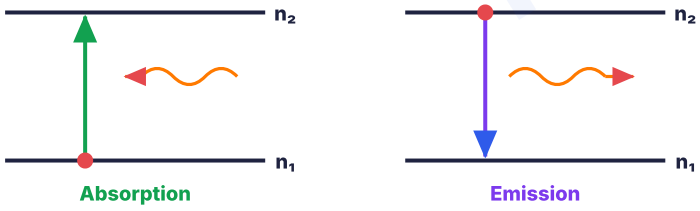
- Electrons move in fixed circular orbits without radiating: **stationary orbits**.
- Angular momentum is a whole multiple of h/2π.
- Going up absorbs a photon, going down emits one.



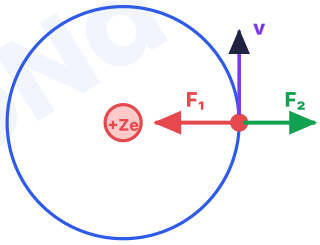
mvr = nh/2π

Up: absorbs a photon

Down: emits a photon



mvr = nh/2π | ΔE = $E_2 - E_1$ = hc/λ



$F_1 = kZe^2/r^2$ (pull)

$F_2 = mv^2/r$

Balance: $F_1 = F_2$

Radius. $kZe^2/r^2 = mv^2/r$, and $v = nh/2\pi mr$. Combine: $r = n^2h^2/(4\pi^2mkZe^2)$.
Speed. $v = nh/2\pi mr = 2\pi kZe^2/nh$.
Energy. $KE = \frac{1}{2}mv^2 = kZe^2/2r$. $PE = -kZe^2/r$. $TE = -kZe^2/2r = -2\pi^2k^2me^4Z^2/n^2h^2$.

Quantity	Value	Depends as
Radius	$0.529\ n^2/Z$ Å	n^2/Z
Speed	$2.18 \times 10^6\ Z/n$ m/s	Z/n
Total energy	$-13.6\ Z^2/n^2$ eV $= -2.18 \times 10^{-18}\ Z^2/n^2$ J	Z^2/n^2
Time period	$T = 2\pi r/v$	n^3/Z^2
Frequency	$f = v/2\pi r$	Z^2/n^3
Acceleration	$a = v^2/r$	Z^3/n^4

$KE = |TE|$ | $PE = 2TE$ | $1/\lambda = RZ^2(1/n_1^2 - 1/n_2^2)$, $R = 109677\ cm^{-1}$

EXAM TRAP

All of these hold only for one-electron species: H, He^+, Li^{2+}, Be^{3+}, Na^{10+}. With more electrons, repulsion enters and $F_1 = F_2$ fails.

HINGLISH MEIN SAMJHO

Teen numbers yaad karo: 0.529, 2.18×10^6, 13.6. Baaki sab n aur Z ki power. KE positive, PE double negative, TE beech mein.

PadhoNa

Active Recall 3

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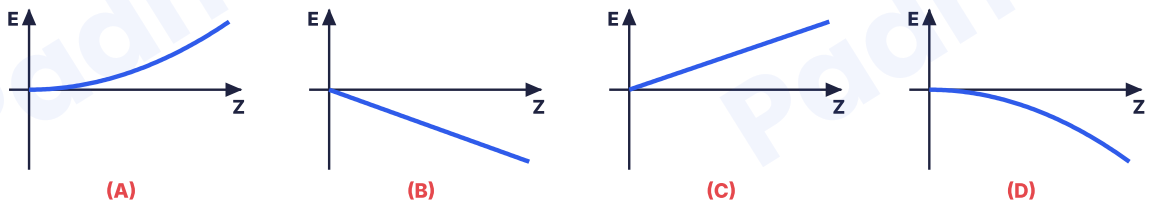
1. r_n?
2. v_n?
3. E_n?
4. PE vs TE?
5. T depends as?
6. a depends as?

Answers: Recall Answer Key (last section). Score likho: ___ / 6

Practice Zone

Bohr formulas

43 For fixed n, which sketch best shows total energy E vs Z in H-like species?



44 Find λ of the photon for 4 → 1 in H, by two methods.

45 Find $(PE)_3 - (PE)_1$ in H.

46 T in orbit 2 of He^+ is T. Find it for orbit 3 of Li^{2+}.

47 Frequency in orbit 3 of He^+ is σ. Find it for orbit 2 of H.

48 Acceleration in orbit 1 of He^+ is a. Find it for orbit 2 of Li^{2+}.

49 The ionisation energy of H is 2.18×10^{-18} J. Find λ for 3 → 2.

50 Radius of the second excited state of Li^{2+}, in a_o: (A) a_o (B) $3a_o$ (C) $9a_o$ (D) $a_o/3$

51 In H, $r_i - r_f = 5a_o$. Find the transition: (A) 3 → 2 (B) 4 → 1 (C) 4 → 2 (D) 3 → 1

52 Which state of Be^{3+} has the same radius as n = 2 of H?

53 v in orbit 1 of H is 2.18×10^6 m/s. Find it in orbit 4.

54 Find KE in the third orbit of H, in terms of h, m, a_o.

55 v in orbit 1 of H is V. Find it in orbit 4 of He^+: (A) V (B) V/2 (C) 2V (D) V/4

56 Match: (a) ground energy of Li^{2+} (b) PE in n = 2 of H (c) KE in first excited He^+ (d) ionisation energy of He^+, with (i) +13.6 eV (ii) −6.8 eV (iii) −122.4 eV (iv) 54.4 eV

57 True or false: S_1: PE of two opposite charges falls as they approach. S_2: Going from a higher to a lower orbit lowers KE. S_3: Going to a higher state raises PE. S_4: A 2 eV photon can free an electron from n = 3 of H.

58 Which relation is wrong for a fixed species? (A) $r \propto n^2$ (B) $KE \propto 1/n^2$ (C) $T \propto n^2$ (D) force $\propto 1/n^4$

59 Find λ for 6 → 2 in H.

60 Light of 286 nm just ionises potassium atoms. Find the ionisation energy in kJ/mol.

61 Number of lines when electrons fall from the fourth excited state to the first excited state.

62 Taking the Rydberg energy as 2.18×10^{-18} J, find v in orbit 2 of H, as $x \times 10^5$ m/s (nearest integer).

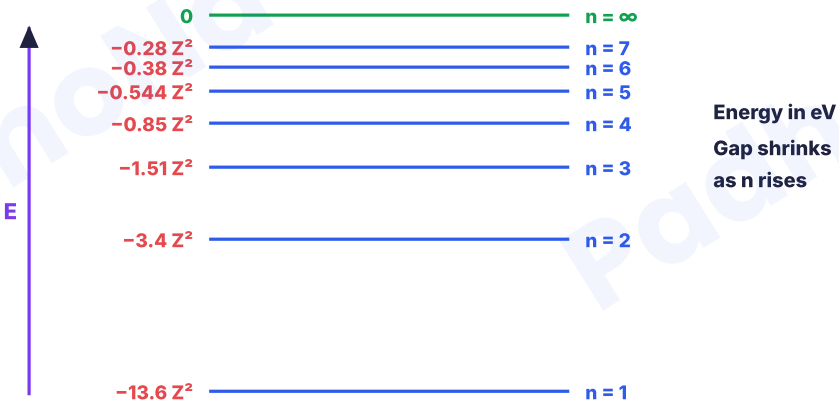
63 E in the second excited state of H is −1.51 eV. Find KE as $x \times 10^{-2}$ eV.

