ABC CHEMISTRY

Mr. Aniket Bhardwaj · 15+ Years Mentorship

Atomic Structure

Premium CSIR-NET PYQ Book

49 Previous-Year Questions · 37 with verified answers · Distractor Analysis

3-Slide Solutions | Distractor Analysis | Exam Tricks | Revision Sheets

CSIR-NET · GATE · IIT-JAM — 1 Topics · 49 Real PYQs

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Course Contents

1 Topics · 49 PYQs

1	**Atomic Structure – General** 49 Qs E 13 · M 35 · H 1	100%

Legend: **E** Easy **M** Medium **H** Hard · **%** = exam weightage (share of the chapter)

TOPIC 1

Atomic Structure – General

49 questions · Easy 13 | Medium 35 | Hard 1 · PYQ frequency: Rare

Q1

The function e^ax² (α > 0) is not an acceptable wave function for bound system, because

A. it is not continuous

B. it is multivalued

C. it is not normalisable

D. all of these

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Atomic Structure – General

PYQ FREQUENCY
Rare · 2 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Part B

MEMORY HOOK
'n−l−1 radial, l angular, n−1 total'.

Correct Answer C it is not normalisable

CONCEPT

Hydrogen-like energies $E_n = -13.6\ Z^2/n^2$ eV; radial nodes $n-l-1$, angular nodes l; quantum numbers n, l, m_l, m_s; Bohr radius $a_0 = 52.9$ pm; de Broglie $\lambda = h/mv$; Heisenberg $\Delta x \Delta p \geq \hbar/2$; Aufbau, Pauli, Hund.

↓

LOGIC / WORKING

- e^(αx²) with α > 0 grows without bound as |x| → ∞, so ∫|ψ|²dx diverges — the function cannot be normalised (it is continuous and single-valued).
- Therefore the answer is (C).

FINAL: (C) it is not normalisable

SHORTCUT / EXAM TRICK

Orbital energy order for multi-electron atoms by (n+l), tie → lower n; for hydrogen only n matters.

COMMON MISTAKE

Counting the angular node of a p orbital as a radial node; forgetting Z^2 in hydrogen-like ions.

EXAM TIP

Degeneracy of level n in hydrogen = n^2 ($2n^2$ with spin).

MEMORY TRICK

'n−l−1 radial, l angular, n−1 total'.

Why the Other Options Are Wrong

Correct answer: C

A **it is not continuous**

Why (C) is the key — e^(αx²) with α > 0 grows without bound as |x| → ∞, so ∫|ψ|²dx diverges — the function cannot be normalised (it is continuous and single-valued).

B **it is multivalued**

Ruled out: Counting the angular node of a p orbital as a radial node; forgetting Z^2 in hydrogen-like ions.

D **all of these**

Ruled out: Degeneracy of level n in hydrogen = n^2 ($2n^2$ with spin).

Q2

The 2s orbital of H – atom has radial node at $2a_0$ because ψ_{2s} is proportional to

A. $((1)/(2) + (r)/(a_0))$

B. $(2 + (r)/(a_0))$

C. $(2 - (r)/(a_0))$

D. $(2 - (r)/(2a_0))$

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Atomic Structure – General

PYQ FREQUENCY
Rare · 2 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'n−l−1 radial, l angular, n−1 total'.

Correct Answer C (2 - (r)/(a_0))

CONCEPT

Hydrogen-like energies $E_n = -13.6\ Z^2/n^2$ eV; radial nodes n−l−1, angular nodes l; quantum numbers n, l, m_l, m_s; Bohr radius $a_0 = 52.9$ pm; de Broglie $\lambda = h/mv$; Heisenberg $\Delta x \Delta p \geq \hbar/2$; Aufbau, Pauli, Hund.

↓

LOGIC / WORKING

- $\psi_{2s} \propto (2 - r/a_0)e^{(-r/2a_0)}$; the polynomial factor vanishes at $r = 2a_0$, giving the single radial node (n − l − 1 = 1).
- Therefore the answer is (C).

FINAL: (C) (2 - (r)/(a_0))

SHORTCUT / EXAM TRICK

Orbital energy order for multi-electron atoms by (n+l), tie → lower n; for hydrogen only n matters.

COMMON MISTAKE

Counting the angular node of a p orbital as a radial node; forgetting Z^2 in hydrogen-like ions.

EXAM TIP

Degeneracy of level n in hydrogen = n^2 ($2n^2$ with spin).

MEMORY TRICK

'n−l−1 radial, l angular, n−1 total'.

Why the Other Options Are Wrong

Correct answer: C

A **((1)/(2) + (r)/(a_0))**

Why (C) is the key — $\psi_{2s} \propto (2 - r/a_0)e^{(-r/2a_0)}$; the polynomial factor vanishes at $r = 2a_0$, giving the single radial node ($n - l - 1 = 1$).

B **(2 + (r)/(a_0))**

Ruled out: Counting the angular node of a p orbital as a radial node; forgetting Z^2 in hydrogen-like ions.

D **(2 - (r)/(2a_0))**

Ruled out: Degeneracy of level n in hydrogen = n^2 ($2n^2$ with spin).

Q3

As per Huckel theory, π-electron energy levels of cyclobutadiene are (a) α + 2β, α + β, α - β, α - 2β (b) α + 2β, α - β, α - β, α - 2β (c) α + 2β, α, α, α - 2β (c) α + β, α - β, α - β, α - 2β

SELF-PRACTICE answer on record: (C) — options were not printed in the source.

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Atomic Structure – General

PYQ FREQUENCY
Rare · 2 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Part B

MEMORY HOOK
'n−l−1 radial, l angular, n−1 total'.

Q4

Given that β = -75 kJ/mol, cyclobutadiene is

A. paramagnetic and its lowest absorption energy is 150 kJ

B. paramagnetic and its lowest absorption energy is 75 kJ

C. dimagnetic and its lowest absorption energy is 75 kJ

D. diamagnetic and its lowest absorption energy is 150 kJ

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Atomic Structure – General

PYQ FREQUENCY
Rare · 2 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Part B

MEMORY HOOK
'n−l−1 radial, l angular, n−1 total'.

Correct Answer A paramagnetic and its lowest absorption energy is 150 kJ

CONCEPT

Hydrogen-like energies $E_n = -13.6\ Z^2/n^2$ eV; radial nodes $n-l-1$, angular nodes l; quantum numbers n, l, m_l, m_s; Bohr radius $a_0 = 52.9$ pm; de Broglie $\lambda = h/mv$; Heisenberg $\Delta x \Delta p \geq \hbar/2$; Aufbau, Pauli, Hund.

↓

LOGIC / WORKING

- Two electrons fill α + 2β, the next two half-fill the degenerate α pair with parallel spins (Hund) → paramagnetic (triplet). The lowest excitation α + 2β → α or α → α − 2β costs $2|\beta| = 150$ kJ mol^{-1}.
- Therefore the answer is (A).

FINAL: (A) paramagnetic and its lowest absorption energy is 150 kJ

SHORTCUT / EXAM TRICK

Orbital energy order for multi-electron atoms by (n+l), tie → lower n; for hydrogen only n matters.

COMMON MISTAKE

Counting the angular node of a p orbital as a radial node; forgetting Z^2 in hydrogen-like ions.

EXAM TIP

Degeneracy of level n in hydrogen = n^2 ($2n^2$ with spin).

MEMORY TRICK

'n−l−1 radial, l angular, n−1 total'.

Why the Other Options Are Wrong

Correct answer: A

B **paramagnetic and its lowest absorption energy is 75 kJ**

Why (A) is the key — Two electrons fill α + 2β, the next two half-fill the degenerate α pair with parallel spins (Hund) → paramagnetic (triplet). The lowest excitation α + 2β → α or α → α − 2β costs 2|β| = 150 kJ mol^{-1}.

C **dimagnetic and its lowest absorption energy is 75 kJ**

Ruled out: Counting the angular node of a p orbital as a radial node; forgetting Z^2 in hydrogen-like ions.

D **diamagnetic and its lowest absorption energy is 150 kJ**

Ruled out: Degeneracy of level n in hydrogen = n^2 ($2n^2$ with spin).

Q5 To demonstrate the variational principle, a trial function $\psi = C_1 \frac{\psi_{2s}+\psi_{3s}}{\sqrt{(2)}} + C_2 \frac{\psi_{2s}-\psi_{3s}}{\sqrt{(2)}}$ where C_1 and C_2 are the variational parameters and ψ_{2s} and ψ_{3s} are the 2s, and 3s orbitals of the hydrogen atom, is constructed. The corresponding secular determinant for the hydrogen atom (in eV) is

A 3.4(1+4/9)2-E & 3.4(1-4/9)/2 3.4(1-4/9)/2 & 3.4(1+4/9)2-E

B 3.4(1+4/9)2-E & 3.4(1-4/9)/2 3.4(1-4/9)/2 & 3.4(1-4/9)2-E

C 3.4(1+4/9)2-E & 3.4(1+4/9)/2 3.4(1-4/9)/2 & 3.4(1-4/9)2-E

D 3.4(1+4/9)2-E & 0 0 & 3.4(1+4/9)2-E

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Atomic Structure – General

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EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'n−l−1 radial, l angular, n−1 total'.

Correct Answer A 3.4(1+4/9)2-E & 3.4(1-4/9)/2 3.4(1-4/9)/2 & 3.4(1+4/9)2-E

CONCEPT

Hydrogen-like energies $E_n = -13.6\ Z^2/n^2$ eV; radial nodes n−l−1, angular nodes l; quantum numbers n, l, m_l, m_s; Bohr radius $a_0 = 52.9$ pm; de Broglie $\lambda = h/mv$; Heisenberg $\Delta x \Delta p \geq \hbar/2$; Aufbau, Pauli, Hund.

↓

LOGIC / WORKING

- With $E_{2s} = -3.4$ eV and $E_{3s} = -3.4(4/9)$ eV: for the ± combinations $H_{11} = H_{22} = (E_{2s} + E_{3s})/2 = -3.4(1 + 4/9)/2$ and $H_{12} = (E_{2s} - E_{3s})/2 = -3.4(1 - 4/9)/2$ (orthonormal basis, $S_{12} = 0$). The determinant with equal diagonal terms and that off-diagonal term is option (a).
- Therefore the answer is (A).

FINAL: (A) 3.4(1+4/9)2-E & 3.4(1-4/9)/2 3.4(1-4/9)/2 & 3.4(1+4/9)2-E

SHORTCUT / EXAM TRICK

Orbital energy order for multi-electron atoms by (n+l), tie → lower n; for hydrogen only n matters.

COMMON MISTAKE

Counting the angular node of a p orbital as a radial node; forgetting Z^2 in hydrogen-like ions.

