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PREVIOUS YEAR QUESTIONS · 2007–2025

JEE Advanced

Chapter-wise PYQs

Chemistry**2007–2025** Questions from 19 years

Chapter-wise previous year questions with full solutions · Papers 1 & 2

618

QUESTIONS

144

FIGURES

23

CHAPTERS



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JEE Advanced Chapter-wise PYQs · Chemistry

Chapter-wise previous year questions with full solutions · Papers 1 & 2

Digital edition · First published October 2026

Published by

Grey Neural Technologies Private Limited

CIN U62011WR2026PTC296120

Registered office: Flat No. E-1/14, S.M. Nagar, Sarkarpool, South 24 Parganas, West Bengal 700143, India

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Typeset by JEEEnius · 618 questions · built 2026-10-16

How to use this book

- **Chapter-wise, newest first.** Every chapter opens with its questions, latest year first, followed by an answer key and then full solutions. Attempt the questions before turning to the key.
- **Source line.** Each question shows where it was asked — year, paper and marking scheme, and its type when it is not a single-correct MCQ.
- **Weightage table.** Chemistry opens with a table of how often every chapter was asked, overall and in the last five years. Use it to plan revision.
- **More than an answer.** Solutions carry a difficulty rating, a suggested time and the topic; many add a quick approach, the common traps students fall into, and what to revise.
- **Ref numbers.** Each solution carries a Ref number. Quote it to report an error.

Questions by year

2007 40	2008 39	2009 33	2010 43	2011 39	2012 38	2013 36	2014 36	2015 39	2016 36	2017 34	2018 29	2019 33
2020 9	2021 32	2022 12	2023 30	2024 30	2025 30							



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JEE Advanced 2007–2025

618 questions

Chemistry

Chapter	All years	Last 5 years
Some Basic Concepts in Chemistry	2	0
Atomic Structure	26	4
Chemical Bonding and Molecular Structure	39	6
Chemical Thermodynamics	55	13
Solid State	16	4
Solutions	42	9
Equilibrium	25	8
Redox Reactions and Electrochemistry	42	11
Chemical Kinetics	22	4
Surface Chemistry	1	0
Classification of Elements and Periodicity in Properties	5	0
p-Block Elements	72	13
d- and f-Block Elements	66	15
Purification and Characterization of Organic Compounds	1	0
Some Basic Principles of Organic Chemistry	23	9
Hydrocarbons	21	3
Organic Compounds Containing Halogens	21	6
Organic Compounds Containing Oxygen	71	14
Organic Compounds Containing Nitrogen	20	4
Polymers	1	0
Biomolecules	26	7
Principles Related to Practical Chemistry	17	4
Other Chemistry questions	4	0

CHEMISTRY · CHAPTER 1

Some Basic Concepts in Chemistry

2 questions · 2007 2

PARAGRAPH

Chemical reactions involve interaction of atoms and molecules. A large number of atoms/molecules (approximately 6.023×10^{23}) are present in a few grams of any chemical compound varying with their atomic/molecular masses. To handle such large numbers conveniently, the mole concept was introduced. This concept has implications in diverse areas such as analytical chemistry, biochemistry, electrochemistry and radiochemistry. The following example illustrates a typical case, involving chemical/electrochemical reaction, which requires a clear understanding of the mole concept.

A 4.0 molar aqueous solution of NaCl is prepared and 500 mL of this solution is electrolysed. This leads to the evolution of chlorine gas at one of the electrodes (atomic mass: Na = 23, Hg = 200; 1 Faraday = 96500 coulombs).

1 JEE ADV 2007 · PAPER 1 · +3, -1

Chemical reactions involve interaction of atoms and molecules. A large number of atoms/molecules (approximately 6.023×10^{23}) are present in a few grams of any chemical compound varying with their atomic/molecular masses. To handle such large numbers conveniently, the mole concept was introduced. This concept has implications in diverse areas such as analytical chemistry, biochemistry, electrochemistry and radiochemistry. The following example illustrates a typical case, involving chemical/electrochemical reaction, which requires a clear understanding of the mole concept.

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The total number of moles of chlorine gas evolved is

- (A) 0.5 (B) 1.0
(C) 2.0 (D) 3.0

PARAGRAPH

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2 JEE ADV 2007 · PAPER 1 · +3, -1

The total charge (coulombs) required for complete electrolysis is

- (A) 24125 (B) 48250
(C) 96500 (D) 193000

Answer key · Some Basic Concepts in Chemistry

1 B 2 D

Solutions · Some Basic Concepts in Chemistry

1 Answer: B

Ref 13079

Easy ~1 min

Molarity is defined as the number of moles of solute per litre of solution. Here the NaCl solution has molarity 4.0 mol L^{-1} and volume $500 \text{ mL} = 0.500 \text{ L}$. Therefore, moles of NaCl present are $n = MV = (4.0)(0.500) = 2.0 \text{ mol}$. Since each mole of NaCl gives one mole of chloride ions, the moles of chloride ions available are 2.0 mol . During electrolysis, chlorine is evolved at

the anode by oxidation of chloride ions: $2\text{Cl}^- \rightarrow \text{Cl}_2 + 2\text{e}^-$.

Thus, 2 mol of Cl^- produce 1 mol of Cl_2 . Hence, the total moles of chlorine gas evolved are $n(\text{Cl}_2) = \frac{2.0}{2} = 1.0 \text{ mol}$. Therefore, the correct option is B.

COMMON TRAPS

- **Treating 4.0 M as moles in the whole sample.** Molarity M means moles per litre of solution, so $n = MV$ with V in litres. Here $V = 500 \text{ mL} = 0.500 \text{ L}$, so $n = 4.0 \times 0.500 = 2.0 \text{ mol NaCl}$. *Avoid it:* Every time the question gives molarity and volume, write units explicitly: $4.0 \text{ mol L}^{-1} \times 0.500 \text{ L} = 2.0 \text{ mol}$.
- **Forgetting to convert 500 mL to 0.500 L.** 4.0 mol L^{-1} must be multiplied by litres, not millilitres: $500 \text{ mL} = 0.500 \text{ L}$. *Avoid it:* Before substituting in $n = MV$, convert the volume and annotate the unit cancellation.

REVISE Molarity calculation $n = MV$ with volume always in litres. · Practice oxidation half-reaction mole ratios, especially $2\text{Cl}^- \rightarrow \text{Cl}_2 + 2\text{e}^-$.

2 Answer: D

Ref 13086

Medium ~1 min

Molarity is defined as $M = \frac{\text{moles of solute}}{\text{volume of solution in L}}$. The given solution is 4.0 M NaCl and the volume electrolysed is $500 \text{ mL} = 0.500 \text{ L}$. Hence, moles of NaCl present are $4.0 \times 0.500 = 2.0 \text{ mol}$. Since NaCl dissociates as $\text{NaCl} \rightarrow \text{Na}^+ + \text{Cl}^-$, the moles of chloride ions are also 2.0 mol. At the anode,

chlorine gas is evolved according to $2\text{Cl}^- \rightarrow \text{Cl}_2 + 2\text{e}^-$. This shows that 1 mole of Cl^- releases 1 mole of electrons. Therefore, for 2.0 moles of Cl^- , the moles of electrons involved are 2.0 mol. Since 1 mole of electrons corresponds to 1 Faraday = 96500 C, the total charge required is $Q = 2.0 \times 96500 = 193000 \text{ C}$. Therefore, the correct answer is option D.

COMMON TRAPS

- **Using 1 Faraday for 1 mole of Cl_2 instead of 2 Faradays.** Faraday counts moles of electrons, not moles of chlorine gas. The half-reaction shows 1 mol Cl_2 corresponds to $2 \text{ mol e}^- = 2 \text{ F}$. *Avoid it:* After writing the half-reaction, always form the ratio $\text{mol e}^-/\text{mol target ion or product}$. Here it is 2 e^- per 1 Cl_2 , or 1 e^- per 1 Cl^- .
- **Forgetting to convert 500 mL to 0.500 L.** The formula quoted in the explanation, " $M = \text{moles of solute} / \text{volume of solution in L}$ ", requires volume in litres. $500 \text{ mL} = 0.500 \text{ L}$. *Avoid it:* Before substituting into molarity, rewrite every volume beside the data: $500 \text{ mL} = 0.500 \text{ L}$.

REVISE Molarity as mol L^{-1} and always convert mL to L before substitution. · For electrolysis, write the electrode half-reaction and calculate moles of electrons by coefficient ratios.