PadhoNa Test Series

Bohr ke formule ratna nahi, ladder se samajhna hai.
PadhoNa Test Series mein ratio wale sawaal practice karo.

08 Energy Levels and Equi-Energy Transitions

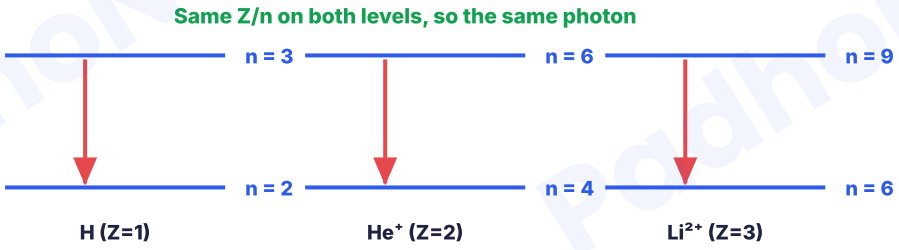
Ladder se sab aasan



Equi-Energy Transitions

In one sample, different low-lying transitions give different energies. In **different** H-like species, they can, when Z/n matches on both levels.

$$Z_1/n_1 = Z_2/n_3 \text{ and } Z_1/n_2 = Z_2/n_4 \mid n_3 = (Z_2/Z_1)n_1,\ n_4 = (Z_2/Z_1)n_2$$



H	He^+	Li^{2+}	Be^{3+}
2 → 1	4 → 2	6 → 3	8 → 4
3 → 2	6 → 4	9 → 6	12 → 8
3 → 1	6 → 2	9 → 3	12 → 4

KEY CONCEPT

The hydrogen emission spectrum is a subset of any H-like spectrum. But He^+ 5 → 2 has no H partner, as it would need n = 2.5.

Terms for One-Electron Systems

Term	Meaning	Value
Ground state	Lowest state, n = 1	$-13.6Z^2$ eV
Excited states	n = 2 first, n = 3 second; nth excited is n + 1	
Ionisation energy	Ground state to n = ∞	$13.6Z^2$ eV
Ionisation potential	Voltage giving an electron that KE	$13.6Z^2$ V
Excitation energy	Ground state to a given state	First: $10.2Z^2$ eV; second: $12.09Z^2$ eV
Excitation potential	Voltage giving that KE	First: $10.2Z^2$ V; second: $12.09Z^2$ V
Binding energy	Any state to n = ∞	$13.6Z^2/n^2$ eV

EXAM TRAP

The 14th excited state is n = 15, not 14. n = 1 is not an excited state. Energy is in eV; potential is in volts.

HINGLISH MEIN SAMJHO

He^+ ka jump H ke jump jaisa dekho: n ko Z se divide karo. He^+ 6 → 2 matlab H 3 → 1. Phir ladder se seedha energy mil jaati hai.

PadhoNa

Active Recall 4

Page cover karo. 2 minute ka timer lagao. Pehle dimaag se likho, phir check karo.

1. H 2 → 1 equals He^+?
2. Third excited state n?
3. IE of Li^{2+}?
4. Second excitation energy of H?
5. BE of n = 3 in H?

Answers: Recall Answer Key (last section). Score likho: ___ / 5

Practice Zone

Using the ladder

64 Find λ for 15 → 6 in Li^{2+}.

65 Find λ for 6 → 2 in He^+: (A) 1026 Å (B) 1216 Å (C) 3648 Å (D) 6563 Å

66 Find PE in orbit 10 of He^+.

67 Find the photon energy for the fall from level 9 to the second excited state in Li^{2+}.

68 A 70 eV photon hits ground-state He^+. Find the stopping potential of the electron.

69 A one-electron system has ionisation potential 217.6 V. Find PE in its 7th excited level.

70 First excitation energy of an H-like ion is 91.8 eV. Find the energy needed to remove its electron.

71 Which are allowed energies in H? (A) −0.85 eV (B) −1.2 eV (C) −1.51 eV (D) −2.0 eV

72 In a one-electron system with IE 217.6 eV, an electron falls from binding energy 3.4 eV to 13.6 eV. Find the change in orbit angular momentum.

73 Which H transition has the same λ as 6 → 2 in He^+? (A) 2 → 1 (B) 3 → 1 (C) 3 → 2 (D) 4 → 2

74 Which Li^{2+} jump matches He^+ 2 → 6? (A) 6 → 2 (B) 3 → 9 (C) 2 → 6 (D) 9 → 3

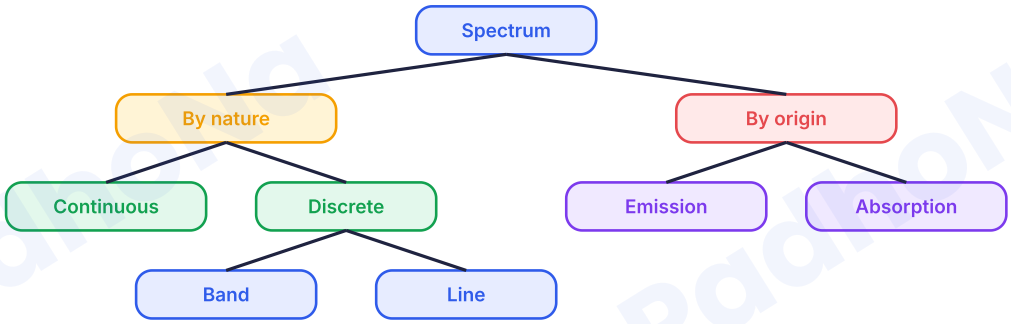
75 For He^+, a transition goes from r = 238 pm to r = 26.45 pm (a_0 = 52.9 pm). Find λ in nm.

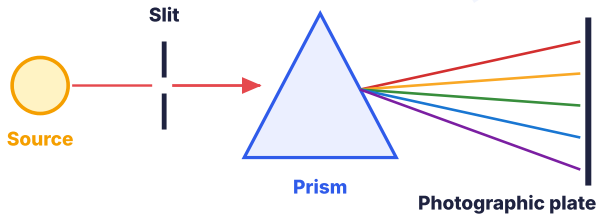
76 An electron in an H-like atom can occupy orbits of radius R and 9R. Find $T_1 : T_2$.

77 Orbit angular momentum is 2h/2π and radius r. Find KE.

09 Spectrum

Emission, absorption, line, band







- **Emission:** light from a hot body or gas discharge passes through a prism onto a plate.
- **Continuous:** white light spreads into VIBGYOR, each colour merging into the next.
- **Band:** coloured bands split by dark space. Usually from molecules.
- **Line:** sharp lines at fixed wavelengths, split by dark space. From atoms, such as hydrogen.
- **Absorption:** white light through a vapour or solution shows dark lines. It looks like a photographic negative of the emission spectrum.

HINGLISH MEIN SAMJHO

Atom se line, molecule se band, garam thos cheez se continuous. Absorption mein rangeen background par kaali lines, emission ka ulta.