EXAM TIP

Degeneracy of level n in hydrogen = n^2 ($2n^2$ with spin).

MEMORY TRICK

'n−l−1 radial, l angular, n−1 total'.

Why the Other Options Are Wrong

Correct answer: A

B

3.4(1+4/9)2-E & 3.4(1-4/9)/2 3.4(1-4/9)/2 & 3.4(1-4/9)2-E

Why (A) is the key — With $E_{2s} = -3.4$ eV and $E_{3s} = -3.4(4/9)$ eV: for the ± combinations $H_{11} = H_{22} = (E_{2s} + E_{3s})/2 = -3.4(1 + 4/9)/2$ and $H_{12} = (E_{2s} - E_{3s})/2 = -3.4(1 - 4/9)/2$ (orthonormal basis, $S_{12} = 0$). The determinant with equal diagonal terms and that off-diagonal term is option (a).

C

3.4(1+4/9)2-E & 3.4(1+4/9)/2 3.4(1-4/9)/2 & 3.4(1-4/9)2-E

Ruled out: Counting the angular node of a p orbital as a radial node; forgetting Z^2 in hydrogen-like ions.

D

3.4(1+4/9)2-E & 0 0 & 3.4(1+4/9)2-E

Ruled out: Degeneracy of level n in hydrogen = n^2 ($2n^2$ with spin).

Q6

Which of the following pairs of operators commute?

A. x and (d)/(dx)

B. (d)/(dx) and $(d^2)/(dx^2) + 2(d)/(dx)$

C. $x^2(d)/(dx)$ and $(d^2)/(dx^2)$

D. x^2 and (d)/(dx)

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Atomic Structure – General

PYQ FREQUENCY
Rare · 2 papers

REVISION PRIORITY
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EXPECTED LEVEL
Part B

MEMORY HOOK
'n−l−1 radial, l angular, n−1 total'.

Correct Answer B (d)/(dx) and (d²)/(dx²) + 2(d)/(dx)

CONCEPT

Hydrogen-like energies $E_n = -13.6\ Z^2/n^2$ eV; radial nodes n−l−1, angular nodes l; quantum numbers n, l, m_l, m_s; Bohr radius $a_0 = 52.9$ pm; de Broglie $\lambda = h/mv$; Heisenberg $\Delta x \Delta p \geq \hbar/2$; Aufbau, Pauli, Hund.

↓

LOGIC / WORKING

- Any two operators that are polynomials in the same operator commute: d/dx commutes with $d^2/dx^2 + 2\ d/dx$. x does not commute with d/dx ([x, d/dx] = −1), nor does x^2 (gives −2x), nor $x^2 d/dx$ with d^2/dx^2.
- Therefore the answer is (B).

FINAL: (B) (d)/(dx) and (d²)/(dx²) + 2(d)/(dx)

SHORTCUT / EXAM TRICK

Orbital energy order for multi-electron atoms by (n+l), tie → lower n; for hydrogen only n matters.

COMMON MISTAKE

Counting the angular node of a p orbital as a radial node; forgetting Z^2 in hydrogen-like ions.

EXAM TIP

Degeneracy of level n in hydrogen = n^2 ($2n^2$ with spin).

MEMORY TRICK

'n−l−1 radial, l angular, n−1 total'.

Why the Other Options Are Wrong

Correct answer: B

A — **x and (d)/(dx)**

Why (B) is the key — Any two operators that are polynomials in the same operator commute: d/dx commutes with $d^2/dx^2 + 2\,d/dx$. x does not commute with d/dx ([x, d/dx] = −1), nor does x^2 (gives −2x), nor $x^2 d/dx$ with d^2/dx^2.

C — **x^2(d)/(dx) and (d^2)/(dx^2)**

Ruled out: Counting the angular node of a p orbital as a radial node; forgetting Z^2 in hydrogen-like ions.

D — **x^2 and (d)/(dx)**

Ruled out: Degeneracy of level n in hydrogen = n^2 ($2n^2$ with spin).

Q7

The first excited state wavefunction for a particle in a box that spans from -a to +a is

A. √((1)/(a))cos((π x)/(a))

B. √((1)/(a))sin((π x)/(a))

C. √((2)/(a))cos((2π x)/(a))

D. √((2)/(a))sin((2π x)/(a))

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Atomic Structure – General

PYQ FREQUENCY
Rare · 2 papers

REVISION PRIORITY
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EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'n−l−1 radial, l angular, n−1 total'.

Correct Answer B $\sqrt{(1)/(a)}\sin((\pi x)/(a))$

CONCEPT

Hydrogen-like energies $E_n = -13.6\ Z^2/n^2$ eV; radial nodes n−l−1, angular nodes l; quantum numbers n, l, m_l, m_s; Bohr radius $a_0 = 52.9$ pm; de Broglie $\lambda = h/mv$; Heisenberg $\Delta x \Delta p \geq \hbar/2$; Aufbau, Pauli, Hund.

↓

LOGIC / WORKING

- For a box from −a to +a (length 2a) the states alternate even/odd: ground $\sqrt{(1/a)}\cos(\pi x/2a)$, first excited $\sqrt{(1/a)}\sin(\pi x/a)$ (one node at the centre, normalised over length 2a).
- Therefore the answer is (B).

FINAL: (B) $\sqrt{(1)/(a)}\sin((\pi x)/(a))$

SHORTCUT / EXAM TRICK

Orbital energy order for multi-electron atoms by (n+l), tie → lower n; for hydrogen only n matters.

COMMON MISTAKE

Counting the angular node of a p orbital as a radial node; forgetting Z^2 in hydrogen-like ions.

EXAM TIP

Degeneracy of level n in hydrogen = n^2 ($2n^2$ with spin).

MEMORY TRICK

'n−l−1 radial, l angular, n−1 total'.

Why the Other Options Are Wrong

Correct answer: B

A **√((1)/(a))cos((π x)/(a))**

Why (B) is the key — For a box from −a to +a (length 2a) the states alternate even/odd: ground √(1/a)cos(πx/2a), first excited √(1/a)sin(πx/a) (one node at the centre, normalised over length 2a).

C **√((2)/(a))cos((2π x)/(a))**

Ruled out: Counting the angular node of a p orbital as a radial node; forgetting Z^2 in hydrogen-like ions.

D **√((2)/(a))sin((2π x)/(a))**

Ruled out: Degeneracy of level n in hydrogen = n^2 ($2n^2$ with spin).

Q8

A perturbation V = δ(x - a/2) is introduced in the box. The first order energy correction to the first excited state is.

A. 0

B. 2/a

C. 1/a

D. 1/2a

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Atomic Structure – General

PYQ FREQUENCY
Rare · 2 papers

REVISION PRIORITY
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EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'n−l−1 radial, l angular, n−1 total'.

Correct Answer A 0

CONCEPT

Hydrogen-like energies $E_n = -13.6\ Z^2/n^2$ eV; radial nodes n−l−1, angular nodes l; quantum numbers n, l, m_l, m_s; Bohr radius $a_0 = 52.9$ pm; de Broglie $\lambda = h/mv$; Heisenberg $\Delta x \Delta p \geq \hbar/2$; Aufbau, Pauli, Hund.

↓

LOGIC / WORKING

- $E^{(1)} = \langle\psi_2|\delta(x - a/2)|\psi_2\rangle = |\psi_2(a/2)|^2 = (2/a)\sin^2(\pi) = 0$ — the first excited state has a node at the box centre. (The printed key 1/a is wrong; 2/a would be the ground-state correction.)
- Therefore the answer is (A).

FINAL: (A) 0

SHORTCUT / EXAM TRICK

Orbital energy order for multi-electron atoms by (n+l), tie → lower n; for hydrogen only n matters.

COMMON MISTAKE

Counting the angular node of a p orbital as a radial node; forgetting Z^2 in hydrogen-like ions.

EXAM TIP

Degeneracy of level n in hydrogen = n^2 ($2n^2$ with spin).

MEMORY TRICK

'n−l−1 radial, l angular, n−1 total'.

Why the Other Options Are Wrong

Correct answer: A

B **2/a**

Why (A) is the key — $E^{(1)} = \langle\psi_2|\delta(x - a/2)|\psi_2\rangle = |\psi_2(a/2)|^2 = (2/a)\sin^2(\pi) = 0$ — the first excited state has a node at the box centre. (The printed key 1/a is wrong; 2/a would be the ground-state correction.)

C **1/a**

Ruled out: Counting the angular node of a p orbital as a radial node; forgetting Z^2 in hydrogen-like ions.

D **1/2a**

Ruled out: Degeneracy of level n in hydrogen = n^2 ($2n^2$ with spin).

Q9

For a homonuclear diatomic molecule, the bonding molecular orbital is

A. σ_u of lowest energy

B. σ_u of second lowest energy

C. π_g of lowest energy

D. π_u of lowest energy

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Atomic Structure – General

PYQ FREQUENCY
Rare · 2 papers

REVISION PRIORITY
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EXPECTED LEVEL
Part B

MEMORY HOOK
'n−l−1 radial, l angular, n−1 total'.

Correct Answer D π_u of lowest energy

CONCEPT

Hydrogen-like energies $E_n = -13.6\ Z^2/n^2$ eV; radial nodes n−l−1, angular nodes l; quantum numbers n, l, m_l, m_s; Bohr radius $a_0 = 52.9$ pm; de Broglie $\lambda = h/mv$; Heisenberg $\Delta x \Delta p \geq \hbar/2$; Aufbau, Pauli, Hund.

↓

LOGIC / WORKING

- Bonding MOs of homonuclear diatomics: σ_g (not σ_u) and π_u; antibonding are σ_u and π_g. Among the options only π_u (lowest) is bonding.
- Therefore the answer is (D).

FINAL: (D) π_u of lowest energy

SHORTCUT / EXAM TRICK

Orbital energy order for multi-electron atoms by (n+l), tie → lower n; for hydrogen only n matters.

COMMON MISTAKE

Counting the angular node of a p orbital as a radial node; forgetting Z^2 in hydrogen-like ions.

EXAM TIP

Degeneracy of level n in hydrogen = n^2 ($2n^2$ with spin).

MEMORY TRICK

'n−l−1 radial, l angular, n−1 total'.

Why the Other Options Are Wrong

Correct answer: D

A **σ_u of lowest energy**

Why (D) is the key — Bonding MOs of homonuclear diatomics: σ_g (not σ_u) and π_u; antibonding are σ_u and π_g. Among the options only π_u (lowest) is bonding.

B **σ_u of second lowest energy**

Ruled out: Counting the angular node of a p orbital as a radial node; forgetting Z^2 in hydrogen-like ions.