CHEMISTRY · CHAPTER 2

Atomic Structure

26 questions · 2024 2 2023 1 2021 1 2019 3 2017 3 2016 2 2014 1 2013 2 2012 1 2011 3 2010 3 2009 2
2007 2

1 JEE ADV 2024 · PAPER 1 · ONE OR MORE CORRECT · +4, PARTIAL +1, -2

Among the following, the correct statement(s) for electrons in an atom is(are)

- (A) Uncertainty principle rules out the existence of definite paths for electrons.
 (B) The energy of an electron in $2s$ orbital of an atom is lower than the energy of an electron that is infinitely far away from the nucleus.
 (C) According to Bohr's model, the most negative energy value for an electron is given by $n = 1$, which corresponds to the most stable orbit.
 (D) According to Bohr's model, the magnitude of velocity of electrons increases with increase in values of n .

2 JEE ADV 2024 · PAPER 2 · +3, -1

According to Bohr's model, the highest kinetic energy is associated with the electron in the

- (A) first orbit of H atom (B) first orbit of He^+
 (C) second orbit of He^+ (D) second orbit of Li^{2+}

3 JEE ADV 2023 · PAPER 2 · NUMERICAL · +4, 0

For He^+ , a transition takes place from the orbit of radius 105.8 pm to the orbit of radius 26.45 pm. The wavelength in nm of the emitted photon during the transition is ____.

Use:

Bohr radius, $a = 52.9$ pm

Rydberg constant, $R_H = 2.2 \times 10^{-18}$ J

Planck's constant, $h = 6.6 \times 10^{-34}$ J s

Speed of light, $c = 3 \times 10^8$ m s $^{-1}$

4 JEE ADV 2021 · PAPER 2 · NUMERICAL · +3, 0

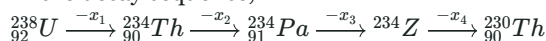
Consider a helium (He) atom that absorbs a photon of wavelength 330 nm. The change in the velocity (in cm s $^{-1}$) of He atom after the photon absorption is ____.

Assume: Momentum is conserved when photon is absorbed.

Use: Planck constant = 6.6×10^{-34} J s, Avogadro number = 6×10^{23} mol $^{-1}$, Molar mass of He = 4 g mol $^{-1}$.

5 JEE ADV 2019 · PAPER 1 · ONE OR MORE CORRECT · +4, PARTIAL +1, -1

In the decay sequence,



x_1, x_2, x_3 and x_4 are particles/radiation emitted by the respective isotopes. The correct option(s) is(are)

- (A) x_3 is γ -ray
 (B) Z is an isotope of uranium
 (C) x_2 is β^-
 (D) x_1 will deflect towards negatively charged plate

6 JEE ADV 2019 · PAPER 2 · ONE OR MORE CORRECT · +4, PARTIAL +1, -1

The ground state energy of hydrogen atom is -13.6 eV.

Consider an electronic state Ψ of He^+ whose energy, azimuthal quantum number and magnetic quantum number are -3.4 eV, 2 and 0, respectively. Which of the following statement(s) is(are) true for the state Ψ ?

- (A) It is a $4d$ state
 (B) It has 2 angular nodes
 (C) It has 3 radial nodes
 (D) The nuclear charge experienced by the electron in this state is less than $2e$, where e is the magnitude of the electronic charge

7 JEE ADV 2019 · PAPER 2 · MATCHING · +3, -1

Consider the Bohr's model of a one-electron atom where the electron moves around the nucleus. In the following, List-I contains some quantities for the n^{th} orbit of the atom and List-II contains options showing how they depend on n .

List-I	List-II
(I) Radius of the n^{th} orbit	(P) $\propto n^{-2}$
(II) Angular momentum of the electron in the n^{th} orbit	(Q) $\propto n^{-1}$
(III) Kinetic energy of the electron in the n^{th} orbit	(R) $\propto n^0$
(IV) Potential energy of the electron in the n^{th} orbit	(S) $\propto n^1$
	(T) $\propto n^2$
	(U) $\propto n^{1/2}$

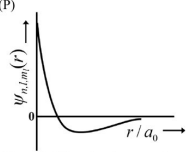
Which of the following options has the correct combination considering List-I and List-II?

- (A) (I), (P) (B) (I), (T)
 (C) (II), (Q) (D) (II), (R)

PARAGRAPH

Answer the following by appropriately matching the information given in the three columns of the following table.

The wave function, ψ_{n,l,m_l} is a mathematical function whose value depends upon spherical polar coordinates (r, θ, ϕ) of the electron and characterized by the quantum numbers n , l and m_l . Here r is distance from nucleus, θ is colatitude and ϕ is azimuth. In the mathematical functions given in the Table, Z is atomic number and a_0 is Bohr radius.

Column 1	Column 2	Column 3
(I) 1s orbital	(i) $\psi_{n,l,m_l} \propto \left(\frac{Z}{a_0}\right)^{\frac{3}{2}} e^{-\left(\frac{Z}{a_0}r\right)}$	(P) 
(II) 2s orbital	(ii) One radial node	(Q) Probability density at nucleus $\propto \frac{1}{a_0^3}$
(III) 2p _z orbital	(iii) $\psi_{n,l,m_l} \propto \left(\frac{Z}{a_0}\right)^{\frac{5}{2}} r e^{-\left(\frac{Z}{a_0}r\right)} \cos\theta$	(R) Probability density is maximum at nucleus
(IV) 3d _{xy} orbital	(iv) xy-plane is a nodal plane	(S) Energy needed to excite electron from $n = 2$ state to $n = 4$ state is $\frac{27}{32}$ times the energy needed to excite electron from $n = 2$ state to $n = 6$ state

8 JEE ADV 2017 · PAPER 1 · MATCHING · +3, -1

For He^+ ion, the only INCORRECT combination is

- (A) (II) (ii) (Q) (B) (I) (i) (S)
(C) (I) (i) (R) (D) (I) (iii) (R)

9 JEE ADV 2017 · PAPER 1 · MATCHING · +3, -1

For the given orbital in Column 1, the only CORRECT combination for any hydrogen-like species is

- (A) (IV) (iv) (R) (B) (II) (ii) (P)
(C) (III) (iii) (P) (D) (I) (ii) (S)

10 JEE ADV 2017 · PAPER 1 · MATCHING · +3, -1

For hydrogen atom, the only CORRECT combination is

- (A) (I) (i) (S) (B) (II) (i) (Q)
(C) (I) (i) (P) (D) (I) (iv) (R)

11 JEE ADV 2016 · PAPER 1 · ONE OR MORE CORRECT · +4, PARTIAL +1, -2

A plot of the number of neutrons N against the number of protons P of stable nuclei exhibits upward deviation from linearity for atomic number $Z > 20$. For an unstable nucleus having N/P ratio less than 1, the possible mode(s) of decay is(are)

- (A) β^- -decay, β emission (B) orbital or K-electron capture
(C) neutron emission (D) β^+ -decay, positron emission

12 JEE ADV 2016 · PAPER 1 · +3, -1

P is the probability of finding the 1s electron of hydrogen atom in a spherical shell of infinitesimal thickness dr , at a distance r from the nucleus. The volume of this shell is $4\pi r^2 dr$. The qualitative sketch of the dependence of P on r is

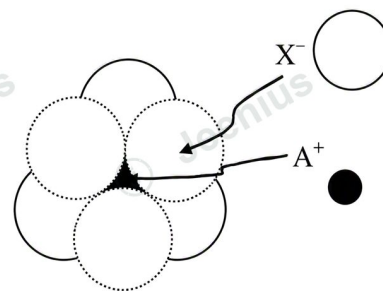
- (A) P is maximum at $r = 0$ and decreases monotonically to nearly zero as r increases.
(B) P starts from zero, rises to a maximum, and returns to zero at a finite value of r , like a semicircular curve.
(C) P is high near $r = 0$, decreases to a minimum, then rises to another maximum and finally decreases.
(D) P starts from zero at $r = 0$, rises to one maximum, and then decreases asymptotically to zero as r increases.

13 JEE ADV 2014 · PAPER 1 · NUMERICAL · +3, 0

In an atom, the total number of electrons having quantum numbers $n = 4$, $|m_l| = 1$ and $m_s = -1/2$ is

14 JEE ADV 2013 · PAPER 1 · +3, -1

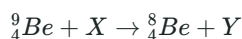
The arrangement of X^- ions around A^+ ion in solid AX is given in the figure, not drawn to scale. If the radius of X^- is 250 pm, the radius of A^+ is



- (A) 104 pm (B) 125 pm
(C) 183 pm (D) 57 pm

15 JEE ADV 2013 · PAPER 2 · ONE OR MORE CORRECT · +4, -1

In the nuclear transmutation



(X, Y) is(are)

- (A) (γ, n) (B) (p, D)
(C) (α, D) (D) (γ, p)

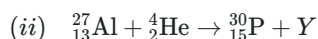
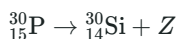
16 JEE ADV 2012 · PAPER 1 · +3, -1

The kinetic energy of an electron in the second Bohr orbit of a hydrogen atom is ? Given: a_0 is Bohr radius.