Practice Zone

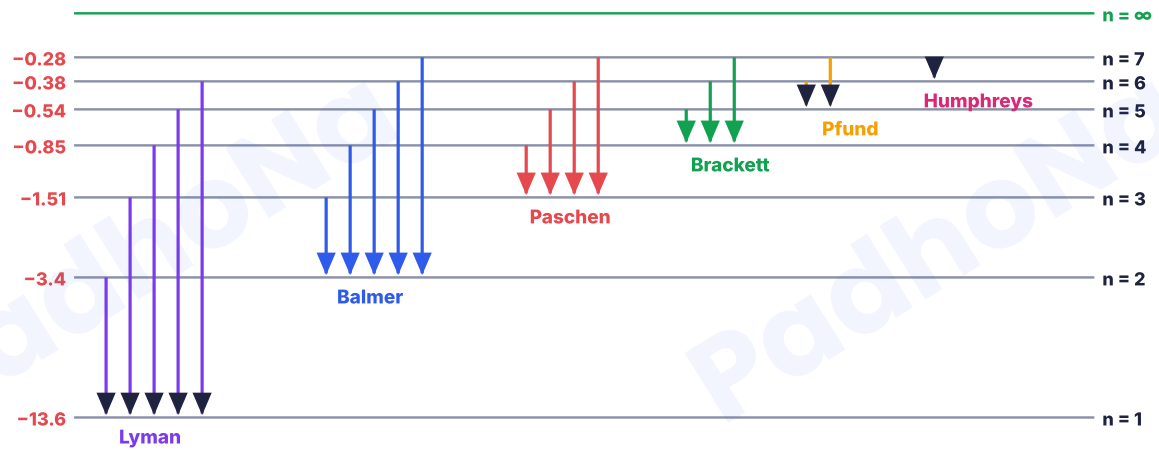
Types of spectra

78 How many statements are wrong? (1) Line spectra help study electronic structure. (2) Atoms in gas phase give a continuous spread from red to violet. (3) Absorption spectrum is like a negative of emission. (4) Helium was found in the Sun by spectroscopy.

79 Molecules generally give: (A) line (B) band (C) continuous (D) no spectrum

10 Hydrogen Spectrum

Lyman se Humphreys



Series	n_1	n_2	E_{max} ($\infty \to n_1$), eV	E_{min} ($n_1 + 1 \to n_1$), eV	Region
Lyman	1	2 to ∞	13.6	10.2	UV
Balmer	2	3 to ∞	3.4	1.89	Mostly visible
Paschen	3	4 to ∞	1.51	0.66	IR
Brackett	4	5 to ∞	0.85	0.31	IR
Pfund	5	6 to ∞	0.544	0.17	IR
Humphreys	6	7 to ∞	0.38	0.10	IR

Limits. Lyman: $\lambda_{max} = 4/(3R) = 12400/10.2$ Å; $\lambda_{min} = 1/R = 12400/13.6$ Å. Balmer: $\lambda_{max} = 36/(5R) = 12400/1.89$ Å; $\lambda_{min} = 4/R = 12400/3.4$ Å.

"Shortest line" means shortest **wavelength**: $\infty \to n_1$. "Longest line" is $n_1 + 1 \to n_1$, also called the first line. Second line: $n_1 + 2 \to n_1$.

Lyman: 10.2 to 13.6 eV

Gap: 3.4 to 10.2 eV: no line

Balmer: 1.89 to 3.4 eV

Gap: 1.51 to 1.89 eV: no line

Paschen: 0.66 to 1.51 eV

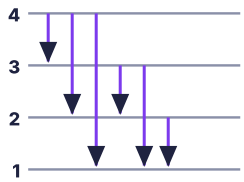
HINGLISH MEIN SAMJHO

Photon ki energy dekho aur zone pehchano. 3.4 aur 10.2 ke beech koi line nahi, 1.51 aur 1.89 ke beech bhi nahi. Agar energy gap mein hai toh transition possible hi nahi.

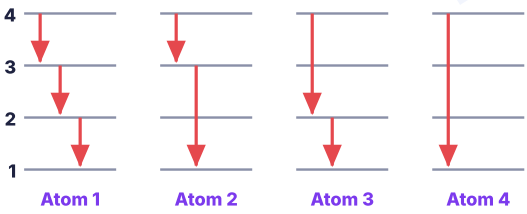
Number of Photons

Unique photons of different energies = number of spectral lines.

Case	Max lines
One atom, n → 1	n − 1
Enough atoms, n → 1	n(n − 1)/2
Enough atoms, $n_2 \rightarrow n_1$	Δn(Δn + 1)/2



n = 4 gives 6 lines



Four atoms are the fewest that show all 6 lines

Start level n	2	3	4	5	6
Atoms "enough" for all lines	1	2	4	6	9

PadhoNa
Active Recall 5

Page cover karo. 2 minute ka timer lagao. Pehle dimaag se likho, phir check karo.

1. Lyman region?
2. Balmer shortest λ?
3. Lyman first line?
4. Gap above Balmer?
5. Lines, n → 1?
6. One atom, n → 1?

Answers: Recall Answer Key (last section). Score likho: ___ / 6

Practice Zone

Series and counting

80 A photon of 2.856 eV is seen in H. Find the transition.

81 Which transition gives a photon of 8.0 eV in H? (A) 3 → 1 (B) 7 → 2 (C) 8 → 4 (D) not possible

82 Shortest Lyman λ of H is λ. Find the longest Lyman λ of He^{+}.

83 First Balmer line of H is 656 nm. Find the second.

84 How many visible lines appear when electrons fall from orbit 6 to the ground state in H? (A) 15 (B) 5 (C) 4 (D) 3

85 H, He^{+} and Li^{2+} samples each absorb 12.09 eV photons. H starts at n = 1, He^{+} at n = 2, Li^{2+} at n = 3. All then fall to n = 1. Count the different photon energies emitted.

86 Fewest H atoms at n = 5 that can show all lines on falling to n = 1?

87 Max lines from one atom, n = 6 to ground?

PadhoNa Test Series

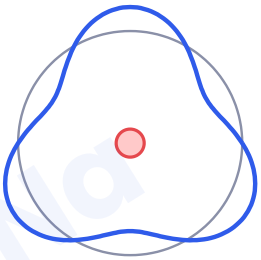
Spectrum ke counting sawaal scoring hain.
PadhoNa Test Series mein inhe timed karo.

11 de Broglie Hypothesis

Electron bhi lehar hai

Light behaves as wave and particle. In 1924 de Broglie proposed that moving electrons, protons and atoms also have wave nature.

From $E = hc/\lambda$ and $E = mc^2$: $\lambda = h/mc$. For any moving particle: $\lambda = h/mv = h/p$.



n = 3 fits 3 full waves

$2\pi r = n\lambda$

So $mvr = nh/2\pi$

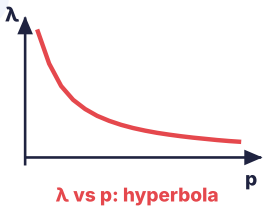
$$\lambda = h/mv = h/\sqrt{(2m\,KE)} = h/\sqrt{(2mqV)} = 2\pi r/n$$

From $\lambda = h/mv$ and $\lambda = 2\pi r/n$ we get $mvr = nh/2\pi$: the Bohr rule.