C **π_g of lowest energy**

Ruled out: Degeneracy of level n in hydrogen = n^2 ($2n^2$ with spin).

Q10

The ionisation potential of hydrogen atom is 13.6 eV. The first ionisation potential of a sodium atom, assuming that the energy of its outer electron can be represented by a H – atom like model with an effective nuclear charge of 1.84, is

A. 46.0 eV

B. 11.5 eV

C. 5.1 eV

D. 2.9 eV

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Atomic Structure – General

PYQ FREQUENCY
Rare · 2 papers

REVISION PRIORITY
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EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'n−l−1 radial, l angular, n−1 total'.

Correct Answer C 5.1 eV

CONCEPT

Hydrogen-like energies $E_n = -13.6\ Z^2/n^2$ eV; radial nodes n−l−1, angular nodes l; quantum numbers n, l, m_l, m_s; Bohr radius $a_0 = 52.9$ pm; de Broglie $\lambda = h/mv$; Heisenberg $\Delta x \Delta p \geq \hbar/2$; Aufbau, Pauli, Hund.

↓

LOGIC / WORKING

- Hydrogen-like model: IE = 13.6 Z_{eff}^2/n^2 = 13.6 × $1.84^2/3^2$ = 13.6 × 3.386/9 = 5.1 eV.
- Therefore the answer is (C).

FINAL: (C) 5.1 eV

SHORTCUT / EXAM TRICK

Orbital energy order for multi-electron atoms by (n+l), tie → lower n; for hydrogen only n matters.

COMMON MISTAKE

Counting the angular node of a p orbital as a radial node; forgetting Z^2 in hydrogen-like ions.

EXAM TIP

Degeneracy of level n in hydrogen = n^2 ($2n^2$ with spin).

MEMORY TRICK

'n−l−1 radial, l angular, n−1 total'.

Why the Other Options Are Wrong

Correct answer: C

A **46.0 eV**

Why (C) is the key — Hydrogen-like model: IE = 13.6 Z_{eff}^2/n^2 = 13.6 × $1.84^2/3^2$ = 13.6 × 3.386/9 = 5.1 eV.

B **11.5 eV**

Ruled out: Counting the angular node of a p orbital as a radial node; forgetting Z^2 in hydrogen-like ions.

D **2.9 eV**

Ruled out: Degeneracy of level n in hydrogen = n^2 ($2n^2$ with spin).

Q11

The lifetime of a molecule in an excited electronic state is 10^{-10} s. The uncertainty in the energy (eV) approximately is

A. 2×10^{-5}

B. 3×10^{-6}

C. 0

D. 10^{-14}

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Atomic Structure – General

PYQ FREQUENCY
Rare · 2 papers

REVISION PRIORITY
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EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'n−l−1 radial, l angular, n−1 total'.

Correct Answer B 3×10^{-6}

CONCEPT

Hydrogen-like energies $E_n = -13.6\ Z^2/n^2$ eV; radial nodes n−l−1, angular nodes l; quantum numbers n, l, m_l, m_s; Bohr radius $a_0 = 52.9$ pm; de Broglie $\lambda = h/mv$; Heisenberg $\Delta x \Delta p \geq \hbar/2$; Aufbau, Pauli, Hund.

↓

LOGIC / WORKING

- $\Delta E \approx \hbar/(2\tau) = 1.055\times10^{-34}/(2 \times 10^{-10}) = 5.3\times10^{-25}$ J $= 3.3\times10^{-6}$ eV $\approx 3\times10^{-6}$ eV.
- Therefore the answer is (B).

FINAL: (B) 3×10^{-6}

SHORTCUT / EXAM TRICK

Orbital energy order for multi-electron atoms by (n+l), tie → lower n; for hydrogen only n matters.

COMMON MISTAKE

Counting the angular node of a p orbital as a radial node; forgetting Z^2 in hydrogen-like ions.

EXAM TIP

Degeneracy of level n in hydrogen = n^2 ($2n^2$ with spin).

MEMORY TRICK

'n−l−1 radial, l angular, n−1 total'.

Why the Other Options Are Wrong

Correct answer: B

A 2×10^{-5}

Why (B) is the key — $\Delta E \approx \hbar/(2\tau) = 1.055\times10^{-34}/(2 \times 10^{-10}) = 5.3\times10^{-25}$ J = 3.3×10^{-6} eV ≈ 3×10^{-6} eV.

C 0

Ruled out: Counting the angular node of a p orbital as a radial node; forgetting Z^2 in hydrogen-like ions.

D 10^{-14}

Ruled out: Degeneracy of level n in hydrogen = n^2 ($2n^2$ with spin).

Q12 The wavefunction of a diatomic molecule has the form $\psi = 0.89\varphi_{convalent} + 0.45\varphi_{ionic}$. The chance that both electrons of the bond will be found on the same atom in 100 inspections of teh molecule approximately is

A 79

B 20

C 45

D 60

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Atomic Structure – General

PYQ FREQUENCY
Rare · 2 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'n−l−1 radial, l angular, n−1 total'.

Correct Answer B 20

CONCEPT

Hydrogen-like energies $E_n = -13.6\ Z^2/n^2$ eV; radial nodes $n-l-1$, angular nodes l; quantum numbers n, l, m_l, m_s; Bohr radius $a_0 = 52.9$ pm; de Broglie $\lambda = h/mv$; Heisenberg $\Delta x \Delta p \geq \hbar/2$; Aufbau, Pauli, Hund.

↓

LOGIC / WORKING

- Probability of the ionic structure = $(0.45)^2 = 0.20$ → about 20 out of 100 inspections.
- Therefore the answer is (B).

FINAL: (B) 20

SHORTCUT / EXAM TRICK

Orbital energy order for multi-electron atoms by (n+l), tie → lower n; for hydrogen only n matters.

COMMON MISTAKE

Counting the angular node of a p orbital as a radial node; forgetting Z^2 in hydrogen-like ions.

EXAM TIP

Degeneracy of level n in hydrogen = n^2 ($2n^2$ with spin).

MEMORY TRICK

'n−l−1 radial, l angular, n−1 total'.

Why the Other Options Are Wrong

Correct answer: B

A — **79**

Why (B) is the key — Probability of the ionic structure = $(0.45)^2 = 0.20$ → about 20 out of 100 inspections.

C — **45**

Ruled out: Counting the angular node of a p orbital as a radial node; forgetting Z^2 in hydrogen-like ions.

D — **60**

Ruled out: Degeneracy of level n in hydrogen = n^2 ($2n^2$ with spin).

Q13

The ground state electronic energy (Hartree) of a helium atom, neglecting the inter-electron repulsion, is

A -1.0

B -0.5

C -2.0

D -4.0

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Atomic Structure – General

PYQ FREQUENCY
Rare · 2 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'n−l−1 radial, l angular, n−1 total'.

Correct Answer D -4.0

CONCEPT

Hydrogen-like energies $E_n = -13.6\ Z^2/n^2$ eV; radial nodes n−l−1, angular nodes l; quantum numbers n, l, m_l, m_s; Bohr radius $a_0 = 52.9$ pm; de Broglie $\lambda = h/mv$; Heisenberg $\Delta x \Delta p \geq \hbar/2$; Aufbau, Pauli, Hund.

↓

LOGIC / WORKING

- Without repulsion each electron is hydrogen-like with Z = 2: $E = -Z^2/2 = -2$ hartree each → total −4 hartree (the real value is −2.90).
- Therefore the answer is (D).

FINAL: (D) -4.0

SHORTCUT / EXAM TRICK

Orbital energy order for multi-electron atoms by (n+l), tie → lower n; for hydrogen only n matters.

COMMON MISTAKE

Counting the angular node of a p orbital as a radial node; forgetting Z^2 in hydrogen-like ions.

EXAM TIP

Degeneracy of level n in hydrogen = n^2 ($2n^2$ with spin).

MEMORY TRICK

'n−l−1 radial, l angular, n−1 total'.

Why the Other Options Are Wrong

Correct answer: D

A **-1.0**

Why (D) is the key — Without repulsion each electron is hydrogen-like with Z = 2: E = $-Z^2/2 = -2$ hartree each → total −4 hartree (the real value is −2.90).

B **-0.5**

Ruled out: Counting the angular node of a p orbital as a radial node; forgetting Z^2 in hydrogen-like ions.

C **-2.0**

Ruled out: Degeneracy of level n in hydrogen = n^2 ($2n^2$ with spin).

Q14 A particle is confined to a one-dimensional box of length 1 mm. If the length is changed by 10^{-9} m, the % change in the ground state energy is

A. 2×10^{-4}

B. 2×10^{-7}

C. 2×10^{-2}

D. 0

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Atomic Structure – General

PYQ FREQUENCY
Rare · 2 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'n−l−1 radial, l angular, n−1 total'.

Correct Answer A 2×10^{-4}

CONCEPT

Hydrogen-like energies $E_n = -13.6\ Z^2/n^2$ eV; radial nodes $n-l-1$, angular nodes l; quantum numbers n, l, m_l, m_s; Bohr radius $a_0 = 52.9$ pm; de Broglie $\lambda = h/mv$; Heisenberg $\Delta x \Delta p \geq \hbar/2$; Aufbau, Pauli, Hund.

↓

LOGIC / WORKING

- $E_1 \propto 1/L^2 \rightarrow \Delta E/E \approx -2\Delta L/L = -2 \times 10^{-9}/10^{-3} = -2\times10^{-6} = 2\times10^{-4}$ % in magnitude.
- Therefore the answer is (A).

FINAL: (A) 2×10^{-4}

SHORTCUT / EXAM TRICK

Orbital energy order for multi-electron atoms by (n+l), tie → lower n; for hydrogen only n matters.

COMMON MISTAKE

Counting the angular node of a p orbital as a radial node; forgetting Z^2 in hydrogen-like ions.

EXAM TIP

Degeneracy of level n in hydrogen = n^2 ($2n^2$ with spin).

MEMORY TRICK

'n−l−1 radial, l angular, n−1 total'.

Why the Other Options Are Wrong

Correct answer: A

B 2×10^{-7}

Why (A) is the key — $E_1 \propto 1/L^2 \rightarrow \Delta E/E \approx -2\Delta L/L = -2 \times 10^{-9}/10^{-3} = -2\times10^{-6} = 2\times10^{-4}$ % in magnitude.

C 2×10^{-2}

Ruled out: Counting the angular node of a p orbital as a radial node; forgetting Z^2 in hydrogen-like ions.

D 0

Ruled out: Degeneracy of level n in hydrogen = n^2 ($2n^2$ with spin).