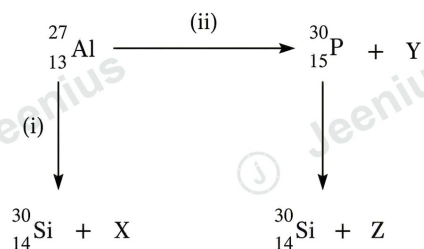
- (A) $\frac{h^2}{4\pi^2 m a_0^2}$ (B) $\frac{h^2}{16\pi^2 m a_0^2}$
(C) $\frac{h^2}{32\pi^2 m a_0^2}$ (D) $\frac{h^2}{64\pi^2 m a_0^2}$

17 JEE ADV 2011 · PAPER 1 · +3, -1

Bombardment of aluminum by α -particle leads to its artificial disintegration in two ways, (i) and (ii), as shown:



Products X , Y and Z respectively are:



- (A) proton, neutron,
positron
(C) proton, positron,
neutron

- (B) neutron, positron,
proton
(D) positron, proton,
neutron

18 JEE ADV 2011 · PAPER 1 · NUMERICAL · +4, 0

The maximum number of electrons that can have principal quantum number, $n = 3$, and spin quantum number, $m_s = -\frac{1}{2}$, is

19 JEE ADV 2011 · PAPER 1 · +3, -1

The wavelength of the first spectral line in the Balmer series of hydrogen atom is 6561 Å. The wavelength of the second spectral line in the Balmer series of singly-ionized helium atom is

- (A) 1215 Å (B) 1640 Å
(C) 2430 Å (D) 4687 Å

20 JEE ADV 2010 · PAPER 1 · NUMERICAL · +4, 0

The number of neutrons emitted when ${}^{235}_{92}\text{U}$ undergoes controlled nuclear fission to ${}^{142}_{54}\text{Xe}$ and ${}^{90}_{38}\text{Sr}$ is

PARAGRAPH

The hydrogen-like species Li^{2+} is in a spherically symmetric state S_1 with one radial node. Upon absorbing light the ion undergoes transition to a state S_2 . The state S_2 has one radial node and its energy is equal to the ground state energy of the hydrogen atom.

21 JEE ADV 2010 · PAPER 2 · +3, -1

The orbital angular momentum quantum number of the state S_2 is

- (A) 0 (B) 1
(C) 2 (D) 3

22 JEE ADV 2010 · PAPER 2 · +3, -1

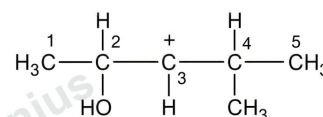
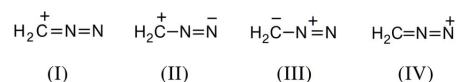
Energy of the state S_1 , in units of the hydrogen atom ground state energy is

- (A) 0.75 (B) 1.50
(C) 2.25 (D) 4.50

23 JEE ADV 2009 · PAPER 2 · +3, -1

The correct stability order of the following resonance structures is:

- (I) $\text{H}_2\text{C} = \text{N}^+ = \text{N}^-$
(II) $\text{H}_2\text{C}^+ - \text{N}^- = \text{N}$
(III) $^-\text{CH}_2 - \text{N}^+ \equiv \text{N}$
(IV) $^-\text{CH}_2 - \text{N} = \text{N}^+$



- (A) (I) > (II) > (IV) > (III)
(B) (I) > (III) > (II) > (IV)
(C) (II) > (I) > (III) > (IV)
(D) (III) > (I) > (IV) > (II)

24 JEE ADV 2009 · PAPER 2 · NUMERICAL · +4, 0

The coordination number of Al in the crystalline state of AlCl_3 is

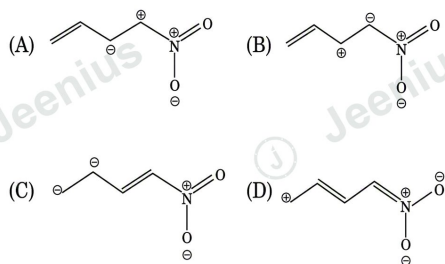
25 JEE ADV 2007 · PAPER 2 · +3, -1

A positron is emitted from ${}^{23}_{11}\text{Na}$. The ratio of the atomic mass and atomic number of the resulting nuclide is

- (A) 22/10 (B) 22/11
(C) 23/10 (D) 23/12

26 JEE ADV 2007 · PAPER 2 · +3, -1

Among the following, the least stable resonance structure is



(A) Structure (A) in the figure

(B) Structure (B) in the figure

(C) Structure (C) in the figure

(D) Structure (D) in the figure

Answer key · Atomic Structure

1 A, B, C	2 B	3 30	4 30	5 B, C, D	6 A, B
7 B	8 D	9 B	10 A	11 B, D	12 D
13 6	14 A	15 A, B	16 C	17 A	18 9
19 A	20 4	21 B	22 C	23 B	24 6
25 C	26 A				

Solutions · Atomic Structure

1 Answer: A, B, C

Ref 14871

Medium ~1.5 min Bohr Model and Uncertainty Principle

QUICK APPROACH Start by applying the Heisenberg uncertainty principle to understand electron paths, and then compare the energy levels of electrons at different orbitals as per Bohr's model.

Check each statement one by one.

Statement A: According to Heisenberg uncertainty principle, the position and momentum of an electron cannot both be known exactly at the same time.

$$\Delta x \Delta p \geq \frac{h}{4\pi}$$

A definite path requires exact position and exact momentum at every instant. Since this is not possible for an electron, the concept of a definite path or orbit is ruled out in the quantum mechanical model. Hence A is correct.

Statement B: The energy of an electron infinitely far away from the nucleus is taken as zero.

$$E_{\infty} = 0$$

For a bound electron in an atom, energy is negative because

energy must be supplied to remove it from the atom.

Therefore, the energy of an electron in the 2s orbital is less than zero.

$$E_{2s} < 0$$

Therefore,

$$E_{2s} < E_{\infty}$$

Hence B is correct.

Statement C: In Bohr's model, the energy of an electron in the n th orbit of a hydrogen-like species is given by

$$E_n = -\frac{13.6Z^2}{n^2} \text{ eV}$$

For fixed Z , the most negative value occurs when n is minimum.

$$n = 1$$

Thus, the first orbit has the most negative energy and is the most stable orbit. Hence C is correct.

Statement D: In Bohr's model, the velocity of an electron in the n th orbit is proportional to $\frac{Z}{n}$.

$$v = 2.186 \times 10^6 \frac{Z}{n} \text{ m/s}$$

For a fixed atom, Z is constant. Therefore, as n increases, velocity decreases, not increases. Hence D is incorrect.

Therefore, the correct statements are A, B and C.

COMMON TRAPS

- **Treating 'definite paths' as allowed Bohr orbits instead of ruled out by uncertainty.** Heisenberg uncertainty principle states $\Delta x \Delta p \geq h/4\pi$; a definite path needs exact position and momentum simultaneously, which is impossible in the quantum mechanical model. *Avoid it:* Whenever a statement mentions uncertainty principle, judge it using Δx and Δp , not Bohr's orbit postulate.
- **Thinking negative energy is 'higher' because its magnitude is larger.** The energy at infinite separation is defined as $E_\infty = 0$; any bound atomic electron has $E < 0$, so $E_{2s} < 0 = E_\infty$. *Avoid it:* Put values on a number line before comparing energies: -3.4 eV is less than 0 eV .

REVIEW The difference between Bohr 'orbit' and quantum-mechanical 'orbital'. · Memorize and test Bohr proportionalities with sample n values: $r \propto n^2/Z$, $v \propto Z/n$, $E \propto -Z^2/n^2$.

2 Answer: B

Ref 14915

Easy ~1 min Bohr model of hydrogen-like species

QUICK APPROACH Use Bohr's model to express kinetic energy in terms of the atomic number and orbit number, and apply the virial theorem for Coulomb forces.

For a hydrogen-like species, Bohr's model gives the total energy of the electron in the n th orbit as

$$E_n = -13.6 \frac{Z^2}{n^2} \text{ eV}$$

For a bound electron in a circular Bohr orbit, by the virial theorem for Coulomb force, kinetic energy is equal to the magnitude of total energy:

$$K = -E_n$$

So,

$$K = 13.6 \frac{Z^2}{n^2} \text{ eV}$$

Now compare all options.

For option A, H atom has $Z = 1$ and first orbit means $n = 1$.

$$K_A = 13.6 \frac{1^2}{1^2} \text{ eV}$$

$$K_A = 13.6 \text{ eV}$$

For option B, He^+ is hydrogen-like with $Z = 2$ and first orbit means $n = 1$.

$$K_B = 13.6 \frac{2^2}{1^2} \text{ eV}$$

$$K_B = 54.4 \text{ eV}$$

For option C, He^+ has $Z = 2$ and second orbit means $n = 2$.

$$K_C = 13.6 \frac{2^2}{2^2} \text{ eV}$$

$$K_C = 13.6 \text{ eV}$$

For option D, Li^{2+} is hydrogen-like with $Z = 3$ and second orbit means $n = 2$.

$$K_D = 13.6 \frac{3^2}{2^2} \text{ eV}$$

$$K_D = 30.6 \text{ eV}$$

The maximum kinetic energy is 54.4 eV , which corresponds to the electron in the first orbit of He^+ .