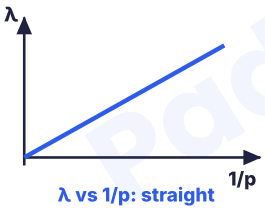
Accelerated through V volts: Electron $\lambda = \sqrt{(150/V)} = 12.3/\sqrt{V}$ Å | Proton $0.286/\sqrt{V}$ Å | α $0.101/\sqrt{V}$ Å

Bohr orbit: $\lambda \approx (10/3)(n/Z)$ Å

n	H	He^+	Li^{2+}	Be^{3+}
1	10/3	5/3	10/9	10/12
2	20/3	10/3	20/9	20/12
3	30/3	15/3	10/3	30/12
4	40/3	20/3	40/9	10/3



λ vs p: hyperbola



λ vs 1/p: straight

HINGLISH MEIN SAMJHO

λ orbit mein n/Z ke hisaab se chalta hai. H ke pehle orbit mein 10/3 Å yaad rakho, baaki ek line mein. Voltage wale sawaal mein √(150/V).

Practice Zone

de Broglie

88 Find λ of an electron in orbit 9 of Li^{2+}.

89 Find λ of an electron in n = 4 of H, by four methods.

90 Find $[(\lambda_{He^+})_8 - (\lambda_H)_2]/(\lambda_{Li^{2+}})_3$.

91 Find $[(\lambda_{He^+})_4 - (\lambda_{Li^{2+}})_4]/(\lambda_H)_1$.

92 Find λ_α/λ_d for an α particle and a deuteron through the same V.

93 H atoms sit at n = 3. A 6 eV photon ejects an electron. Find its λ.

94 Radius of first orbit of H is a_o. Find λ in orbit 5.

95 An electron with KE 5 eV is accelerated through 4 V. Find λ.

96 An electron at rest is accelerated through 144 V (λ_1), then is slowed by 44 V (λ_2), then by 19 V (λ_3). Find $(\lambda_3 - \lambda_2)/\lambda_1$.

97 Find the λ ratio for electrons at rest crossing 25 V and 400 V.

98 An electron with KE 4 eV is accelerated through 21 V. Find λ.

99 A photon equal to the binding energy of n = 2 in He^+ hits a metal with W = 2.6 eV. The electron is then accelerated through 4 V. Find the least λ.

100 λ in orbit 3 of He^+ equals λ in: (A) n = 4 of H (B) n = 6 of Be^{3+} (C) n = 3 of Li^{2+} (D) n = 2 of H

101 Find λ of electrons accelerated through 50 kV, in pm. ($h = 6.63 \times 10^{-34}$; ignore relativity)

102 Find λ in orbit 3 of He^+, in terms of a_o.

103 A straight line through the origin is got by plotting λ against: (A) p (B) 1/p (C) p^2 (D) $\sqrt{p}$

104 Find λ in orbit 3 of H in terms of a_o.

12 Heisenberg's Uncertainty Principle

x aur p ek saath nahi

The exact position and momentum of a tiny moving particle can't both be known at one time.

$$\Delta x \cdot \Delta p \geq h/4\pi \mid \Delta x \cdot m\Delta v \geq h/4\pi \mid \Delta E \cdot \Delta t \geq h/4\pi$$

- If $\Delta x \to 0$, then $\Delta p \to \infty$, and the reverse.
- Light of wavelength λ locates a particle to about $\pm\lambda$. A shorter λ means a high-energy photon, which disturbs momentum.



HINGLISH MEIN SAMJHO

Electron ko dekhne ke liye chhoti wavelength ki roshni chahiye, par woh photon itna bhaari hit karta hai ki electron ka momentum hi badal jaata hai.

PadhoNa
Active Recall 6

Page cover karo. 2 minute ka timer lagao. Pehle dimaag se likho, phir check karo.

1. Uncertainty relation?
2. λ of electron with V?
3. 2πr = ?
4. λ vs p shape?
5. Who proposed matter waves?

Answers: Recall Answer Key (last section). Score likho: ___ / 5

Practice Zone

Uncertainty

105 Statement I: position and momentum can't both be fixed exactly. Statement II: if $\Delta x = \Delta p$ for an electron, then $\Delta v \geq (1/2m)\sqrt{(h/\pi)}$.

106 A 150 g ball moves at 40 m/s, known within 1%. Find Δx.

107 $\Delta x = 4\Delta p$. Find Δv.

108 Find Δv of an electron held within 2×10^{-14} m. ($\pi = 3.14$) Why does this matter?

109 Electron and proton have equal λ. Find v_e/v_p, with $m_p = 1.67 \times 10^{-27}$ kg.

13 Quantum Mechanical Model

Wave function aur nodes

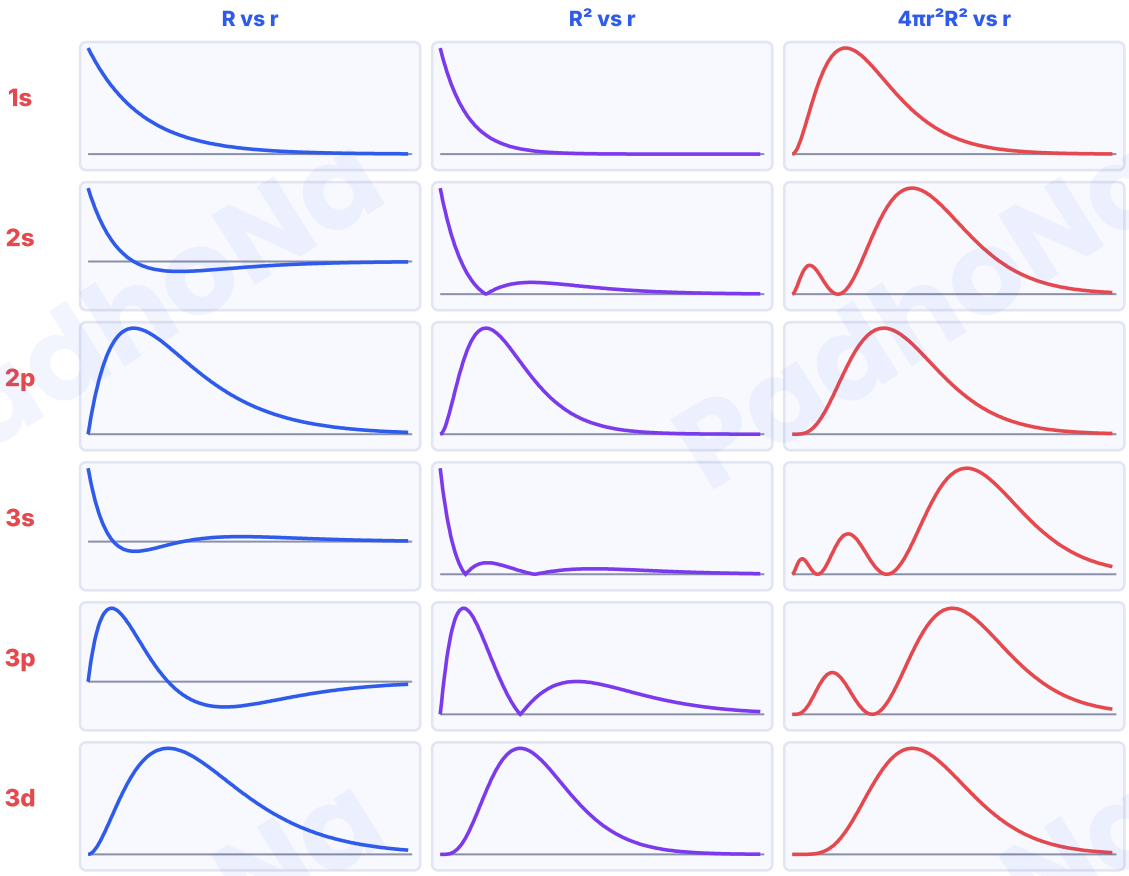
Quantum mechanics describes the motion of tiny objects with wave and particle nature. Applied to large objects, it gives the same results as classical mechanics.

$$\hat{H}\psi = E\psi \;\big|\; \partial^2\psi/\partial x^2 + \partial^2\psi/\partial y^2 + \partial^2\psi/\partial z^2 + 8\pi^2 m(E - V)\psi/h^2 = 0$$

For the H atom, $V = -ke^2/r$, so $E - V = E + ke^2/r$. ψ has no direct physical meaning, but ψ^2 is a probability density. So ψ must be finite, single-valued, continuous with a continuous slope, and square integrable.