Q15

The operation of the commutator [x, d/dx] on a function f(x) is equal to

A. 0

B. f(x)

C. -f(x)

D. x df/dx

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Atomic Structure – General

PYQ FREQUENCY
Rare · 2 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Part B

MEMORY HOOK
'n−l−1 radial, l angular, n−1 total'.

Correct Answer C -f(x)

CONCEPT

Hydrogen-like energies $E_n = -13.6\ Z^2/n^2$ eV; radial nodes n−l−1, angular nodes l; quantum numbers n, l, m_l, m_s; Bohr radius $a_0 = 52.9$ pm; de Broglie $\lambda = h/mv$; Heisenberg $\Delta x \Delta p \geq \hbar/2$; Aufbau, Pauli, Hund.

↓

LOGIC / WORKING

- $[x, d/dx]f = x f' - d(xf)/dx = x f' - f - x f' = -f(x)$.
- Therefore the answer is (C).

FINAL: (C) -f(x)

SHORTCUT / EXAM TRICK

Orbital energy order for multi-electron atoms by (n+l), tie → lower n; for hydrogen only n matters.

COMMON MISTAKE

Counting the angular node of a p orbital as a radial node; forgetting Z^2 in hydrogen-like ions.

EXAM TIP

Degeneracy of level n in hydrogen = n^2 ($2n^2$ with spin).

MEMORY TRICK

'n−l−1 radial, l angular, n−1 total'.

Why the Other Options Are Wrong

Correct answer: C

A **0**

Why (C) is the key — [x, d/dx]f = x f′ − d(xf)/dx = x f′ − f − x f′ = −f(x).

B **f(x)**

Ruled out: Counting the angular node of a p orbital as a radial node; forgetting Z^2 in hydrogen-like ions.

D **x df/dx**

Ruled out: Degeneracy of level n in hydrogen = n^2 ($2n^2$ with spin).

Q16

The de-Broglie wavelength of the electron is (λ)/(pm) = ((a)/(varphi)). The value of 'a' in volts is

A. 1.5×10^{-18}

B. 1.5×10^{6}

C. 6.63×10^{-5}

D. 2.5×10^{18}

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Atomic Structure – General

PYQ FREQUENCY
Rare · 2 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'n−l−1 radial, l angular, n−1 total'.

Correct Answer B 1.5 × 10⁶

CONCEPT

Hydrogen-like energies $E_n = -13.6\ Z^2/n^2$ eV; radial nodes n−l−1, angular nodes l; quantum numbers n, l, m_l, m_s; Bohr radius $a_0 = 52.9$ pm; de Broglie $\lambda = h/mv$; Heisenberg $\Delta x \Delta p \geq \hbar/2$; Aufbau, Pauli, Hund.

↓

LOGIC / WORKING

- $\lambda = h/\sqrt{(2m_e\ eV)} = 1226\ pm/\sqrt{(V)}$: written as $\lambda/pm = \sqrt{(a/\varphi)}$, $a = 1226^2 \approx 1.5\times10^6$ V.
- Therefore the answer is (B).

FINAL: (B) 1.5 × 10⁶

SHORTCUT / EXAM TRICK

Orbital energy order for multi-electron atoms by (n+l), tie → lower n; for hydrogen only n matters.

COMMON MISTAKE

Counting the angular node of a p orbital as a radial node; forgetting Z^2 in hydrogen-like ions.

EXAM TIP

Degeneracy of level n in hydrogen = n^2 ($2n^2$ with spin).

MEMORY TRICK

'n−l−1 radial, l angular, n−1 total'.

Why the Other Options Are Wrong

Correct answer: B

A **1.5×10^{-18}**

Why (B) is the key — λ = h/√(2m_e eV) = 1226 pm/√(V): written as λ/pm = √(a/φ), a = $1226^2 \approx 1.5 \times 10^6$ V.

C **6.63×10^{-5}**

Ruled out: Counting the angular node of a p orbital as a radial node; forgetting Z^2 in hydrogen-like ions.

D **2.5×10^{18}**

Ruled out: Degeneracy of level n in hydrogen = n^2 ($2n^2$ with spin).

Q17

The degeneracy of a quantum particle in a cubic box having energy four times that of the lowest energy is

A) 3

B) 6

C) 1

D) 4

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Atomic Structure – General

PYQ FREQUENCY
Rare · 2 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'n−l−1 radial, l angular, n−1 total'.

Correct Answer C 1

CONCEPT

Hydrogen-like energies $E_n = -13.6\ Z^2/n^2$ eV; radial nodes n−l−1, angular nodes l; quantum numbers n, l, m_l, m_s; Bohr radius $a_0 = 52.9$ pm; de Broglie $\lambda = h/mv$; Heisenberg $\Delta x \Delta p \geq \hbar/2$; Aufbau, Pauli, Hund.

↓

LOGIC / WORKING

- $E = (h^2/8ma^2)(n_x^2 + n_y^2 + n_z^2)$; $4E_1$ needs $n_x^2 + n_y^2 + n_z^2 = 12 = 4 + 4 + 4$ only (2,2,2) → non-degenerate (degeneracy 1).
- Therefore the answer is (C).

FINAL: (C) 1

SHORTCUT / EXAM TRICK

Orbital energy order for multi-electron atoms by (n+l), tie → lower n; for hydrogen only n matters.

COMMON MISTAKE

Counting the angular node of a p orbital as a radial node; forgetting Z^2 in hydrogen-like ions.

EXAM TIP

Degeneracy of level n in hydrogen = n^2 ($2n^2$ with spin).

MEMORY TRICK

'n−l−1 radial, l angular, n−1 total'.

Why the Other Options Are Wrong

Correct answer: C

A **3**

Why (C) is the key — $E = (h^2/8ma^2)(n_x^2 + n_y^2 + n_z^2)$; $4E_1$ needs $n_x^2 + n_y^2 + n_z^2 = 12 = 4 + 4 + 4$ only (2,2,2) → non-degenerate (degeneracy 1).

B **6**

Ruled out: Counting the angular node of a p orbital as a radial node; forgetting Z^2 in hydrogen-like ions.

D **4**

Ruled out: Degeneracy of level n in hydrogen = n^2 ($2n^2$ with spin).

Q18

The de-Broglie wavelength for a He atom travelling at 1000 m s^{-1} (typical speed at room temperature) is

A. 99.7×10^{-12} m

B. 199.4×10^{-12} m

C. 199.4×10^{-18} m

D. 99×10^{-6} m

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Atomic Structure – General

PYQ FREQUENCY
Rare · 2 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'n−l−1 radial, l angular, n−1 total'.

Correct Answer A 99.7 × 10^{-12} m

CONCEPT

Hydrogen-like energies $E_n = -13.6\ Z^2/n^2$ eV; radial nodes n−l−1, angular nodes l; quantum numbers n, l, m_l, m_s; Bohr radius a_0 = 52.9 pm; de Broglie λ = h/mv; Heisenberg ΔxΔp ≥ ħ/2; Aufbau, Pauli, Hund.

↓

LOGIC / WORKING

- λ = h/mv = $6.626\times10^{-34}/(6.64\times10^{-27} \times 1000) = 9.97\times10^{-11}$ m = 99.7 pm.
- Therefore the answer is (A).

FINAL: (A) 99.7 × 10^{-12} m

SHORTCUT / EXAM TRICK

Orbital energy order for multi-electron atoms by (n+l), tie → lower n; for hydrogen only n matters.

COMMON MISTAKE

Counting the angular node of a p orbital as a radial node; forgetting Z^2 in hydrogen-like ions.

EXAM TIP

Degeneracy of level n in hydrogen = n^2 ($2n^2$ with spin).

MEMORY TRICK

'n−l−1 radial, l angular, n−1 total'.

Why the Other Options Are Wrong

Correct answer: A

B **199.4×10^{-12} m**

Why (A) is the key — $\lambda = h/mv = 6.626\times10^{-34}/(6.64\times10^{-27} \times 1000) = 9.97\times10^{-11}$ m = 99.7 pm.

C **199.4×10^{-18} m**

Ruled out: Counting the angular node of a p orbital as a radial node; forgetting Z^2 in hydrogen-like ions.

D **99×10^{-6} m**

Ruled out: Degeneracy of level n in hydrogen = n^2 ($2n^2$ with spin).

Q19

For eigen functions $\psi_1 = \sqrt{((1)/(b))}\sin((\pi x)/(b))$ and $\psi_2 = \sqrt{((2)/(b))}\sin((2\pi x)/(b))$ os particle in a 1 - D box of length b (0 ≤ x ≤ b) (b) ψ_2 is normalized but not orthogonal to ψ_1 (a) ψ_1 is normalized but not orthogonal to ψ_2 (c) ψ_2 is normalized and orthogonal to ψ_1 (d) ψ_2 is neither normalized nor orthogonal to ψ_1

SELF-PRACTICE answer on record: (C) — options were not printed in the source.

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Atomic Structure – General

PYQ FREQUENCY
Rare · 2 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'n−l−1 radial, l angular, n−1 total'.

Q20

The commutator $[x^3, p_x]$ is equal to

A. $-(3hx^2)/(2\pi i)$

B. $(hx)/(2\pi i)$

C. $(hx^2)/(2\pi i)$

D. $(3hx^2)/(2\pi i)$

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Atomic Structure – General

PYQ FREQUENCY
Rare · 2 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Part B

MEMORY HOOK
'n−l−1 radial, l angular, n−1 total'.

Correct Answer A -(3hx²)/(2π i)

CONCEPT

Hydrogen-like energies $E_n = -13.6\ Z^2/n^2$ eV; radial nodes n−l−1, angular nodes l; quantum numbers n, l, m_l, m_s; Bohr radius $a_0 = 52.9$ pm; de Broglie $\lambda = h/mv$; Heisenberg $\Delta x \Delta p \geq \hbar/2$; Aufbau, Pauli, Hund.

↓

LOGIC / WORKING

- $[f(x), p_x] = i\hbar f'(x) \rightarrow [x^3, p_x] = 3i\hbar x^2 = 3ihx^2/2\pi = -3hx^2/(2\pi i)$ (since $i = -1/i$).
- Therefore the answer is (A).

FINAL: (A) -(3hx²)/(2π i)

SHORTCUT / EXAM TRICK

Orbital energy order for multi-electron atoms by (n+l), tie → lower n; for hydrogen only n matters.

COMMON MISTAKE

Counting the angular node of a p orbital as a radial node; forgetting Z^2 in hydrogen-like ions.

EXAM TIP

Degeneracy of level n in hydrogen = n^2 ($2n^2$ with spin).

MEMORY TRICK

'n−l−1 radial, l angular, n−1 total'.