Therefore, the correct answer is option B.

COMMON TRAPS

- **Comparing total energy instead of kinetic energy.** For a bound electron in Bohr orbit, $K = -E_n = +13.6 Z^2/n^2 \text{ eV}$. Kinetic energy is positive and proportional to Z^2/n^2 . *Avoid it:* Underline "kinetic energy" and write $K = -E_n$ before substituting options.
- **Using charge state as Z .** In Bohr formula, Z is atomic number/nuclear charge, not the ion charge: H:1, He :2, Li:3. *Avoid it:* Before calculation, write element atomic number separately from ionic charge.

REVIEW Bohr energy relations: $E = -13.6 Z^2/n^2 \text{ eV}$, $K = +13.6 Z^2/n^2 \text{ eV}$, $\text{PE} = 2E$. · Practice identifying atomic number Z versus ionic charge for hydrogen-like ions.

3 Answer: 30

Ref 14825

Medium ~2 min Bohr model of hydrogen-like species

QUICK APPROACH Start by using the Bohr radius formula for hydrogen-like ions to find the principal quantum numbers corresponding to the given orbit radii.

For a hydrogen-like species, the radius of the n th Bohr orbit is given by

$$r_n = \frac{an^2}{Z}$$

For He^+ , the atomic number is

$$Z = 2$$

Given Bohr radius is

$$a = 52.9 \text{ pm}$$

So,

$$r_n = \frac{52.9n^2}{2} \text{ pm}$$

First orbit radius given is 105.8 pm . Let the corresponding orbit be n_i .

$$105.8 = \frac{52.9n_i^2}{2}$$

$$n_i^2 = 4$$

$$n_i = 2$$

Second orbit radius given is 26.45 pm. Let the corresponding orbit be n_f .

$$26.45 = \frac{52.9n_f^2}{2}$$

$$n_f^2 = 1$$

$$n_f = 1$$

Thus, the transition is from $n_i = 2$ to $n_f = 1$.

The energy emitted in a transition for a hydrogen-like ion is

$$\Delta E = R_H Z^2 \left(\frac{1}{n_f^2} - \frac{1}{n_i^2} \right)$$

Substituting values:

$$\Delta E = 2.2 \times 10^{-18} \times 2^2 \left(\frac{1}{1^2} - \frac{1}{2^2} \right)$$

$$\Delta E = 2.2 \times 10^{-18} \times 4 \left(1 - \frac{1}{4} \right)$$

$$\Delta E = 2.2 \times 10^{-18} \times 4 \times \frac{3}{4}$$

$$\Delta E = 6.6 \times 10^{-18} \text{ J}$$

For the emitted photon,

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

So,

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

$$\lambda = \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{6.6 \times 10^{-18}}$$

$$\lambda = 3 \times 10^{-8} \text{ m}$$

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

$$\lambda = 30 \text{ nm}$$

Therefore, the wavelength of the emitted photon is 30 nm.

4 Answer: 30

Ref 15271

Medium ~1.5 min Photon momentum and recoil velocity

QUICK APPROACH Use conservation of momentum between the photon and the helium atom, and start by calculating the photon's momentum using $p = h/\lambda$.

The photon carries momentum. When the helium atom absorbs the photon, momentum conservation gives the change in momentum of the helium atom equal to the photon momentum.

Photon momentum is

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

If the change in velocity of the helium atom is Δv , then

$$m\Delta v = \frac{h}{\lambda}$$

So,

$$\Delta v = \frac{h}{m\lambda}$$

Mass of one helium atom is obtained from molar mass and Avogadro number.

$$m = \frac{4 \times 10^{-3}}{6 \times 10^{23}} \text{ kg}$$

$$m = \frac{2}{3} \times 10^{-26} \text{ kg}$$

$$m = 6.67 \times 10^{-27} \text{ kg}$$

Wavelength is

$$\lambda = 330 \times 10^{-9} \text{ m}$$

$$\lambda = 3.30 \times 10^{-7} \text{ m}$$

Now substitute the values:

$$\Delta v = \frac{6.6 \times 10^{-34}}{(6.67 \times 10^{-27})(3.30 \times 10^{-7})}$$

The denominator is approximately

$$(6.67 \times 10^{-27})(3.30 \times 10^{-7}) = 2.20 \times 10^{-33}$$

Therefore,

$$\Delta v = \frac{6.6 \times 10^{-34}}{2.20 \times 10^{-33}}$$

$$\Delta v = 0.30 \text{ m s}^{-1}$$

Convert to cm s^{-1} :

$$0.30 \text{ m s}^{-1} = 30 \text{ cm s}^{-1}$$

Hence, the change in velocity of the helium atom is 30 cm s^{-1} .

5 Answer: B, C, D

Ref 14529

Medium ~1.5 min Radioactive decay series

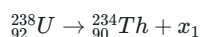
For nuclear decay, use the changes in mass number and atomic number.

In α -emission, the emitted particle is ${}^4_2\text{He}$, so the daughter nucleus has mass number decreased by 4 and atomic number decreased by 2.

In β^- -emission, a neutron changes into a proton, so the mass number remains unchanged and the atomic number increases by 1.

In γ -emission, neither mass number nor atomic number changes.

First transition:

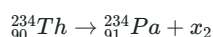


Mass number decreases from 238 to 234 and atomic number decreases from 92 to 90.

So, $x_1 = \alpha$.

An α -particle is positively charged, so it will deflect towards the negatively charged plate. Hence option D is correct.

Second transition:

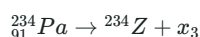


Mass number remains 234, while atomic number increases from 90 to 91.

So, $x_2 = \beta^-$.

Hence option C is correct.

Third transition:



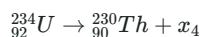
The next transition finally gives ${}^{230}_{90}\text{Th}$ by emission of x_4 . For an α -emission to produce ${}^{230}_{90}\text{Th}$, the parent must be ${}^{234}_{92}\text{U}$.

Therefore, $Z = {}^{234}_{92}\text{U}$.

So, Z is an isotope of uranium, and option B is correct.

Also, since ${}^{234}_{91}\text{Pa}$ changes to ${}^{234}_{92}\text{U}$, the atomic number increases by 1 while mass number remains unchanged. Therefore, $x_3 = \beta^-$, not γ -ray. Hence option A is incorrect.

Fourth transition:



Mass number decreases by 4 and atomic number decreases by 2.

So, $x_4 = \alpha$.

Thus, the correct options are B, C and D.

6 Answer: A, B

Ref 14579

Medium ~2 min Hydrogen-like species, quantum numbers and nodes

For a hydrogen-like species, the energy of the electron is given by $E_n = -\frac{13.6Z^2}{n^2}$ eV. For He^+ , the nuclear charge is $Z = 2$. Therefore, $E_n = -\frac{13.6 \times 2^2}{n^2}$. Given energy is -3.4 eV, so $-3.4 = -\frac{13.6 \times 4}{n^2}$. Hence $n^2 = 16$, so $n = 4$. The azimuthal quantum number is given as $l = 2$. The subshell corresponding to $l = 2$ is d , so the state is $4d$. Thus option A is correct. The number of angular nodes is equal to l . Hence angular nodes = 2, so option B is correct. The number of radial nodes is $n - l - 1$. Thus radial nodes = $4 - 2 - 1 = 1$, not 3, so option C is incorrect. Since this is a hydrogen-like He^+ ion with only one electron, the electron experiences nuclear charge $+2e$ without shielding by other electrons. Hence the nuclear charge experienced is not less than $2e$, so option D is incorrect.

7 Answer: B

Ref 14591

Medium ~1.5 min Bohr model of one-electron atom

Write each Bohr quantity as a power of n .

Step 1. Radius: $r_n = \frac{a_0 n^2}{Z}$, so $r \propto n^2$, which is (T).

Step 2. Angular momentum: $mvr = \frac{nh}{2\pi}$, so $L \propto n^1$, which is (S), not (Q) or (R).

Step 3. So (I), (P) is wrong and (I), (T) is right.

Answer: (B) (I), (T)

COMMON TRAPS

- **Taking the radius as $\propto n^{-2}$.** The Bohr radius is $r_n = \frac{a_0 n^2}{Z}$, so it grows as n^2 ; it is the energy and the kinetic energy that go as n^{-2} . *Avoid it:* Write r_n , v_n , L_n and E_n with their powers of n before reading List-II.
- **Thinking the angular momentum does not depend on n .** Bohr's condition $mvr = \frac{nh}{2\pi}$ makes $L \propto n^1$, which is (S); the speed, not L , goes as n^{-1} . *Avoid it:* Separate the quantisation condition for L from the formula for the speed $v_n \propto \frac{Z}{n}$.