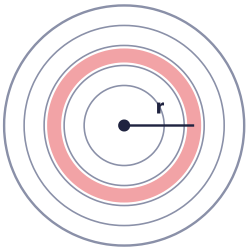
Radial Wave Functions

Orbital	R (with $\sigma = Zr/a_o$)	Radial nodes
1s	$2(Z/a_o)^{3/2}\, e^{-\sigma}$	0
2s	$(Z/a_o)^{3/2}\, (1/2\sqrt{2})(2 - \sigma)\, e^{-\sigma/2}$	1, at $r = 2a_o/Z$
2p	$(Z/a_o)^{3/2}\, (1/2\sqrt{6})\, \sigma\, e^{-\sigma/2}$	0
3s	$(Z/a_o)^{3/2}\, (2/81\sqrt{3})(27 - 18\sigma + 2\sigma^2)\, e^{-\sigma/3}$	2, at $\sigma \approx 1.9, 7.1$
3p	$(Z/a_o)^{3/2}\, (4/81\sqrt{6})(6\sigma - \sigma^2)\, e^{-\sigma/3}$	1, at $r = 6a_o/Z$
3d	$(Z/a_o)^{3/2}\, (4/81\sqrt{30})\, \sigma^2\, e^{-\sigma/3}$	0



Sketches, $a_o = 1$. Some R^2 curves are stretched so that small peaks show.

Radial Probability



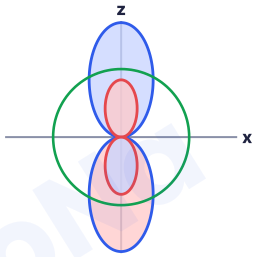
Shell of radius r, thickness dr

$dV = 4\pi r^2 \, dr$

Probability = $R^2 \times 4\pi r^2 \, dr$

- Only s orbitals have a finite R at the nucleus. All others have R = 0 there.
- $[R]^2$ is never negative. It gives probability density at a point.
- $4\pi r^2R^2$ dr gives the probability in a thin shell of thickness dr, whatever the direction. So it is zero at r = 0 for every orbital.
- In $[R]^2$ plots, the first peak is the highest. In $4\pi r^2R^2$ plots, the last peak is the highest.
- In $4\pi r^2R^2$ plots: 1s, 2p, 3d, 4f have one peak. 2s, 3p, 4d, 5f: two. 3s, 4p, 5d, 6f: three.
- For 1s in H, the most probable distance is a_o.

Radial nodes = n − l − 1 | Angular nodes = l | Total nodes = n − 1



Green circle: radial node (n − l − 1 = 1)

xy plane: angular node (l = 1)

Total nodes = n − 1 = 2

EXAM TRAP

Plots of 2p, 3d and 4f look alike in having no radial node, but they are not identical curves: the peak moves out in $4\pi r^2R^2$.

HINGLISH MEIN SAMJHO

Node ka matlab wahan electron milne ka chance zero. Curve jitni baar zero ko touch kare (r = 0 aur r = ∞ chhodkar), utne radial nodes. n − l − 1 yaad rakho.

Practice Zone

Radial functions

110 Maximum radial probability of 1s in H is at: (A) a_0 (B) $2a_0$ (C) $a_0/2$ (D) $a_0/4$

111 Which are wrong? (A) Density in the xy plane is zero for $3dx^2-y^2$. (B) Density in the xy plane is zero for $3dz^2$. (C) 2s has one spherical node. (D) For 2pz, xy is a nodal plane.

112 For Li^{2+}, $\psi_{2s} \propto (2 - Zr/a_0)\, e^{-Zr/2a_0}$. Find the radial node.

113 Find the number of radial nodes in 4d, 5p, 3s.

114 Number of correct statements: (1) 1s density is largest at the nucleus. (2) 2s density rises to a peak from the nucleus and then falls sharply to zero. (3) A boundary surface encloses 100% probability. (4) p and d have 1 and 2 angular nodes. (5) p density at the nucleus is zero.

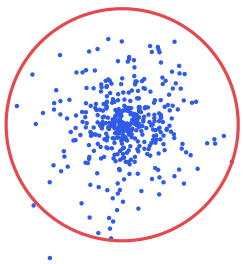
PadhoNa Test Series

Graphs aur nodes JEE Advanced tak kaam aate hain.
PadhoNa Test Series mein concept check karo.

14 Orbitals and Their Shapes

Bohr ke orbit se alag

An **orbital** is a one-electron wave function. Its boundary surface encloses the region where the electron is found with 90 to 95% probability. Orbitals do **not** define a path.

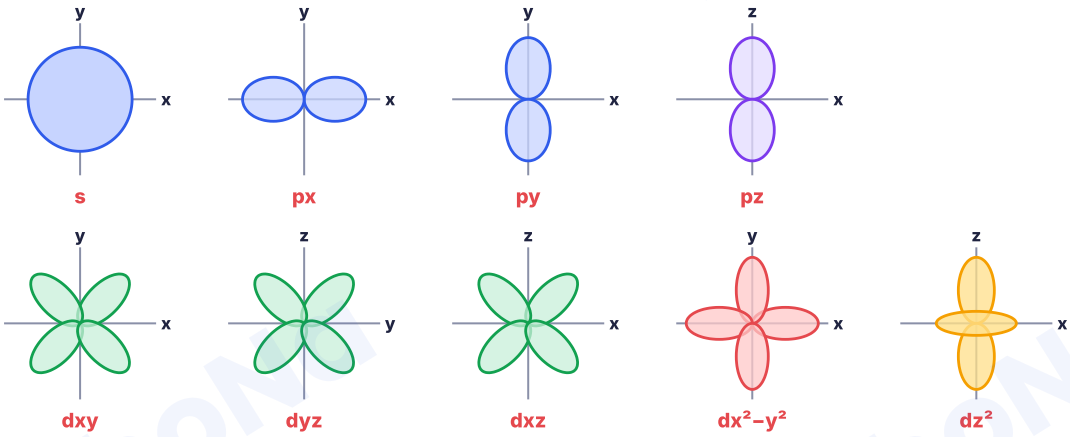


Dense dots: high probability

Red line: boundary surface

It holds about 90 to 95%

Orbit	Orbital
Fixed circular path	Region of probability
Planar motion	Three-dimensional
Holds up to $2n^2$ electrons	Holds at most 2 electrons
Circular	s spherical, p dumb-bell, d double dumb-bell (dz^2: dumb-bell with a ring)
Non-directional, can't explain molecular shapes	Directional (except s), explains shapes
Against Heisenberg	Agrees with Heisenberg



- s: spherical, non-directional, holds 2.
- p: three dumb-bells, px, py, pz, holds 6.
- d: five orbitals, holds 10. dxy, dyz, dxz lie between axes, with zero probability along axes and most at 45°. $dx^2–y^2$ and dz^2 lie along axes.