Why the Other Options Are Wrong

Correct answer: A

B **(hx)/(2π i)**

Why (A) is the key — $[f(x), p_x] = i\hbar f'(x) \rightarrow [x^3, p_x] = 3i\hbar x^2 = 3ihx^2/2\pi = -3hx^2/(2\pi i)$ (since $i = -1/i$).

C **(hx²)/(2π i)**

Ruled out: Counting the angular node of a p orbital as a radial node; forgetting Z^2 in hydrogen-like ions.

D **(3hx²)/(2π i)**

Ruled out: Degeneracy of level n in hydrogen = n^2 ($2n^2$ with spin).

Q21

An electron of mass ‘m’ is confined to a one dimensional box of length ‘b’. If it makes a radiative transition from second excited state to the ground state, the frequency of the photon emitted is

A (9h)/(8mb²)

B (3h)/(8mb²)

C (h)/(mb²)

D (2h)/(mb²)

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Atomic Structure – General

PYQ FREQUENCY
Rare · 2 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'n−l−1 radial, l angular, n−1 total'.

Correct Answer C (h)/(mb²)

CONCEPT

Hydrogen-like energies $E_n = -13.6\ Z^2/n^2$ eV; radial nodes n−l−1, angular nodes l; quantum numbers n, l, m_l, m_s; Bohr radius $a_0 = 52.9$ pm; de Broglie $\lambda = h/mv$; Heisenberg $\Delta x \Delta p \geq \hbar/2$; Aufbau, Pauli, Hund.

↓

LOGIC / WORKING

- $h\nu = E_3 - E_1 = (9-1)h^2/(8mb^2) \rightarrow \nu = h/(mb^2)$.
- Therefore the answer is (C).

FINAL: (C) (h)/(mb²)

SHORTCUT / EXAM TRICK

Orbital energy order for multi-electron atoms by (n+l), tie → lower n; for hydrogen only n matters.

COMMON MISTAKE

Counting the angular node of a p orbital as a radial node; forgetting Z^2 in hydrogen-like ions.

EXAM TIP

Degeneracy of level n in hydrogen = n^2 ($2n^2$ with spin).

MEMORY TRICK

'n−l−1 radial, l angular, n−1 total'.

Why the Other Options Are Wrong

Correct answer: C

A **(9h)/(8mb²)**

Why (C) is the key — $h\nu = E_3 - E_1 = (9 - 1)h^2/(8mb^2) \rightarrow \nu = h/(mb^2)$.

B **(3h)/(8mb²)**

Ruled out: Counting the angular node of a p orbital as a radial node; forgetting Z^2 in hydrogen-like ions.

D **(2h)/(mb²)**

Ruled out: Degeneracy of level n in hydrogen = n^2 ($2n^2$ with spin).

Q22

The wave function for a harmonic oscillator described by Nxexp(-α x²/2) has

A. One maximum only

B. One maximum, one minimum only

C. Two maxima, one minimum only

D. Two maxima, two minima only

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Atomic Structure – General

PYQ FREQUENCY
Rare · 2 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Part B

MEMORY HOOK
'n−l−1 radial, l angular, n−1 total'.

Correct Answer B One maximum, one minimum only

CONCEPT

Hydrogen-like energies $E_n = -13.6\ Z^2/n^2$ eV; radial nodes n−l−1, angular nodes l; quantum numbers n, l, m_l, m_s; Bohr radius $a_0 = 52.9$ pm; de Broglie $\lambda = h/mv$; Heisenberg $\Delta x \Delta p \geq \hbar/2$; Aufbau, Pauli, Hund.

↓

LOGIC / WORKING

- $\psi_1 \propto x\ e^{(-\alpha x^2/2)}$ is odd: one maximum at $x = +1/\sqrt{\alpha}$ and one minimum at $x = -1/\sqrt{\alpha}$ (a single node at the origin).
- Therefore the answer is (B).

FINAL: (B) One maximum, one minimum only

SHORTCUT / EXAM TRICK

Orbital energy order for multi-electron atoms by (n+l), tie → lower n; for hydrogen only n matters.

COMMON MISTAKE

Counting the angular node of a p orbital as a radial node; forgetting Z^2 in hydrogen-like ions.

EXAM TIP

Degeneracy of level n in hydrogen = n^2 ($2n^2$ with spin).

MEMORY TRICK

'n−l−1 radial, l angular, n−1 total'.

Why the Other Options Are Wrong

Correct answer: B

A — **One maximum only**

Why (B) is the key — $\psi_1 \propto x\, e^{(-\alpha x^2/2)}$ is odd: one maximum at $x = +1/\sqrt{\alpha}$ and one minimum at $x = -1/\sqrt{\alpha}$ (a single node at the origin).

C — **Two maxima, one minimum only**

Ruled out: Counting the angular node of a p orbital as a radial node; forgetting Z^2 in hydrogen-like ions.

D — **Two maxima, two minima only**

Ruled out: Degeneracy of level n in hydrogen = n^2 ($2n^2$ with spin).

Q23

If an arbitrary wave function is used to calculate the energy of a quantum mechanical system, the value calculated is never less than the true energy. The above statement relates to

A. Perturbation theory

B. Variation principle

C. Heisenberg's uncertainty principle

D. quantization of energy

QUESTION INSIGHTS

ESTIMATED TIME
3–5 min

DIFFICULTY
Hard

CONCEPT TESTED
Atomic Structure – General

PYQ FREQUENCY
Rare · 2 papers

REVISION PRIORITY
★★★★★

EXPECTED LEVEL
Part C (high merit)

MEMORY HOOK
'n−l−1 radial, l angular, n−1 total'.

Correct Answer B Variation principle

CONCEPT

Hydrogen-like energies $E_n = -13.6\ Z^2/n^2$ eV; radial nodes n−l−1, angular nodes l; quantum numbers n, l, m_l, m_s; Bohr radius $a_0 = 52.9$ pm; de Broglie $\lambda = h/mv$; Heisenberg $\Delta x \Delta p \geq \hbar/2$; Aufbau, Pauli, Hund.

↓

LOGIC / WORKING

- The variation theorem: ⟨H⟩ for any trial function is an upper bound to the true ground-state energy.
- Therefore the answer is (B).

FINAL: (B) Variation principle

SHORTCUT / EXAM TRICK

Orbital energy order for multi-electron atoms by (n+l), tie → lower n; for hydrogen only n matters.

COMMON MISTAKE

Counting the angular node of a p orbital as a radial node; forgetting Z^2 in hydrogen-like ions.

EXAM TIP

Degeneracy of level n in hydrogen = n^2 ($2n^2$ with spin).

MEMORY TRICK

'n−l−1 radial, l angular, n−1 total'.

Why the Other Options Are Wrong

Correct answer: B

A **Perturbation theory**

Why (B) is the key — The variation theorem: ⟨H⟩ for any trial function is an upper bound to the true ground-state energy.

C **Heisenberg's uncertainty principle**

Ruled out: Counting the angular node of a p orbital as a radial node; forgetting Z^2 in hydrogen-like ions.

D **quantization of energy**

Ruled out: Degeneracy of level n in hydrogen = n^2 ($2n^2$ with spin).

Q24

The wave function for a quantum mechanical particle in a 1-dimensional box of length 'a' is given by ψ = Asin(π x)/(a). The value of 'A' for a box of length 200 nm is

A. 4×10^4 $(nm)^2$

B. $10\sqrt{(2)}$ $(nm)^{1}/2$

C. $\sqrt{(2)}/10$ $(nm)^{-}1/2$

D. 0.1 $(nm)^{-}1/2$

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Atomic Structure – General

PYQ FREQUENCY
Rare · 2 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'n−l−1 radial, l angular, n−1 total'.

Correct Answer D 0.1 (nm)¯1/2

CONCEPT

Hydrogen-like energies $E_n = -13.6\ Z^2/n^2$ eV; radial nodes n−l−1, angular nodes l; quantum numbers n, l, m_l, m_s; Bohr radius $a_0 = 52.9$ pm; de Broglie $\lambda = h/mv$; Heisenberg $\Delta x \Delta p \geq \hbar/2$; Aufbau, Pauli, Hund.

↓

LOGIC / WORKING

- Normalisation gives A = √(2/a) = √(2/200 nm) = 0.1 nm^(−1/2).
- Therefore the answer is (D).

FINAL: (D) 0.1 (nm)¯1/2

SHORTCUT / EXAM TRICK

Orbital energy order for multi-electron atoms by (n+l), tie → lower n; for hydrogen only n matters.

COMMON MISTAKE

Counting the angular node of a p orbital as a radial node; forgetting Z^2 in hydrogen-like ions.

EXAM TIP

Degeneracy of level n in hydrogen = n^2 ($2n^2$ with spin).

MEMORY TRICK

'n−l−1 radial, l angular, n−1 total'.

Why the Other Options Are Wrong

Correct answer: D

A $4 \times 10^{4}\ (nm)^{2}$

Why (D) is the key — Normalisation gives A = √(2/a) = √(2/200 nm) = 0.1 nm^(−1/2).

B $10\sqrt{(2)}\ (nm)^{1}/2$

Ruled out: Counting the angular node of a p orbital as a radial node; forgetting Z^2 in hydrogen-like ions.

C $\sqrt{(2)}/10\ (nm)^{-}1/2$

Ruled out: Degeneracy of level n in hydrogen = n^2 ($2n^2$ with spin).

Q25 If Δ y and Δ P_y are the uncertainties in the y - coordinate and the y component of the momentum of a particle respectively, then, according to uncertainty principle Δ y Δ P_y is: (ħ = (h)/(2π). and h is Planck's constant.)

A > ħ

B > ħ/2

C > ħ

D ≥ ħ/2

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Atomic Structure – General

PYQ FREQUENCY
Rare · 2 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'n−l−1 radial, l angular, n−1 total'.

Correct Answer D ≥ ħ/2

CONCEPT

Hydrogen-like energies $E_n = -13.6\ Z^2/n^2$ eV; radial nodes n−l−1, angular nodes l; quantum numbers n, l, m_l, m_s; Bohr radius $a_0 = 52.9$ pm; de Broglie $\lambda = h/mv$; Heisenberg $\Delta x \Delta p \geq \hbar/2$; Aufbau, Pauli, Hund.

↓

LOGIC / WORKING

- Heisenberg: Δy Δp_y ≥ ħ/2 (the equality holds for a Gaussian wave packet).
- Therefore the answer is (D).

FINAL: (D) ≥ ħ/2

SHORTCUT / EXAM TRICK

Orbital energy order for multi-electron atoms by (n+l), tie → lower n; for hydrogen only n matters.

COMMON MISTAKE

Counting the angular node of a p orbital as a radial node; forgetting Z^2 in hydrogen-like ions.