REVISE The n and Z dependence of every Bohr-model quantity.

8 Answer: D

Ref 14314

Hard ~1.5 min Hydrogen-like species and atomic orbitals

Check each combination against the table.

Step 1. (I)(iii)(R): function (iii), $\propto r e^{-Zr/2a_0} \cos \theta$, is the $2p_z$ wave function, not $1s$. This combination is wrong.

Step 2. The rest hold for He^+ : $2s$ has one radial node, and its density at the nucleus $\propto 1/a_0^3$ for fixed Z ; $1s$ has function (i) and its density is greatest at the nucleus.

Step 3. (S) holds for any one-electron species: $\frac{1/4 - 1/16}{1/4 - 1/36} = \frac{3/16}{2/9} = \frac{27}{32}$.

Answer: (D) (I) (iii) (R)

9 Answer: B

Ref 14315

Medium ~1.5 min Hydrogen-like atomic orbitals and radial nodes

QUICK APPROACH Start by recalling the formula for the number of radial nodes in hydrogen-like orbitals: $n - l - 1$, and analyze how many times the radial wavefunction crosses the axis in the given plot.

Match nodes and the graph to each orbital.

Step 1. $2s$: radial nodes $= n - l - 1 = 1$, so (ii) fits. Graph (P) starts at a finite value at the nucleus and crosses zero once: an s orbital with one radial node, the $2s$. So (II)(ii)(P) is right.

Step 2. (III)(iii)(P) fails: a $2p_z$ function is zero at the nucleus. (I)(ii)(S) fails: $1s$ has no radial node.

Step 3. (IV)(iv)(R) fails: the xy -plane is not a nodal plane of $3d_{z^2}$, and its density at the nucleus is zero.

Answer: (B) (II) (ii) (P)

COMMON TRAPS

- **Using the wrong radial-node formula.** For hydrogen-like orbitals, radial nodes $= n - l - 1$; total nodes $= n - 1$; angular nodes $= l$. *Avoid it:* Before matching options, write all three node formulas separately and substitute n and l only after identifying the orbital.
- **Confusing the plotted wave function with probability density.** The wave function can be positive or negative and can cross zero; a zero crossing away from the origin is a radial node. Probability density is squared and non-negative. *Avoid it:* Circle the plotted quantity: ψ , $R(r)$, $|\psi|^2$, or $4\pi r^2 R^2$. Interpret nodes according to the plotted quantity.

REVISE The distinction between radial nodes, angular nodes, and total nodes. · Memorize spectroscopic notation: $s=0$, $p=1$, $d=2$, $f=3$.

10 Answer: A

Ref 14317

Hard ~2 min Hydrogen atom orbitals and Bohr energy levels

QUICK APPROACH Identify which orbital function (i) describes, then test each third-column statement against that orbital or against the hydrogen energy formula.

Match the $1s$ orbital with its wave function and with the energy statement that holds for hydrogen.

Step 1. Function (i), $\psi \propto (Z/a_0)^{3/2} e^{-Zr/a_0}$, has no radial node and no angular part. It is the $1s$ wave function, so it pairs with (I), not with (II).

Step 2. Graph (P) changes sign once, so it shows a radial node. The $1s$ orbital has none, so (I) with (P) fails.

Step 3. The $1s$ orbital is spherical and has no nodal plane, so (I) with (iv) fails.

Step 4. For hydrogen, $E_n \propto -\frac{1}{n^2}$. The energy to go from $n = 2$ to $n = 4$ is proportional to $\frac{1}{4} - \frac{1}{16} = \frac{3}{16}$, and from $n = 2$ to $n = 6$ to $\frac{1}{4} - \frac{1}{36} = \frac{2}{9}$.

Step 5. Their ratio is $\frac{3}{16} \div \frac{2}{9} = \frac{27}{32}$, so statement (S) is true for the hydrogen atom.

Step 6. Only the combination (I), (i), (S) is correct throughout.

Answer: (A) (I) (i) (S)

COMMON TRAPS

- **Pairing the $2s$ orbital with the $1s$ wave function.** A $2s$ wave function has a factor that changes sign, giving one radial node; function (i) never changes sign, so it is $1s$. *Avoid it:* Count the radial nodes in each function before matching it to an orbital.
- **Reversing the excitation-energy ratio.** The jump from $n = 2$ to $n = 4$ needs less energy than the jump from $n = 2$ to $n = 6$, so their ratio is $\frac{27}{32}$, less than 1. *Avoid it:* Compute both differences of $\frac{1}{n^2}$ before dividing, and check that the smaller jump gives the smaller energy.

REVISE Hydrogen orbital wave functions and their nodes. · Energy levels of the hydrogen atom.

11 Answer: B, D

Ref 14204

Medium ~1.5 min Nuclear stability and radioactive decay modes

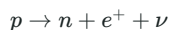
For a stable nucleus, the neutron-to-proton ratio must lie in the stability belt. For heavier nuclei, stable nuclei need comparatively more neutrons, so the N/P ratio is generally greater than 1.

Here the given unstable nucleus has

$$\frac{N}{P} < 1$$

This means the nucleus is proton-rich. To become stable, it must increase the neutron-to-proton ratio.

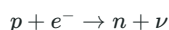
In β^+ decay, a proton changes into a neutron with emission of a positron and a neutrino:



So the number of protons decreases and the number of neutrons increases. Hence N/P increases.

Therefore β^+ decay is possible.

In K-electron capture, a proton captures an inner orbital electron and changes into a neutron:



Again, the number of protons decreases and the number of neutrons increases. Hence N/P increases.

Therefore K-electron capture is also possible.

In β^- decay, a neutron changes into a proton:



This decreases N/P , so it is not suitable here.

Neutron emission also decreases the number of neutrons, so it further decreases N/P and is not suitable.

Thus the correct options are B and D.

COMMON TRAPS

- **Treating $N/P < 1$ as neutron-rich instead of proton-rich.** If $N/P < 1$, then $N < P$. The nucleus is proton-rich and must convert protons into neutrons to increase N/P . *Avoid it:* Rewrite the inequality explicitly as $N/P < 1 \Rightarrow N < P$ before choosing the decay mode.
- **Reversing the nucleon conversion in β^+ decay.** In β^+ decay, $p \rightarrow n + e^+ + \nu$. Thus P decreases by 1 and N increases by 1, increasing N/P . *Avoid it:* For every beta mode, write the parent nucleon conversion before judging the option: $\beta^+ =$ positron emitted = proton converted to neutron.

REVISE Memorize decay modes by nucleon conversion, not only by emitted particle: β^- : $n \rightarrow p$, β^+ : $p \rightarrow n$, electron capture: $p + e^- \rightarrow n$. For every nuclear stability question, first write whether N/P must increase or decrease.

12 Answer: D

Ref 14208

Medium ~1 min Radial probability distribution of hydrogen atom

For the hydrogen atom $1s$ orbital, the wave function has maximum magnitude at the nucleus, but the radial probability also depends on the volume of the spherical shell.

The probability in a shell of radius r and thickness dr is proportional to

$$P dr = 4\pi r^2 |\psi_{1s}|^2 dr$$

For the $1s$ orbital,

$$\psi_{1s} \propto e^{-r/a_0}$$

So,

$$P \propto r^2 e^{-2r/a_0}$$

At the nucleus,

$$r = 0$$

Therefore,

$$P = 0$$

As r increases, the factor r^2 initially increases the probability.

At large r , the exponential factor e^{-2r/a_0} dominates and the probability decreases towards zero. Hence the curve starts from zero, rises to a single maximum, and then falls asymptotically to zero. This corresponds to option D.

COMMON TRAPS

- **Confusing orbital density with radial probability.** Radial probability in a shell is proportional to $4\pi r^2 |\psi|^2$, not just $|\psi|^2$. The r^2 factor makes $P(0) = 0$. *Avoid it:* Whenever the question says probability in a spherical shell, explicitly write $P dr = 4\pi r^2 |\psi|^2 dr$ before choosing the graph.
- **Treating shell probability as cumulative probability inside a sphere.** Shell probability is a density over radius and can rise and fall; cumulative probability from 0 to r only increases. *Avoid it:* Underline "spherical shell" and "thickness dr "; do not replace it with "sphere of radius r ".

REVISE The distinction between ψ , $|\psi|^2$, and $4\pi r^2 |\psi|^2$. Memorize the qualitative $1s$ radial probability graph: zero at nucleus, one peak at a_0 , asymptotic decay.

13 Answer: 6

Ref 13942

Medium ~1.5 min Quantum numbers

For a given principal quantum number $n = 4$, the allowed values of azimuthal quantum number l are:

$$l = 0, 1, 2, 3$$

The magnetic quantum number m_l can take values from $-l$ to

$$+l.$$

We need:

$$|m_l| = 1$$

So:

$$m_l = +1$$

or

$$m_l = -1$$

Now check which l values can have $m_l = \pm 1$.