Practice Zone

Orbitals

115 Statement I: A line appears for 2px → 2py. Statement II: 2px and 2py are degenerate.

116 How many of these have electron density along axes? pz, dxy, $dx^2–y^2$, dyz, dz^2, dxz, px

15 Quantum Numbers

n, l, m, s

Number	Tells	Values	Results
Principal n	Size, energy (K, L, M, N)	1, 2, 3...	n subshells, n^2 orbitals, $2n^2$ electrons, orbit L = nh/2π
Azimuthal l	Shape, subshell	0 to n − 1 (s, p, d, f)	2l + 1 orbitals, 2(2l + 1) electrons
Magnetic m	Orientation	−l to +l	One value per orbital
Spin s	Spin	+½, −½	Spin moment √(n(n + 2)) BM, n = number of unpaired electrons

Orbit: mvr = nh/2π | Orbital: L = √(l(l + 1)) h/2π | Spin: √(s(s + 1)) h/2π, s = total spin = unpaired/2

Orbital	s	p	d	f
L in h/2π	0	√2	√6	√12

HINGLISH MEIN SAMJHO

n batata hai kaunsi building, l kaunsi manzil ka type, m kaunsa kamra, s kamre ke andar kis taraf. Do electron poore chaar number same nahi rakh sakte.

PadhoNa

Active Recall 7

Page cover karo. 2 minute ka timer lagao. Pehle dimaag se likho, phir check karo.

1. Orbitals in shell n?
2. Electrons in a subshell?
3. L of d orbital?
4. Radial nodes?
5. Max in an orbital?

Answers: Recall Answer Key (last section). Score likho: ___ / 5

Practice Zone

Quantum numbers

117 In a multi-electron atom, which have the same energy without fields? A: 2,0,0 B: 3,1,0 C: 3,1,1 D: 3,2,0 E: 4,0,0

118 Electrons with n = 3 and s = +½, in filled subshells?

119 Quantum numbers of the valence electron of Cs (Z = 55)?

120 Statement I: Same-energy orbitals are degenerate. Statement II: In H, 3s and 3p are not degenerate.

121 Quantum numbers of the outer electron of Na (Z = 11)?

122 Orbitals with n = 3, m = 0?

123 Electrons with n = 3, |m| = 1, s = −½?

124 Arrange by energy: (a) 5p (b) 5s (c) 4d (d) 4f (e) 6s

125 How many of these have 4 radial nodes? 5s, 6p, 7d, 6s, 7p

126 Statement I: A shell has n^2 orbitals. Statement II: A subshell has m from −l to +l.

127 Find the orbital angular momentum of a 4f electron.

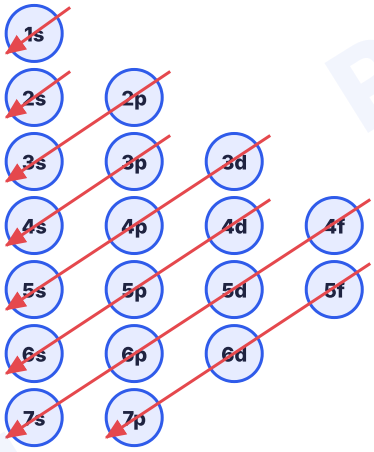
16 Electronic Configuration

Pauli, Aufbau, Hund

Pauli: no two electrons in an atom have all four quantum numbers alike. So an orbital holds at most two, with opposite spins.

Aufbau: electrons fill orbitals in order of rising energy: 1s, 2s, 2p, 3s, 3p, 4s, 3d, 4p, 5s, 4d, 5p, 6s, 4f, 5d, 6p, 7s, 5f, 6d...

(n + l) rule: lower n + l fills first. If equal, lower n fills first.

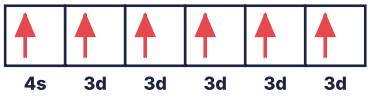


EXAM TRAP

The n + l rule is for multi-electron atoms. In H, energy depends only on n: 3s = 3p = 3d.

Hund: electrons in a subshell don't pair until each orbital has one, with parallel spins.

Extra stability of half-filled and filled subshells (p^3, p^6, d^5, d^{10}, f^7, f^{14}) comes from symmetry, less repulsion, smaller shielding and large exchange energy. So Cr is $[Ar]3d^5 4s^1$ and Cu is $[Ar]3d^{10} 4s^1$.



HINGLISH MEIN SAMJHO

Pauli: ek kamre mein do log, ulti disha. Aufbau: pehle sasta kamra. Hund: pehle sab akele, phir pairing. Cr aur Cu exception yaad rakho.

Practice Zone

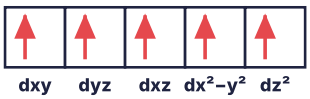
Configuration

128 In H, the lowest energy among 4s, 3px, 3dxy, $3dz^2$, 4pz: (A) 3px only (B) 4s only (C) 4s, 4pz (D) 3px, 3dxy, $3dz^2$

129 Which is wrong for H? (A) 1s < 2p < 3d < 4s (B) 1s < 2s = 2p < 3s = 3p (C) 1s < 2s < 2p < 3s (D) 1s < 2s < 4s < 3d

130 Unpaired electrons in Ni (Z = 28)?

131 Find the spin moment and spin angular momentum of Mn (Z = 25).



132 Which Bohr idea disagrees with quantum mechanics? (A) No radiation in a stationary state (B) Only certain energies exist (C) Falling emits a photon (D) The electron moves in a fixed circle

133 Half-filled subshells are extra stable due to: (a) symmetry (b) less repulsion (c) same spin in non-degenerate orbitals (d) large exchange energy (e) smaller shielding

134 Unpaired electrons in Cr (Z = 24)?

135 Which breaks Hund's rule: nitrogen 2p with two electrons paired in one orbital, or with three unpaired?

Rapid Revision

Exam se ek din pehle sirf yeh page

Rays
Cathode: e/m constant. Anode: depends on gas.

Charge
$q = ne$; $e = 1.6 \times 10^{-19}$ C.

Accelerate
$qV = \frac{1}{2}mv^2$; 1 eV = 1.6×10^{-19} J.

R_o
α: $4kZe^2/mv^2$; p: $2kZe^2/mv^2$.

Photon
$E = hc/\lambda$; 12400/E Å.

Photoelectric
$h\nu = h\nu_o + KE$; $KE = eV_o$.

Bohr
$0.529n^2/Z$ Å; 2.18×10^6 Z/n; $-13.6Z^2/n^2$.

Links
$KE = |TE|$; $PE = 2TE$.

Rydberg
$1/\lambda = RZ^2(1/n_1^2 - 1/n_2^2)$.

Equi-energy
Match Z/n on both levels.

Series
Lyman UV; Balmer visible; others IR.

Lines
$n(n-1)/2$; $\Delta n(\Delta n + 1)/2$; one atom $n - 1$.

de Broglie
h/p; $12.3/\sqrt{V}$ Å; $2\pi r = n\lambda$.

Heisenberg
$\Delta x \cdot \Delta p \geq h/4\pi$.