EXAM TIP

Degeneracy of level n in hydrogen = n^2 ($2n^2$ with spin).

MEMORY TRICK

'n−l−1 radial, l angular, n−1 total'.

Why the Other Options Are Wrong

Correct answer: D

A **> ħ**

Why (D) is the key — Heisenberg: Δy Δp_y ≥ ħ/2 (the equality holds for a Gaussian wave packet).

B **> ħ/2**

Ruled out: Counting the angular node of a p orbital as a radial node; forgetting Z^2 in hydrogen-like ions.

C **> ħ**

Ruled out: Degeneracy of level n in hydrogen = n^2 ($2n^2$ with spin).

Q26

Choose the allowed transition

A $^1\Sigma_g^+ \rightarrow {}^3\Sigma_u^+$

B $^1\Sigma_g^+ \rightarrow {}^3\Sigma_u^-$

C $^1\Sigma_g^+ \rightarrow {}^1\Sigma_u^+$

D $^1\Sigma_g^+ \rightarrow {}^1\Sigma_u^-$

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Atomic Structure – General

PYQ FREQUENCY
Rare · 2 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Part B

MEMORY HOOK
'n−l−1 radial, l angular, n−1 total'.

Correct Answer C $^1\Sigma_g^+ \rightarrow {}^1\Sigma_u^+$

CONCEPT

Hydrogen-like energies $E_n = -13.6\ Z^2/n^2$ eV; radial nodes $n-l-1$, angular nodes l; quantum numbers n, l, m_l, m_s; Bohr radius $a_0 = 52.9$ pm; de Broglie $\lambda = h/mv$; Heisenberg $\Delta x \Delta p \geq \hbar/2$; Aufbau, Pauli, Hund.

↓

LOGIC / WORKING

- Rules: $\Delta S = 0$, $g \leftrightarrow u$, $\Sigma^+ \leftrightarrow \Sigma^+$ only. $^1\Sigma_g^+ \rightarrow {}^1\Sigma_u^+$ obeys all three; (a),(b) change spin; (d) is $\Sigma^+ \rightarrow \Sigma^-$.
- Therefore the answer is (C).

FINAL: (C) $^1\Sigma_g^+ \rightarrow {}^1\Sigma_u^+$

SHORTCUT / EXAM TRICK

Orbital energy order for multi-electron atoms by (n+l), tie → lower n; for hydrogen only n matters.

COMMON MISTAKE

Counting the angular node of a p orbital as a radial node; forgetting Z^2 in hydrogen-like ions.

EXAM TIP

Degeneracy of level n in hydrogen = n^2 ($2n^2$ with spin).

MEMORY TRICK

'n−l−1 radial, l angular, n−1 total'.

Why the Other Options Are Wrong

Correct answer: C

A $^1\Sigma_g^+ \rightarrow {}^3\Sigma_u^+$

Why (C) is the key — Rules: $\Delta S = 0$, g ↔ u, $\Sigma^+ \leftrightarrow \Sigma^+$ only. $^1\Sigma_g^+ \rightarrow {}^1\Sigma_u^+$ obeys all three; (a),(b) change spin; (d) is $\Sigma^+ \rightarrow \Sigma^-$.

B $^1\Sigma_g^+ \rightarrow {}^3\Sigma_u^-$

Ruled out: Counting the angular node of a p orbital as a radial node; forgetting Z^2 in hydrogen-like ions.

D $^1\Sigma_g^+ \rightarrow {}^1\Sigma_u^-$

Ruled out: Degeneracy of level n in hydrogen = n^2 ($2n^2$ with spin).

Q27 The wavefunction of a 1 – D harmonic oscillator between x=+∞ and x=-∞ is given by ψ(x)=N(2x²-1)e⁻x²/2. The value of N that normalizes the function ψ(x) is: (Given ∫₋∞⁺infty x²ⁿe⁻x² dx=(1·3·5···(2n-1))/(2ⁿ)√(π))

A (frac18√(π))^(1)/(2)

B (frac13√(π))^(1)/(2)

C (frac12√(π))^(1)/(2)

D (frac14√(π))^(1)/(2)

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Atomic Structure – General

PYQ FREQUENCY
Rare · 2 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'n−l−1 radial, l angular, n−1 total'.

Correct Answer C (frac12√(π))^(1)/(2)

CONCEPT

Hydrogen-like energies $E_n = -13.6\ Z^2/n^2$ eV; radial nodes n−l−1, angular nodes l; quantum numbers n, l, m_l, m_s; Bohr radius $a_0 = 52.9$ pm; de Broglie $\lambda = h/mv$; Heisenberg $\Delta x \Delta p \geq \hbar/2$; Aufbau, Pauli, Hund.

↓

LOGIC / WORKING

- ∫N²(2x² − 1)²e^(−x²)dx = N²[4·(3/4)√π − 4·(½)√π + √π] = 2√π N² = 1 → N = (1/(2√π))^½.
- Therefore the answer is (C).

FINAL: (C) (frac12√(π))^(1)/(2)

SHORTCUT / EXAM TRICK

Orbital energy order for multi-electron atoms by (n+l), tie → lower n; for hydrogen only n matters.

COMMON MISTAKE

Counting the angular node of a p orbital as a radial node; forgetting Z^2 in hydrogen-like ions.

EXAM TIP

Degeneracy of level n in hydrogen = n^2 ($2n^2$ with spin).

MEMORY TRICK

'n−l−1 radial, l angular, n−1 total'.

Why the Other Options Are Wrong

Correct answer: C

A **(frac18√(π))^(1)/(2)**

Why (C) is the key — $\int N^2(2x^2 - 1)^2 e^{-x^2} dx = N^2[4\cdot(3/4)\sqrt{\pi} - 4\cdot(½)\sqrt{\pi} + \sqrt{\pi}] = 2\sqrt{\pi}$ $N^2 = 1 \rightarrow N = (1/(2\sqrt{\pi}))^{½}$.

B **(frac13√(π))^(1)/(2)**

Ruled out: Counting the angular node of a p orbital as a radial node; forgetting Z^2 in hydrogen-like ions.

D **(frac14√(π))^(1)/(2)**

Ruled out: Degeneracy of level n in hydrogen = n^2 ($2n^2$ with spin).

Q28

The secular determinant (where α, β and E have their usual meanings) is given by

A. α-E & β & 0 β & α-E & β 0 & β & α-E

B. α-E & 0 & 0 0 & α-E & β 0 & β & α-E

C. α-E & 0 & 0 β & α-E & 0 0 & 0 & α-E

D. α-E & -β & 0 -β & α-E & -β 0 & -β & α-E

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Atomic Structure – General

PYQ FREQUENCY
Rare · 2 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'n−l−1 radial, l angular, n−1 total'.

Correct Answer A α-E & β & 0 β & α-E & β 0 & β & α-E

CONCEPT

Hydrogen-like energies $E_n = -13.6\ Z^2/n^2$ eV; radial nodes n−l−1, angular nodes l; quantum numbers n, l, m_l, m_s; Bohr radius $a_0 = 52.9$ pm; de Broglie $\lambda = h/mv$; Heisenberg $\Delta x \Delta p \geq \hbar/2$; Aufbau, Pauli, Hund.

↓

LOGIC / WORKING

- For a linear three-centre π system (allyl) only adjacent atoms interact: diagonal α − E, off-diagonals β between 1–2 and 2–3, zero between 1–3 — option (a).
- Therefore the answer is (A).

FINAL: (A) α-E & β & 0 β & α-E & β 0 & β & α-E

SHORTCUT / EXAM TRICK

Orbital energy order for multi-electron atoms by (n+l), tie → lower n; for hydrogen only n matters.

COMMON MISTAKE

Counting the angular node of a p orbital as a radial node; forgetting Z^2 in hydrogen-like ions.

EXAM TIP

Degeneracy of level n in hydrogen = n^2 ($2n^2$ with spin).

MEMORY TRICK

'n−l−1 radial, l angular, n−1 total'.

Why the Other Options Are Wrong

Correct answer: A

B

α-E & 0 & 0 0 & α-E & β 0 & β & α-E

Why (A) is the key — For a linear three-centre π system (allyl) only adjacent atoms interact: diagonal α − E, off-diagonals β between 1–2 and 2–3, zero between 1–3 — option (a).

C

α-E & 0 & 0 β & α-E & 0 0 & 0 & α-E

Ruled out: Counting the angular node of a p orbital as a radial node; forgetting Z^2 in hydrogen-like ions.

D

α-E & -β & 0 -β & α-E & -β 0 & -β & α-E

Ruled out: Degeneracy of level n in hydrogen = n^2 ($2n^2$ with spin).

Q29

The possible value of E are

A. α + √(2)β, α, α - √(2)β

B. α + 2√(2)β, α, α - 2√(2)β

C. α + β, α, α - β

D. α + 2β, α, α - 2β

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Atomic Structure – General

PYQ FREQUENCY
Rare · 2 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Part B

MEMORY HOOK
'n−l−1 radial, l angular, n−1 total'.

Correct Answer A $\alpha + \sqrt{(2)}\beta, \alpha, \alpha - \sqrt{(2)}\beta$

CONCEPT

Hydrogen-like energies $E_n = -13.6\ Z^2/n^2$ eV; radial nodes $n-l-1$, angular nodes l; quantum numbers n, l, m_l, m_s; Bohr radius $a_0 = 52.9$ pm; de Broglie $\lambda = h/mv$; Heisenberg $\Delta x \Delta p \geq \hbar/2$; Aufbau, Pauli, Hund.

↓

LOGIC / WORKING

- Expanding the allyl determinant: $(\alpha - E)[(\alpha - E)^2 - 2\beta^2] = 0 \rightarrow E = \alpha \pm \sqrt{2}\beta, \alpha$.
- Therefore the answer is (A).

FINAL: (A) $\alpha + \sqrt{(2)}\beta, \alpha, \alpha - \sqrt{(2)}\beta$

SHORTCUT / EXAM TRICK

Orbital energy order for multi-electron atoms by (n+l), tie → lower n; for hydrogen only n matters.

COMMON MISTAKE

Counting the angular node of a p orbital as a radial node; forgetting Z^2 in hydrogen-like ions.

EXAM TIP

Degeneracy of level n in hydrogen = n^2 ($2n^2$ with spin).

MEMORY TRICK

'n−l−1 radial, l angular, n−1 total'.

Why the Other Options Are Wrong

Correct answer: A

B **α + 2√(2)β, α, α - 2√(2)β**

Why (A) is the key — Expanding the allyl determinant: (α − E)[(α − E)² − 2β²] = 0 → E = α ± √2β, α.