For $l = 0$, only $m_l = 0$ is possible, so it is not counted.

For $l = 1$, $m_l = -1, 0, +1$, so two orbitals are possible.

For $l = 2$, $m_l = -2, -1, 0, +1, +2$, so two orbitals are possible.

For $l = 3$, $m_l = -3, -2, -1, 0, +1, +2, +3$, so two orbitals are possible.

Total number of orbitals satisfying $n = 4$ and $|m_l| = 1$ is:

$$2 + 2 + 2 = 6$$

For each orbital, only one electron can have the specified spin:

$$m_s = -1/2$$

Therefore, the total number of electrons is:

$$6$$

COMMON TRAPS

- **Treating $|m_l| = 1$ as only $m_l = +1$.** $|m_l| = 1$ means m_l can be $+1$ or -1 . Both are allowed if the chosen l is at least 1. *Avoid it:* Write the two possibilities explicitly before counting: $m_l = +1$ and $m_l = -1$.
- **Including $l = 4$ for $n = 4$.** For a given n , l ranges from 0 to $n-1$, so for $n = 4$ only $l = 0, 1, 2, 3$ are allowed. *Avoid it:* Before using m_l , list allowed l values using $l = 0$ to $n-1$.

REVISE Allowed quantum number ranges: $l = 0$ to $n-1$, $m_l = -l$ to $+l$, $m_s = \pm 1/2$. Practice counting states by listing allowed tuples (n, l, m_l, m_s) rather than using memorized shell capacities directly.

14 Answer: A

Ref 13829

Medium ~1 min Radius ratio and octahedral voids in ionic solids

From the given arrangement, A^+ is located in an octahedral void formed by surrounding X^- ions.

For a cation just fitting into an octahedral void, the limiting radius ratio is:

$$r_{\text{void}} = 0.414 r_{\text{sphere}}$$

Here, the sphere is the anion X^- , so:

$$r_{A^+} = 0.414r_{X^-}$$

Given:

$$r_{X^-} = 250 \text{ pm}$$

Therefore:

$$r_{A^+} = 0.414 \times 250$$

$$r_{A^+} = 103.5 \text{ pm}$$

Thus, approximately:

$$r_{A^+} \approx 104 \text{ pm}$$

Hence, the correct option is A.

COMMON TRAPS

- **Using tetrahedral radius ratio 0.225 instead of octahedral 0.414.** For an octahedral void, the limiting radius ratio is $r_{\text{cation}}/r_{\text{anion}} = \sqrt{2} - 1 \approx 0.414$. For tetrahedral void, it is ≈ 0.225 . *Avoid it:* Before substituting numbers, write the coordination/void type next to the formula: octahedral $\rightarrow$ 6 surrounding ions $\rightarrow$ 0.414; tetrahedral $\rightarrow$ 4 surrounding ions $\rightarrow$ 0.225.
- **Using radius ratio backwards.** The void radius is the radius of the cation just fitting in it, so $r_{A^+} = 0.414r_{X^-}$, not the inverse. *Avoid it:* Check physical size: in AX ionic solids, A^+ in a void should usually be smaller than X^- . A result bigger than 250 pm is impossible for this calculation.

REVISE Memorize radius-ratio constants with their coordination numbers, not as isolated numbers. In every radius-ratio problem, first write $r^+/r^- = \text{constant}$ and label which ion is cation and which is anion.

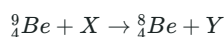
15 Answer: A, B

Ref 13893

Medium ~2 min Nuclear transmutation and conservation laws

In a nuclear reaction, both mass number and atomic number must be conserved.

Given reaction:



Check option A: $X = \gamma$, $Y = n$.

A gamma photon has mass number 0 and atomic number 0. A neutron has mass number 1 and atomic number 0.

Left side mass number:

$$9 + 0 = 9$$

Right side mass number:

$$8 + 1 = 9$$

Left side atomic number:

$$4 + 0 = 4$$

Right side atomic number:

$$4 + 0 = 4$$

So option A is valid.

Check option B: $X = p$, $Y = D$.

A proton is ${}^1_1p$ and deuteron is ${}^2_1D$.

Left side mass number:

$$9 + 1 = 10$$

Right side mass number:

$$8 + 2 = 10$$

Left side atomic number:

$$4 + 1 = 5$$

Right side atomic number:

$$4 + 1 = 5$$

So option B is valid.

Check option C: $X = \alpha$, $Y = D$.

An alpha particle is ${}^4_2\alpha$.

Left side mass number:

$$9 + 4 = 13$$

Right side mass number:

$$8 + 2 = 10$$

Mass number is not conserved, so option C is invalid.

Check option D: $X = \gamma$, $Y = p$.

Left side mass number:

$$9 + 0 = 9$$

Right side mass number:

$$8 + 1 = 9$$

Left side atomic number:

$$4 + 0 = 4$$

Right side atomic number:

$$4 + 1 = 5$$

Atomic number is not conserved, so option D is invalid.

Therefore, the correct options are A and B.

COMMON TRAPS

- **Treating it as a single-correct MCQ and stopping after option A.** Each listed pair must be independently checked by conservation of mass number A and atomic number Z. *Avoid it:* After finding one valid option, continue testing all options using two columns: total mass number and total atomic number.
- **Misassigning gamma photon as having mass or charge.** Gamma radiation changes only energy state, not nucleon count or proton count; represent it as ${}^0_0\gamma$. *Avoid it:* Write nuclear notation above each symbol before adding: $\gamma = {}^0_0\gamma$, $n = {}^1_0n$, $p = {}^1_1p$, $D = {}^2_1D$, $\alpha = {}^4_2\alpha$.

REVISE Memorize common nuclear particles: $\gamma = {}^0_0\gamma$, $n = {}^1_0n$, $p = {}^1_1p$, $D = {}^2_1D$, $\alpha = {}^4_2\alpha$. For multi-correct JEE Advanced questions, verify every option even after finding a correct one.

16 Answer: C

Ref 13720

Easy ~1 min Bohr model of hydrogen atom

QUICK APPROACH Start by using Bohr's quantization of angular momentum to find the velocity of the electron in the n th orbit.

For an electron in the n th Bohr orbit, Bohr's angular momentum quantization gives

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

So the speed is

$$v = \frac{nh}{2\pi mr}$$

For hydrogen atom, the radius of the n th orbit is

$$r_n = n^2 a_0$$

For the second Bohr orbit,

$$n = 2$$

$$r_2 = 2^2 a_0$$

$$r_2 = 4a_0$$

Substitute in the velocity formula:

$$v = \frac{2h}{2\pi m \cdot 4a_0}$$

$$v = \frac{h}{4\pi ma_0}$$

Kinetic energy is

$$K = \frac{1}{2}mv^2$$

Substitute $v = \frac{h}{4\pi ma_0}$:

$$K = \frac{1}{2}m \left(\frac{h}{4\pi ma_0} \right)^2$$

$$K = \frac{1}{2}m \cdot \frac{h^2}{16\pi^2 m^2 a_0^2}$$

$$K = \frac{h^2}{32\pi^2 ma_0^2}$$

Therefore, the correct option is C.

COMMON TRAPS

- **Forgetting to square velocity in kinetic energy.** Squaring $v = h/(4\pi ma_0)$ gives $v^2 = h^2/(16\pi^2 m^2 a_0^2)$. *Avoid it:* Put the entire fraction in parentheses before squaring and check that π , m , and a_0 are squared in v^2 .
- **Missing the factor 1/2 in kinetic energy.** Kinetic energy is half mass times speed squared: $K = 1/2 mv^2$. *Avoid it:* Before matching options, compare denominator from v^2 (16) and then double it due to 1/2, giving 32.

REVISE The two Bohr model formulas used here: $mvr = nh/(2\pi)$ and $r_n = n^2 a_0$. Practice deriving K for $n=1,2,3$ from $v = nh/(2\pi m r_n)$ to see the n -dependence.

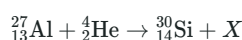
17 Answer: A

Ref 13566

Medium ~1.5 min Artificial transmutation and radioactive decay

Use conservation of mass number and atomic number in every nuclear reaction.

For path (i):



Total mass number on the left is:

$$27 + 4 = 31$$

Mass number of silicon is:

$$30$$

Therefore, mass number of X is:

$$31 - 30 = 1$$

Total atomic number on the left is:

$$13 + 2 = 15$$

Atomic number of silicon is:

$$14$$

Therefore, atomic number of X is:

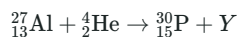
$$15 - 14 = 1$$

So,



Hence, X is a proton.