Nodes
Radial $n - l - 1$; angular l.

L
$\sqrt{l(l+1)}\ h/2\pi$.

Fill
$(n + l)$, then n. H: only n.

Spin
$\sqrt{n(n+2)}$ BM, n = unpaired electrons.

PadhoNa Mega Recall

Poora chapter, bina dekhe, 10 minute

PadhoNa

Active Recall 8

Page cover karo. 10 minute ka timer lagao. Pehle dimaag se likho, phir check karo.

1. e/m of electron?
2. Mass of electron?
3. Work function formula?
4. KE in n = 2 of H?
5. He^+ 6 → 4 equals H?
6. Balmer longest λ?
7. λ in n = 1 of H?
8. Radial nodes in 4p?
9. Cu configuration?
10. Orbitals in n = 4?

Answers: Recall Answer Key (last section). Score likho: ____ / 10

PadhoNa

Notes khatam. Asli game ab shuru.

Bohr, spectrum aur quantum numbers ke sawaal speed se solve hote hain, aur speed sirf practice se aati hai. Isi ke liye hai **PadhoNa Test Series**.

- Chapter-wise topic tests
- Timed full-length practice
- Detailed solutions
- Apni weak areas pehchano

Aaj hi PadhoNa Test Series join karo.

Detailed Solutions

Pehle khud try karo, phir yahan check karo

01. Discovery of the Electron

1 **(D).** It is a universal constant.

2 (i) $1/9.1 \times 10^{-31} = \mathbf{1.10 \times 10^{30}}$. (ii) Mass = $2 \times 6.022 \times 10^{23} \times 9.1 \times 10^{-31} = \mathbf{1.10 \times 10^{-6}\ kg}$. Charge = $-2 \times 96500 = \mathbf{-1.93 \times 10^{5}\ C}$.

02. Millikan, Proton, Neutron

3 All are multiples of 3×10^{-18}: 2, 5, 3, 7, 4 times. **(B).**

4 $q = mg/E = 3.2 \times 10^{-19}$ C, so **n = 2**.

5 **(C).** Anode rays form in the gas between the electrodes.

6 Ratios of charge to mass number: ½, ½, 1, ¼. **(C).**

7 **(C).**

8 (2/3) × (6/5) = **4 : 5**.

03. Charge, Potential, Closest Approach

9 (i) **T**. (ii) **T**: $2.5N_A$ is a whole number of electrons. (iii) **F**.

10 $v \propto \sqrt{(q/m)}$: $v_p/v_\alpha = \mathbf{\sqrt{2}}$. $V \propto m/q$: $V_\alpha/V_p = \mathbf{2}$.

11 KE = 40 eV = 6.4×10^{-18} J. $m = 2.5 \times 10^{-23}$ kg. $v = \mathbf{716\ m/s}$.

12 $m = 1.6 \times 10^{-26}$ kg. $v = \sqrt{(2 \times 8 \times 10^{-18}/1.6 \times 10^{-26})} = \mathbf{3.16 \times 10^{4}\ m/s}$.

13 KE = 1.28×10^{-17} J. $v = \mathbf{5.30 \times 10^{6}\ m/s}$.

14 $½mv^2/e = \mathbf{80\ V}$.

15 $\mathbf{R_o = 316ke^2/m_\alpha v^2}$.

16 $R_o = k(2e)(79e)/KE = \mathbf{2.84 \times 10^{-14}\ m}$.

04. Black Body and Photons

17 Only (4): the peak moves to higher frequency. **1**.

18 (1), (2), (4) are correct. **3**.

19 From hc/E: $6.626 \times 10^{-34} \times 3 \times 10^{8}/(4 \times 1.6 \times 10^{-19}) \approx$ 3106 Å. From 12400/4 = **3100 Å**.

20 E = 3.98×10^{-19} J. n = $\mathbf{1.51 \times 10^{20}}$.

21 E = 4.04×10^{-19} J. $\bar{\nu} = E/hc = \mathbf{2.03 \times 10^{6}\ m^{-1}}$.

22 **(C)**: 299 kJ/mol.

23 5 eV each: **250 eV**.

24 $P \propto 1/\lambda$: **60 W**.

25 E = 2.5 eV = 4×10^{-19} J. $\mathbf{2.5 \times 10^{16}}$.

26 2.5 eV × 96.5 = **241 kJ/mol**.

27 E = 3.0×10^{-19} J. $\mathbf{10^{5}}$.

28 The mark runs crest to next zero, $\lambda/4 = 2.0$ pm. $\lambda = 8$ pm. $v = \mathbf{3.75 \times 10^{19}\ Hz}$.

29 $\mathbf{16000\ cm^{-1}}$.

05. Photoelectric Effect

30 $h \times 7 \times 10^{14} = \mathbf{4.64 \times 10^{-19}\ J}$.

31 $\mathbf{9.9 \times 10^{-19}\ J}$.

32 $E = W + 2$; $2E = W + 6$. $\mathbf{W = 2\ eV}$.

33 $KE \propto p^2$, so KE × 4, hence **λ/4**.

34 $hc/\lambda = hc/\lambda_o + ½mv^2$. $\mathbf{v = \sqrt{[2hc(\lambda_o - \lambda)/(m\lambda\lambda_o)]}}$.

35 E = 1240/300 = 4.13 eV. Li, Na, K, Mg: **4**.

36 **400 nm**.

37 KE = 4.97 − 3.6 = $\mathbf{1.37 \times 10^{-19}\ J}$. $V_o = \mathbf{0.86\ V}$.

38 Current **doubles**; KE_{max} stays the **same**.

06. Thomson and Rutherford Models

39 **(D).**

40 **(B).**

41 **(A).**

42 **(C).**

07. Bohr's Model

43 $E = -13.6Z^2/n^2$: E is negative and $|E| \propto Z^2$, so a parabola falls from the origin. (A) has the wrong sign; (B) and (C) are straight. **(D).**

44 $1/\lambda = 109677 \times 15/16 = 102822\ cm^{-1}$: **972.6 Å**. Or 12.75 eV: 12400/12.75 = **972.5 Å**.

45 −3.02 + 27.2 = **24.18 eV**.

46 n^3/Z^2: 8/4 = 2; 27/9 = 3. **3T/2**.

47 Z^2/n^3: 4/27; 1/8. **27σ/32**.

48 Z^3/n^4: 8; 27/16. **27a/128**.

49 $\Delta E = (5/36) \times 2.18 \times 10^{-18} = 3.03 \times 10^{-19}$ J. **λ ≈ 6560 Å**.

50 n = 3: 9/3. **(B).**

51 $n_i^2 - n_f^2 = 5$. **(A).**

52 $n^2/4 = 4$: **n = 4**.

53 **5.45×10^5 m/s**.

54 $KE = n^2h^2/8\pi^2mr^2$, $r = 9a_o$. **$h^2/(72\pi^2ma_o^2)$**.

55 Z/n = ½. **(B).**

56 **a–iii, b–ii, c–i, d–iv**.

57 **T, F, T, T**. KE rises on going down. S_4: 2 > 1.51 eV.

58 $T \propto n^3$. **(C).**

59 $1/\lambda = 109677 \times 2/9 = 24372\ cm^{-1}$. **$4.10 \times 10^{-5}$ cm**.

60 1240/286 = 4.34 eV. × 96.5 = **418 kJ/mol**.