C **α + β, α, α - β**

Ruled out: Counting the angular node of a p orbital as a radial node; forgetting Z^2 in hydrogen-like ions.

D **α + 2β, α, α - 2β**

Ruled out: Degeneracy of level n in hydrogen = n^2 ($2n^2$ with spin).

Q30

Two trial wavefunction $\varphi = c_1 x(a-x)$ and $\varphi_2 = c_1 x(a-x) + c_2 x^2(a-x)^2$ give ground state energies E_1 and E_2, respectively, for the microscopic particle in a 1-D box by using the variation method. If the exact ground state energy is E_0, the correct relationship between E_0, E_1 and E_2 is:

A. $E_0 = E_1 = E_2$

B. $E_0 < E_1 < E_2$

C. $E_0 < E_2 < E_1$

D. $E_0 > E_2 = E_1$

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Atomic Structure – General

PYQ FREQUENCY
Rare · 2 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Part B

MEMORY HOOK
'n−l−1 radial, l angular, n−1 total'.

Correct Answer C $E_0<E_2<E_1$

CONCEPT

Hydrogen-like energies $E_n = -13.6\ Z^2/n^2$ eV; radial nodes $n-l-1$, angular nodes l; quantum numbers n, l, m_l, m_s; Bohr radius $a_0 = 52.9$ pm; de Broglie $\lambda = h/mv$; Heisenberg $\Delta x \Delta p \geq \hbar/2$; Aufbau, Pauli, Hund.

↓

LOGIC / WORKING

- Both trial energies lie above the exact value; the two-parameter function contains the one-parameter function as a special case, so it can only do better: $E_0 < E_2 < E_1$.
- Therefore the answer is (C).

FINAL: (C) $E_0<E_2<E_1$

SHORTCUT / EXAM TRICK

Orbital energy order for multi-electron atoms by (n+l), tie → lower n; for hydrogen only n matters.

COMMON MISTAKE

Counting the angular node of a p orbital as a radial node; forgetting Z^2 in hydrogen-like ions.

EXAM TIP

Degeneracy of level n in hydrogen = n^2 ($2n^2$ with spin).

MEMORY TRICK

'n−l−1 radial, l angular, n−1 total'.

Why the Other Options Are Wrong

Correct answer: C

A $E_0=E_1=E_2$

Why (C) is the key — Both trial energies lie above the exact value; the two-parameter function contains the one-parameter function as a special case, so it can only do better: $E_0 < E_2 < E_1$.

B $E_0<E_1<E_2$

Ruled out: Counting the angular node of a p orbital as a radial node; forgetting Z^2 in hydrogen-like ions.

D $E_0>E_2=E_1$

Ruled out: Degeneracy of level n in hydrogen = n^2 ($2n^2$ with spin).

Q31 The ground state energies of H atom and H_2 molecule -13.6 eV and -31.7 eV, respectively. The dissociation energy of H_2 is _____ eV. (Numerical answer type — write the value.)

ANSWER: 4.5 eV

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Atomic Structure – General

PYQ FREQUENCY
Rare · 2 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
$D(H_2) = 2E(H) - E(H_2) = 2(-13.6) - (-31.7) = 4.5$ eV.

Q32

e^{-2x^2} is an eigen function on the operator $((d^2)/(dx^2) - 16x^2)$. The corresponding eigen value is

A. +4

B. −4

C. +2

D. −2

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Atomic Structure – General

PYQ FREQUENCY
Rare · 2 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'n−l−1 radial, l angular, n−1 total'.

Correct Answer B −4

CONCEPT

Hydrogen-like energies $E_n = -13.6\ Z^2/n^2$ eV; radial nodes n−l−1, angular nodes l; quantum numbers n, l, m_l, m_s; Bohr radius $a_0 = 52.9$ pm; de Broglie $\lambda = h/mv$; Heisenberg $\Delta x \Delta p \geq \hbar/2$; Aufbau, Pauli, Hund.

↓

LOGIC / WORKING

- f = e^(−2x²): f′ = −4x f, f″ = (16x² − 4)f. (d²/dx² − 16x²)f = −4f → eigenvalue −4.
- Therefore the answer is (B).

FINAL: (B) −4

SHORTCUT / EXAM TRICK

Orbital energy order for multi-electron atoms by (n+l), tie → lower n; for hydrogen only n matters.

COMMON MISTAKE

Counting the angular node of a p orbital as a radial node; forgetting Z^2 in hydrogen-like ions.

EXAM TIP

Degeneracy of level n in hydrogen = n^2 ($2n^2$ with spin).

MEMORY TRICK

'n−l−1 radial, l angular, n−1 total'.

Why the Other Options Are Wrong

Correct answer: B

A **+4**

Why (B) is the key — f = e^(−2x²): f′ = −4x f, f″ = (16x² − 4)f. (d²/dx² − 16x²)f = −4f → eigenvalue −4.

C **+2**

Ruled out: Counting the angular node of a p orbital as a radial node; forgetting Z^2 in hydrogen-like ions.

D **−2**

Ruled out: Degeneracy of level n in hydrogen = n^2 ($2n^2$ with spin).

Q33

The value of the magnetic quantum number of a p_x orbital is

A. -1

B. 0

C. +1

D. undefined

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Atomic Structure – General

PYQ FREQUENCY
Rare · 2 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Part B

MEMORY HOOK
'n−l−1 radial, l angular, n−1 total'.

Correct Answer D undefined

CONCEPT

Hydrogen-like energies $E_n = -13.6\ Z^2/n^2$ eV; radial nodes n−l−1, angular nodes l; quantum numbers n, l, m_l, m_s; Bohr radius $a_0 = 52.9$ pm; de Broglie $\lambda = h/mv$; Heisenberg $\Delta x \Delta p \geq \hbar/2$; Aufbau, Pauli, Hund.

↓

LOGIC / WORKING

- p_x is the combination $(p_{+1} - p_{-1})/\sqrt{2}$ of m = +1 and m = −1 functions, so m_l is not a sharp (defined) value for it.
- Therefore the answer is (D).

FINAL: (D) undefined

SHORTCUT / EXAM TRICK

Orbital energy order for multi-electron atoms by (n+l), tie → lower n; for hydrogen only n matters.

COMMON MISTAKE

Counting the angular node of a p orbital as a radial node; forgetting Z^2 in hydrogen-like ions.

EXAM TIP

Degeneracy of level n in hydrogen = n^2 ($2n^2$ with spin).

MEMORY TRICK

'n−l−1 radial, l angular, n−1 total'.

Why the Other Options Are Wrong

Correct answer: D

A **-1**

Why (D) is the key — p_x is the combination $(p_{+1} - p_{-1})/\sqrt{2}$ of m = +1 and m = −1 functions, so m_l is not a sharp (defined) value for it.

B **0**

Ruled out: Counting the angular node of a p orbital as a radial node; forgetting Z^2 in hydrogen-like ions.

C **+1**

Ruled out: Degeneracy of level n in hydrogen = n^2 ($2n^2$ with spin).

Q34 Suppose ψ_1 and ψ_2, are two hybrid orbitals: $\psi_1 = 0.12\psi_{3s} + 0.63\psi_{3p_x} + 0.77\psi_{3p_y}$ and $\psi_2 = 0.12\psi_{3s} - 0.63\psi_{3p_x} - 0.77\psi_{3p_y}$ The angle (in degrees) between them is _____
(Numerical answer type — write the value.)

ANSWER: 180°

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Atomic Structure – General

PYQ FREQUENCY
Rare · 2 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
The p-parts of the two hybrids are (0.63, 0.77) and (−0.63, −0.77): antiparallel vectors, so the hybrids point in opposite directions — 180° (two sp-type hybrids on the x–y diagonal).

Q35

When the operator, $-\hbar^2 d^2/dx^2$, operates on the function $e^{-}ikx$, the result is

A. $k^2\hbar^2 e^{-}ikx$

B. $ik^2\hbar^2 e^{-}ikx$

C. $i\hbar^2 e^{-}ikx$

D. $\hbar^2 e^{-}ikx$

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Atomic Structure – General

PYQ FREQUENCY
Rare · 2 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Part B

MEMORY HOOK
'n−l−1 radial, l angular, n−1 total'.

Correct Answer A $k^2\hbar^2 e^{-}ikx$

CONCEPT

Hydrogen-like energies $E_n = -13.6\ Z^2/n^2$ eV; radial nodes n−l−1, angular nodes l; quantum numbers n, l, m_l, m_s; Bohr radius $a_0 = 52.9$ pm; de Broglie $\lambda = h/mv$; Heisenberg $\Delta x \Delta p \geq \hbar/2$; Aufbau, Pauli, Hund.

↓

LOGIC / WORKING

- $d^2/dx^2\ e^{(-ikx)} = (-ik)^2\ e^{(-ikx)} = -k^2 e^{(-ikx)}$; multiplying by $-\hbar^2$ gives $+k^2\hbar^2\ e^{(-ikx)}$.
- Therefore the answer is (A).

FINAL: (A) $k^2\hbar^2 e^{-}ikx$

SHORTCUT / EXAM TRICK

Orbital energy order for multi-electron atoms by (n+l), tie → lower n; for hydrogen only n matters.

COMMON MISTAKE

Counting the angular node of a p orbital as a radial node; forgetting Z^2 in hydrogen-like ions.

EXAM TIP

Degeneracy of level n in hydrogen = n^2 ($2n^2$ with spin).

MEMORY TRICK

'n−l−1 radial, l angular, n−1 total'.

Why the Other Options Are Wrong

Correct answer: A

B $ik^2\hbar^2 e^{-}ikx$

Why (A) is the key — d²/dx² e^(−ikx) = (−ik)² e^(−ikx) = −k²e^(−ikx); multiplying by −ħ² gives +k²ħ² e^(−ikx).

C $i\hbar^2 e^{-}ikx$

Ruled out: Counting the angular node of a p orbital as a radial node; forgetting Z^2 in hydrogen-like ions.

D $\hbar^2 e^{-}ikx$

Ruled out: Degeneracy of level n in hydrogen = n^2 ($2n^2$ with spin).

Q36

The difference in the ground state energies (kJ/mol) of an electron in one-dimensional boxes of lengths 0.2 nm and 2nm is ___. 49. The linear momentum of a particle described by the wavefunction e⁻ikx is

A kh

B -kh

C kℏ

D -kℏ

ANSWER: ≈ 898 kJ mol⁻¹; momentum = −kℏ (d)

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Atomic Structure – General

PYQ FREQUENCY
Rare · 2 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
$E_1 = h^2/8mL^2$: L = 0.2 nm → 1.51×10⁻¹⁸ J = 907 kJ mol⁻¹; L = 2 nm → 9.07 kJ mol⁻¹; difference ≈ 898 kJ mol⁻¹. The second part: p̂ e^(−ikx) = −iℏ(−ik)e^(−ikx) = −kℏ e^(−ikx) → momentum −kℏ.