For path (ii):



Total mass number on the left is:

$$27 + 4 = 31$$

Mass number of phosphorus is:

$$30$$

Therefore, mass number of Y is:

$$31 - 30 = 1$$

Total atomic number on the left is:

$$13 + 2 = 15$$

Atomic number of phosphorus is:

$$15$$

Therefore, atomic number of Y is:

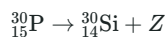
$$15 - 15 = 0$$

So,



Hence, Y is a neutron.

Now consider the decay:



Mass number remains unchanged:

$$30 \rightarrow 30$$

So, Z has mass number:

$$0$$

Atomic number changes from 15 to 14. Therefore, Z must have atomic number:

$$15 - 14 = 1$$

A particle with mass number 0 and atomic number +1 is a positron:



Therefore, X , Y , and Z are respectively proton, neutron, and positron.

Correct option: A

COMMON TRAPS

- **Swapping mass number and atomic number in nuclear notation.** In ${}^A_ZX$, conserve A separately and Z separately in every nuclear equation. *Avoid it:* Label every nucleus as top= A , bottom= Z before adding/subtracting.
- **Identifying X using only mass number.** A proton is ${}^1_1\text{H}$; a neutron is ${}^1_0\text{n}$. Atomic number distinguishes them. *Avoid it:* Never identify a particle until both mass number and atomic number are found.

REVIEW Memorize particle notation as ordered pairs (A, Z): proton (1,+1), neutron (1,0), positron (0,+1), electron (0,-1), alpha (4,2). For every nuclear equation, write two balance equations before naming the unknown particle.

18 Answer: 9

Ref 13580

Easy ~1 min Quantum numbers and maximum number of electrons

For a given principal quantum number n , the total number of orbitals in that shell is given by:

$$\text{Number of orbitals} = n^2$$

Here:

$$n = 3$$

So, the number of orbitals in the third shell is:

$$n^2 = 3^2$$

$$n^2 = 9$$

These orbitals are distributed as:

$$3s : 1 \text{ orbital}$$

$$3p : 3 \text{ orbitals}$$

$$3d : 5 \text{ orbitals}$$

Total orbitals:

$$1 + 3 + 5 = 9$$

Each orbital can contain two electrons, one with spin quantum number $m_s = +\frac{1}{2}$ and one with spin quantum number $m_s = -\frac{1}{2}$.

The question asks for the maximum number of electrons with $m_s = -\frac{1}{2}$ only.

Since each of the 9 orbitals can have one electron with spin

$m_s = -\frac{1}{2}$, the maximum number of such electrons is:

9

Therefore, the answer is 9.

19 Answer: A

Ref 13589

Medium ~1.5 min Hydrogen spectrum and Rydberg formula

QUICK APPROACH Start by using the Rydberg formula for hydrogen-like atoms and identify the quantum numbers for the Balmer series transitions.

For a hydrogen-like species, the Rydberg formula is

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

For the Balmer series, the final level is

$$n_1 = 2$$

The first spectral line in the Balmer series of hydrogen corresponds to the transition

$$n_2 = 3 \rightarrow n_1 = 2$$

For hydrogen, $Z = 1$, so

$$\frac{1}{6561} = R \left(\frac{1}{2^2} - \frac{1}{3^2} \right)$$

$$\frac{1}{6561} = R \left(\frac{1}{4} - \frac{1}{9} \right)$$

$$\frac{1}{6561} = R \left(\frac{5}{36} \right)$$

The second spectral line in the Balmer series of singly-ionized helium corresponds to

$$n_2 = 4 \rightarrow n_1 = 2$$

For singly-ionized helium, $Z = 2$. Therefore,

$$\frac{1}{\lambda} = R(2)^2 \left(\frac{1}{2^2} - \frac{1}{4^2} \right)$$

$$\frac{1}{\lambda} = 4R \left(\frac{1}{4} - \frac{1}{16} \right)$$

$$\frac{1}{\lambda} = 4R \left(\frac{3}{16} \right)$$

$$\frac{1}{\lambda} = \frac{3R}{4}$$

Now compare with the hydrogen first Balmer line:

$$\frac{1}{6561} = \frac{5R}{36}$$

So,

$$R = \frac{36}{5 \times 6561}$$

Substitute this in the helium expression:

$$\frac{1}{\lambda} = \frac{3}{4} \times \frac{36}{5 \times 6561}$$

$$\frac{1}{\lambda} = \frac{27}{5 \times 6561}$$

Therefore,

$$\lambda = \frac{5 \times 6561}{27}$$

$$\lambda = 5 \times 243$$

$$\lambda = 1215 \text{ Å}$$

Hence, the correct option is A.

COMMON TRAPS

- **Using the first Balmer transition for helium instead of the second.** In a given series, first line means $n_2 = n_1 + 1$, second line means $n_2 = n_1 + 2$. For Balmer, $n_1 = 2$, so first is $3 \rightarrow 2$ and second is $4 \rightarrow 2$. *Avoid it:* Before applying Z^2 scaling, write the transition explicitly for each species: H first Balmer = $3 \rightarrow 2$; He^+ second Balmer = $4 \rightarrow 2$.
- **Treating singly ionized helium as $Z = 1$ instead of $Z = 2$.** For He^+ , the nucleus still has $Z = 2$ protons; one electron has been removed, making it hydrogen-like. Rydberg formula uses nuclear charge Z , not ionic charge. *Avoid it:* Translate species notation: H has $Z = 1$; He^+ has $Z = 2$; Li^{2+} has $Z = 3$.

REVISE Series definitions by fixed final level: Lyman $n_1 = 1$, Balmer $n_1 = 2$, Paschen $n_1 = 3$. Practice identifying Z for hydrogen-like species: H, He^+ , Li^{2+} , Be^{3+} .

20 Answer: 4

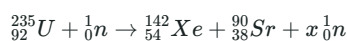
Ref 13448

Easy ~1 min Controlled nuclear fission and balancing nuclear equations

In controlled nuclear fission of ${}_{92}^{235}\text{U}$, a neutron is first absorbed by uranium.

Let the number of neutrons emitted be x .

The balanced nuclear equation is:



Now conserve atomic number.

Left side atomic number:

$$92 + 0 = 92$$

Right side atomic number:

$$54 + 38 + 0 = 92$$

So atomic number is balanced.

Now conserve mass number.

Left side mass number:

$$235 + 1 = 236$$

Right side mass number:

$$142 + 90 + x = 232 + x$$

Equating mass numbers:

$$236 = 232 + x$$

$$x = 4$$

Therefore, the number of neutrons emitted is 4.

COMMON TRAPS

- **Ignoring the initially absorbed neutron.** For neutron-induced fission of U-235, balance the compound nucleus mass as $235 + 1 = 236$, not just 235. *Avoid it:* Before balancing, write both reactants exactly as in the nuclear equation: " ${}_{92}^{235}\text{U} + {}_0^1\text{n} \rightarrow \dots$ ".
- **Using atomic-number conservation to find x.** Free neutrons change mass number by 1 each, but atomic number by 0 each. Atomic number check gives $92 = 54 + 38$, not x. *Avoid it:* For every emitted particle, read both numbers: in " ${}_0^1\text{n}$ ", superscript 1 goes into mass balance; subscript 0 goes into charge/atomic-number balance.

REVISE Always split nuclear balancing into two rows: mass number A and atomic number Z. In neutron-induced fission, explicitly mark the incident neutron and the emitted neutrons as different terms.

21 Answer: B

Ref 13520

Easy ~0.5 min Azimuthal quantum number and atomic orbitals

QUICK APPROACH Recall that the orbital angular momentum quantum number is the azimuthal quantum number l , which corresponds to the type of orbital (s, p, d, f).

Find n from the energy, then l from the radial node.

Step 1. For Li^{2+} , $E_n = -13.6 Z^2/n^2$ eV with $Z = 3$. S_2 has the hydrogen ground-state energy, -13.6 eV, so $9/n^2 = 1$ and $n = 3$.

Step 2. Radial nodes $= n - l - 1 = 1$, so $l = 3 - 1 - 1 = 1$ (a $3p$ state).

Answer: (B) 1

COMMON TRAPS

- **Using the angular momentum magnitude formula instead of the quantum number asked.** The explanation explicitly says "the orbital angular momentum quantum number is the azimuthal quantum number l ". Options A "0", B "1", C "2", D "3" are dimensionless quantum numbers, not angular momentum values with units of $\hbar$. *Avoid it:* Check whether the options are plain integers or include $\hbar$. If plain integers are listed, the problem is asking for l , not $|L|$.
- **Confusing orbital angular momentum quantum number l with magnetic quantum number m_l .** The exact explanation says "the orbital angular momentum quantum number is the azimuthal quantum number l ". It is not asking for the magnetic quantum number m_l . *Avoid it:* Key phrase check: "azimuthal/orbital angular momentum quantum number" means l ; "magnetic/orientation" means m_l .