61 n = 5 to 2, Δn = 3. **6**.

62 $KE = 5.45 \times 10^{-19}$ J. $v = 1.09 \times 10^6$ m/s. **x = 11**.

63 **x = 151**.

08. Energy Levels and Equi-Energy Transitions

64 Same as H 5 → 2: 3.4 − 0.544 = 2.856 eV. **4342 Å**.

65 H 3 → 1: 12.09 eV. **(A).**

66 Same as H n = 5: TE = −0.544 eV. PE = **−1.09 eV**.

67 9 → 3 = H 3 → 1: **12.09 eV**.

68 70 − 54.4 = 15.6 eV. **15.6 V**.

69 Z = 4, n = 8, n/Z = 2. TE = −3.4 eV. PE = **−6.8 eV**.

70 $Z^2 = 9$. **122.4 eV**.

71 **(A) and (C)**: n = 4, 3.

72 $217.6/n^2$: n = 8 and n = 4. $\Delta = 4h/2\pi$ = **2h/π**.

73 **(B).**

74 Absorption stays absorption. **(B).**

75 n = 3 to 1. $\Delta E = 54.4 \times 8/9 = 48.4$ eV. **25.6 nm**.

76 $r \propto n^2$, so $n_2 = 3n_1$. $T \propto n^3$: **1 : 27**.

77 **$h^2/(2\pi^2mr^2)$**.

09. Spectrum

78 Only (2). **1**.

79 **(B).**

10. Hydrogen Spectrum

80 In Balmer: 3.4 − 2.856 = 0.544. **5 → 2**.

81 In the gap. **(D).**

82 $1/\lambda' = 4R \times ¾ = 3R$. **λ/3**.

83 Ratio (5/36)/(3/16) = 20/27. **486 nm**.

84 Balmer lines 6, 5, 4, 3 → 2. **(C).**

85 H to n = 3: 3 lines. He^+ 2 → 6: 15 lines. Li^{2+} 3 → 9: 36 lines. Total 54. H's 3 energies repeat in both ions (He^+ 6, 4, 2; Li^{2+} 9, 6, 3), so remove 6. **48**.

86 **6**.

87 **5**.

11. de Broglie Hypothesis

88 n/Z = 3: TE = −1.51 eV. λ = √(150/1.51) = **9.97 ≈ 10 Å**.

89 h/mv, with $v = 5.45 \times 10^5$: 13.4 Å. 2πr/n = 2π(8.46)/4: 13.3 Å. h/√(2mKE) at 0.85 eV: 13.3 Å. √(150/0.85): **13.3 Å**.

90 (40/3 − 20/3)/(10/3) = **2**.

91 (20/3 − 40/9)/(10/3) = **2/3**.

92 $\sqrt{(m_d q_d/m_\alpha q_\alpha)} = \sqrt{(2/8)}$ = **1/2**.

93 KE = 4.49 eV. √(150/4.49) = **5.78 Å**.

94 $2\pi(25a_o)/5$ = **$10\pi a_o$**.

95 9 eV: **4.08 Å**.

96 √V = 12, 10, 9. (1/9 − 1/10) × 12 = **2/15**.

97 √(400/25) = **4 : 1**.

98 25 eV: √6 = **2.45 Å**.

99 13.6 − 2.6 = 11 eV. + 4 = 15 eV. √10 = **3.16 Å**.

100 n/Z = 3/2. **(B).**

101 **5.5 pm**.

102 $r = 9a_o/2$. $2\pi r/3$ = **$3\pi a_o$**.

103 **(B).**

104 **$6\pi a_o$**.

12. Heisenberg's Uncertainty Principle

105 $\Delta p^2 \geq h/4\pi$, so $\Delta p \geq \frac{1}{2}\sqrt{(h/\pi)}$. **Both true.**

106 $\Delta v = 0.4$ m/s. $\Delta x \geq h/(4\pi m \Delta v) =$ **8.8×10^{-34} m.**

107 $4\Delta p^2 \geq h/4\pi$. **$\Delta v \geq (1/4m)\sqrt{(h/\pi)}$.**

108 **2.9×10^9 m/s**, above c. So electrons can't stay inside a nucleus.

109 $m_p/m_e =$ **1835.**

13. Quantum Mechanical Model

110 **(A).**

111 **(A) and (B).**

112 **$r = 2a_o/3$.**

113 **1, 3, 2.**

114 (1), (4), (5). **3.**

14. Orbitals and Their Shapes

115 Same energy, so no line. **I false, II true.**

116 pz, dx^2-y^2, dz^2, px: **4.**

15. Quantum Numbers

117 Same n and l: **B and C.**

118 Half of 18: **9.**

119 $6s^1$: **6, 0, 0, ±½.**

120 **I true, II false.**

121 **3, 0, 0, ±½.**

122 3s, 3p, 3d: **3.**

123 p: 2, d: 2. **4.**

124 n + l: 6, 5, 6, 7, 6. Ties: lower n first. **b < c < a < e < d.**

125 5s, 6p, 7d: **3.**

126 **Both true.**

127 **$\sqrt{12}$ h/2π.**

16. Electronic Configuration

128 n = 3 for all three. **(D).**

129 **(C) and (D).**

130 $[Ar]3d^8 4s^2$: **2.**

131 5 unpaired. μ = $\sqrt{35}$ = **5.92 BM.** s = 5/2: $\sqrt{(35/4)}$ = **2.96 h/2π.**

132 **(D).**

133 Same-spin electrons here sit in degenerate orbitals, so (c) is wrong. **(a), (b), (d), (e).**

134 **6.**

135 **The paired one.**

Recall Answer Key

Score dekho, jo galat hua usko dobara padho

Active Recall 1

1. 1.76×10^{11} C/kg.
2. 1.6×10^{-19} C.
3. Chadwick.
4. H^+.
5. Particles have mass.
6. In the gas between electrodes.

Active Recall 2

1. hc/λ.
2. 12400/E(eV).
3. Temperature only.
4. To shorter λ.
5. Multiply by N_A.

Active Recall 3

1. $0.529\ n^2/Z$ Å.
2. $2.18 \times 10^6\ Z/n$ m/s.
3. $-13.6\ Z^2/n^2$ eV.
4. PE = 2TE.
5. n^3/Z^2.
6. Z^3/n^4.

Active Recall 4

1. 4 → 2.
2. 4.
3. 122.4 eV.
4. 12.09 eV.
5. 1.51 eV.

Active Recall 5

1. UV.
2. 4/R, 3647 Å.
3. 2 → 1.
4. 3.4 to 10.2 eV.
5. $n(n-1)/2$.
6. $n - 1$.

Active Recall 6

1. $\Delta x \cdot \Delta p \geq h/4\pi$.
2. $12.3/\sqrt{V}$ Å.
3. $n\lambda$.
4. Rectangular hyperbola.
5. de Broglie.

Active Recall 7

1. n^2.
2. $2(2l + 1)$.
3. $\sqrt{6}\ h/2\pi$.
4. $n - l - 1$.
5. 2 electrons.

Active Recall 8

1. 1.76×10^{11} C/kg.
2. 9.1×10^{-31} kg.
3. $h\nu_o$.
4. 3.4 eV.
5. 3 → 2.
6. 6563 Å, 3 → 2.
7. 3.3 Å.
8. 2.
9. $[Ar]3d^{10}4s^1$.
10. 16.