REVISE The mapping $s, p, d, f \rightarrow l = 0, 1, 2, 3$ along with the distinction between standard lowercase orbital symbols and arbitrary state labels. Drill allowed values $l = 0$ to $n - 1$ for each n , especially $n=2$ where $l=2$ is not allowed.

22 Answer: C

Ref 13521

Medium ~1 min Energy levels of hydrogen-like species

QUICK APPROACH Use the concept of energy levels in hydrogen-like atoms, where energy is inversely proportional to the square of the principal quantum number (n).

Identify S_1 , then use the hydrogen-like energy formula.

Step 1. Spherically symmetric means $l = 0$; one radial node means $n - 0 - 1 = 1$, so $n = 2$ and S_1 is $2s$.

Step 2. $E = -13.6 \times \frac{3^2}{2^2}$ eV $= 2.25 \times (-13.6$ eV), that is 2.25 times the hydrogen ground-state energy.

Answer: (C) 2.25

COMMON TRAPS

- **Treating 2.25 as an absolute energy instead of a unitless ratio.** Here the choices are dimensionless multiples of the hydrogen atom ground-state energy magnitude/convention used by the problem, not standalone eV values. *Avoid it:* Before calculating, write the requested quantity as $E(S_1)/E_{H, \text{ground}}$ or $E(S_1)/|E_{H, \text{ground}}|$ depending on the convention implied by options.
- **Dropping the square on Z or n in the energy-level ratio.** Hydrogen-like energy levels obey $E_n = -13.6 Z^2/n^2$ eV, so ratios involve squares. *Avoid it:* Write the full formula before substituting numbers; circle the exponents on Z and n.

REVISE Hydrogen-like energy formula $E_n = -13.6 Z^2/n^2$ eV and ratio form relative to hydrogen ground state. Practise extracting Z and n from labelled energy-level diagrams before calculating.

23 Answer: B

Ref 13372

Medium ~1.5 min Stability of resonance structures

QUICK APPROACH Start by applying the criteria for resonance structure stability, focusing on octet completion and the location of charges on more electronegative atoms.

To compare the stability of resonance structures, use the following criteria:

1. Structures in which all atoms have complete octets are more stable.
2. Negative charge is more stable on a more electronegative atom.

3. Positive charge is less favorable on highly electronegative atoms unless octet completion and bonding compensate.
4. Structures with charge separation are less stable, but among charge-separated structures, proper placement of charges matters.

For structure (I):



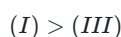
All atoms have complete octets, and the negative charge is on nitrogen, which is electronegative. This is highly stable among the given resonance contributors.

For structure (III):

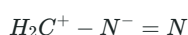


This structure also has complete octets due to the $N \equiv N$ bond. However, the negative charge is on carbon, which is less electronegative than nitrogen. Hence it is less stable than (I).

So,

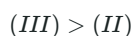


For structure (II):

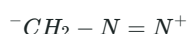


Here carbon bears a positive charge and has an incomplete octet. A carbocationic carbon is electron deficient, making this structure significantly less stable than structures with complete octets.

Thus,



For structure (IV):



This has an unfavorable placement of positive charge on terminal nitrogen and an overall less favorable bonding/electron distribution. Hence it is the least stable contributor among the four.

Therefore, the correct stability order is:



COMMON TRAPS

- **Using electronegativity rule before checking octets.**

Complete octet generally has higher priority than placing negative charge on the more electronegative atom among resonance contributors. *Avoid it:* Before comparing charge positions, count octet electrons on every atom in each contributor.

- **Miscounting $^-CH_2$ in structure III as electron-deficient.**

A carbanion carbon with three sigma bonds plus one lone pair has an octet. *Avoid it:* For every formal negative charge, explicitly draw one lone pair unless valence dictates otherwise.

REVISE Formal charge and octet counting for C and N.

Compare resonance contributors using a fixed checklist: octet first, charge placement second, charge separation/bonding third.

24 Answer: 6

Ref 13384

Medium ~1 min Coordination number in crystalline solids

In crystalline anhydrous $AlCl_3$, aluminium is not present as the simple molecular dimeric form that is commonly observed in vapour phase.

In the solid crystalline state, $AlCl_3$ has a layer-like structure. The chloride ions form a close-packed arrangement, and aluminium ions occupy octahedral voids.

An octahedral environment means that one central atom or ion is surrounded by six nearest neighbours.

So, each aluminium atom is surrounded by 6 chloride ions.

Therefore, the coordination number of aluminium in crystalline $AlCl_3$ is:

6

COMMON TRAPS

- **Using vapour-phase dimer instead of crystalline solid structure.**

The explanation explicitly says "aluminium is not present as the simple molecular dimeric form that is commonly observed in vapour phase"; in crystalline anhydrous $AlCl_3$, Al occupies octahedral sites and has 6 nearest Cl neighbours. *Avoid it:* Before counting bonds/neighbours, identify the physical state named in the stem: crystalline solid vs vapour/molecular form.

- **Equating covalency/valency of Al with coordination number.**

Coordination number in a crystal is the number of nearest neighbouring ions/atoms around a given ion/atom, not the charge or formula subscript. *Avoid it:* Ask: am I counting nearest neighbours in a lattice, or balancing charge/formula? Only nearest neighbours count for coordination number.

REVISE Differences between molecular Al_2Cl_6 and crystalline anhydrous $AlCl_3$. · Practise mapping interstitial sites to coordination numbers: tetrahedral void = 4, octahedral void = 6.

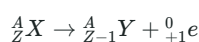
25 Answer: C

Ref 13127

Easy ~1 min Nuclear reactions: positron emission

In positron emission, a proton inside the nucleus is converted into a neutron and a positron is emitted.

The general nuclear change is:



Here, the mass number remains unchanged because the total number of nucleons remains the same.

The atomic number decreases by 1 because one proton changes into one neutron.

Given nuclide is:



After positron emission, the mass number remains:

$$A = 23$$

The atomic number becomes:

$$Z = 11 - 1$$

$$Z = 10$$

So, the resulting nuclide has mass number 23 and atomic number 10.

Therefore, the required ratio of atomic mass to atomic number is:

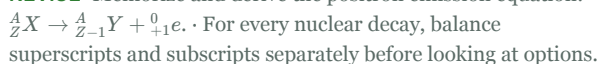
$$\frac{A}{Z} = \frac{23}{10}$$

Hence, the correct option is C.

COMMON TRAPS

- **Treating positron emission as loss of a nucleon, changing A from 23 to 22.** In beta-plus/positron emission, " ${}^A_ZX \rightarrow {}^A_{Z-1}Y + {}^0_{+1}e$ "; the mass number A remains unchanged. *Avoid it:* Balance the top numbers explicitly; initial 23 must equal product A plus 0, so product A = 23.
- **Increasing Z instead of decreasing it for positron emission.** The emitted particle is " ${}^0_{+1}e$ ", so the daughter must have bottom number $Z - 1$ to conserve charge: $11 = Z_{\text{daughter}} + 1$. *Avoid it:* Always balance bottom numbers: $11 = Z_{\text{daughter}} + 1$, hence $Z_{\text{daughter}} = 10$, not 12.

REVISE Memorize and derive the positron emission equation:



Hard

~1.5 min

Stability of resonance structures

QUICK APPROACH Write the formal charge of the nitro nitrogen into each structure, then look for two bonded atoms that carry the same charge.

The least stable resonance form is the one that puts like charges on neighbouring atoms.

Step 1. All four structures are resonance forms of the same nitro-substituted diene, so they differ only in where the formal charges sit.

Step 2. The nitrogen of the nitro group carries a positive formal charge in every structure, balanced by a negative charge on one oxygen.

Step 3. In structure (A), the carbon bonded directly to that nitrogen also carries a positive charge. Two positive centres on bonded atoms repel strongly, and the electron-withdrawing nitro group makes the carbocation even poorer in electrons. This raises the energy of the form sharply.

Step 4. In structure (B), the carbon next to the nitrogen carries a negative charge, so the neighbouring opposite charges attract and the form is comparatively stabilised.

Step 5. In structures (C) and (D), the charges lie along the conjugated chain and no positive carbon sits beside the positive nitrogen.

Step 6. Hence structure (A), with adjacent like charges, contributes least and is the least stable.

Answer: (A) Structure (A) in the figure

COMMON TRAPS

- **Counting charges instead of judging where they sit.** Resonance forms with the same number of formal charges differ in stability mainly by how those charges are placed relative to each other. *Avoid it:* Check every bonded pair of atoms and reject first any form that puts like charges side by side.
- **Forgetting the positive charge on the nitro nitrogen.** The nitrogen of a nitro group always carries a positive formal charge, so a carbocation bonded to it places two positive centres together. *Avoid it:* Draw the charges of the nitro group into every structure before comparing the carbon charges.

REVISE The rules for ranking resonance contributors by stability. • Formal charges in the nitro group.



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