Q37

The experimental ionization energies of hydrogen and helium atoms in their ground states are, respectively, 13.6 eV and 24.6 eV. The ground state energy of helium atom, in eV, is

A. -(1)/(2)(13.6) - 24.6

B. -4(13.6) - 24.6

C. -(1)/(4)(13.6) - 24.6

D. -2(13.6) - 24.6

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Atomic Structure – General

PYQ FREQUENCY
Rare · 2 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'n−l−1 radial, l angular, n−1 total'.

Correct Answer B -4(13.6) - 24.6

CONCEPT

Hydrogen-like energies $E_n = -13.6\ Z^2/n^2$ eV; radial nodes n−l−1, angular nodes l; quantum numbers n, l, m_l, m_s; Bohr radius $a_0 = 52.9$ pm; de Broglie $\lambda = h/mv$; Heisenberg $\Delta x \Delta p \geq \hbar/2$; Aufbau, Pauli, Hund.

↓

LOGIC / WORKING

- E(He) = −[IE_1 + IE_2]; IE_2 is hydrogen-like with Z = 2: 4 × 13.6 = 54.4 eV. So E = −4(13.6) − 24.6 = −79.0 eV.
- Therefore the answer is (B).

FINAL: (B) -4(13.6) - 24.6

SHORTCUT / EXAM TRICK

Orbital energy order for multi-electron atoms by (n+l), tie → lower n; for hydrogen only n matters.

COMMON MISTAKE

Counting the angular node of a p orbital as a radial node; forgetting Z^2 in hydrogen-like ions.

EXAM TIP

Degeneracy of level n in hydrogen = n^2 ($2n^2$ with spin).

MEMORY TRICK

'n−l−1 radial, l angular, n−1 total'.

Why the Other Options Are Wrong

Correct answer: B

A **-(1)/(2)(13.6) - 24.6**

Why (B) is the key — E(He) = −[IE_1 + IE_2]; IE_2 is hydrogen-like with Z = 2: 4 × 13.6 = 54.4 eV. So E = −4(13.6) − 24.6 = −79.0 eV.

C **-(1)/(4)(13.6) - 24.6**

Ruled out: Counting the angular node of a p orbital as a radial node; forgetting Z^2 in hydrogen-like ions.

D **-2(13.6) - 24.6**

Ruled out: Degeneracy of level n in hydrogen = n^2 ($2n^2$ with spin).

Q38

For ortho-hydrogen, the nuclear wavefunction and the rotational quantum number, respectively, are

A. antisymmetric and even

B. symmetric and odd

C. symmetric and even

D. antisymmetric and odd

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Atomic Structure – General

PYQ FREQUENCY
Rare · 2 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'n−l−1 radial, l angular, n−1 total'.

Correct Answer B symmetric and odd

CONCEPT

Hydrogen-like energies $E_n = -13.6\ Z^2/n^2$ eV; radial nodes $n-l-1$, angular nodes l; quantum numbers n, l, m_l, m_s; Bohr radius $a_0 = 52.9$ pm; de Broglie $\lambda = h/mv$; Heisenberg $\Delta x \Delta p \geq \hbar/2$; Aufbau, Pauli, Hund.

↓

LOGIC / WORKING

- Ortho-H_2: nuclear spins parallel (symmetric triplet); the total wavefunction must be antisymmetric for the fermionic protons, so the rotational function must be antisymmetric → odd J.
- Therefore the answer is (B).

FINAL: (B) symmetric and odd

SHORTCUT / EXAM TRICK

Orbital energy order for multi-electron atoms by (n+l), tie → lower n; for hydrogen only n matters.

COMMON MISTAKE

Counting the angular node of a p orbital as a radial node; forgetting Z^2 in hydrogen-like ions.

EXAM TIP

Degeneracy of level n in hydrogen = n^2 ($2n^2$ with spin).

MEMORY TRICK

'n−l−1 radial, l angular, n−1 total'.

Why the Other Options Are Wrong

Correct answer: B

A — **antisymmetric and even**

Why (B) is the key — Ortho-H_2: nuclear spins parallel (symmetric triplet); the total wavefunction must be antisymmetric for the fermionic protons, so the rotational function must be antisymmetric → odd J.

C — **symmetric and even**

Ruled out: Counting the angular node of a p orbital as a radial node; forgetting Z^2 in hydrogen-like ions.

D — **antisymmetric and odd**

Ruled out: Degeneracy of level n in hydrogen = n^2 ($2n^2$ with spin).

Q39

Assume 1,3,5-hexatriene to be a linear molecule and model the π electrons as particles in a one-dimensional box of length 0.70 nm. The wavelength (in nm) corresponding to the transition from the ground-state to the first excited-state is ___. (Numerical answer type — write the value.)

ANSWER: 231 nm

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Atomic Structure – General

PYQ FREQUENCY
Rare · 2 papers

REVISION PRIORITY
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EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
6 π electrons fill n = 1–3; transition 3 → 4: $\Delta E = 7h^2/(8mL^2) = 7 \times (6.626\times10^{-34})^2/(8 \times 9.11\times10^{-31} \times (0.70\times10^{-9})^2) = 8.6\times10^{-19}$ J → $\lambda = hc/\Delta E = 2.31\times10^{-7}$ m = 231 nm.

Q40 The angle of orientation (in degrees) of the angular momentum vector with respect to z-axis for l = 2 and m_ell = +2 state of H-atom is _____ (up to two decimal places)
(Numerical answer type — write the value.)

ANSWER: 35.26°

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Atomic Structure – General

PYQ FREQUENCY
Rare · 2 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
cos θ = m_l/√(l(l+1)) = 2/√6 = 0.8165 → θ = 35.26°.

Q41 $\Psi = [c\varphi_1 - (1-\sqrt{(3)})\varphi_2]$ represents a normalized molecular orbital constructed from two different atomic orbitals φ_1 and φ_2 that form an orthonormal set. The value of $|c|$ is ___ . (up to two decimal places) (Numerical answer type — write the value.)

ANSWER: 0.68

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Atomic Structure – General

PYQ FREQUENCY
Rare · 2 papers

REVISION PRIORITY
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EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
Orthonormal basis: $c^2 + (1 - \sqrt{3})^2 = 1 \rightarrow c^2 = 1 - 0.536 = 0.464 \rightarrow |c| = 0.68$.

Q42

Consider the operators, $\hat{a}_+ = \frac{1}{\sqrt{2}}(\hat{x} + i\hat{p}_x)$ and $\hat{a}_- = \frac{1}{\sqrt{2}}(\hat{x} - i\hat{p}_x)$, where $\hat{x}$ and $\hat{p}_x$ are the position and linear momentum operators, respectively. The commutator, $[\hat{a}_+, \hat{a}_-]$ is equal to

A. $i\hbar$

B. $-i\hbar$

C. $\hbar$

D. $-\hbar$

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Atomic Structure – General

PYQ FREQUENCY
Rare · 2 papers

REVISION PRIORITY
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EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'n−l−1 radial, l angular, n−1 total'.

Correct Answer C ħ

CONCEPT

Hydrogen-like energies $E_n = -13.6\ Z^2/n^2$ eV; radial nodes n−l−1, angular nodes l; quantum numbers n, l, m_l, m_s; Bohr radius $a_0 = 52.9$ pm; de Broglie $\lambda = h/mv$; Heisenberg $\Delta x \Delta p \geq \hbar/2$; Aufbau, Pauli, Hund.

↓

LOGIC / WORKING

- $[\hat{a}_+, \hat{a}_-] = \frac{1}{2}[x + ip, x - ip] = \frac{1}{2}(-i[x,p] + i[p,x]) = \frac{1}{2}(-i \cdot i\hbar + i \cdot (-i\hbar)) = \frac{1}{2}(\hbar + \hbar) = \hbar$.
- Therefore the answer is (C).

FINAL: (C) ħ

SHORTCUT / EXAM TRICK

Orbital energy order for multi-electron atoms by (n+l), tie → lower n; for hydrogen only n matters.

COMMON MISTAKE

Counting the angular node of a p orbital as a radial node; forgetting Z^2 in hydrogen-like ions.

EXAM TIP

Degeneracy of level n in hydrogen = n^2 ($2n^2$ with spin).

MEMORY TRICK

'n−l−1 radial, l angular, n−1 total'.

Why the Other Options Are Wrong

Correct answer: C

A **iħ**

Why (C) is the key — $[\hat{a}_+, \hat{a}_-] = \frac{1}{2}[x + ip, x - ip] = \frac{1}{2}(-i[x,p] + i[p,x]) = \frac{1}{2}(-i \cdot i\hbar + i \cdot (-i\hbar)) = \frac{1}{2}(\hbar + \hbar) = \hbar$.

B **-iħ**

Ruled out: Counting the angular node of a p orbital as a radial node; forgetting Z^2 in hydrogen-like ions.

D **-ħ**

Ruled out: Degeneracy of level n in hydrogen = n^2 ($2n^2$ with spin).

Q43

In a molecule XY, let ψ_X and ψ_Y denote normalized atomic orbitals of atoms X and Y, respectively. A normalized molecular orbital of XY is given by $\psi_+ = 0.56(\psi_X + \psi_Y)$. The value of the overlap integral of ψ_X and ψ_Y is ___ (Upto two decimal place) (Numerical answer type — write the value.)

ANSWER: 0.59

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Atomic Structure – General

PYQ FREQUENCY
Rare · 2 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
Normalisation: $0.56^2(1 + 1 + 2S) = 1 \rightarrow 2 + 2S = 3.19 \rightarrow S = 0.59$.

Q44

Suppose the wave function of a one dimensional system is ψ = sin(kx)exp(3ikx) In an experiment measuring the momentum of the system, one of the expected outcomes is

A. 0

B. ħ k

C. 2ħ k

D. 3ħ k

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Atomic Structure – General

PYQ FREQUENCY
Rare · 2 papers

REVISION PRIORITY
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EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'n−l−1 radial, l angular, n−1 total'.

Correct Answer C 2ħ k

CONCEPT

Hydrogen-like energies $E_n = -13.6\ Z^2/n^2$ eV; radial nodes n−l−1, angular nodes l; quantum numbers n, l, m_l, m_s; Bohr radius $a_0 = 52.9$ pm; de Broglie $\lambda = h/mv$; Heisenberg $\Delta x \Delta p \geq \hbar/2$; Aufbau, Pauli, Hund.

↓

LOGIC / WORKING

- sin(kx)e^(3ikx) = (e^(4ikx) − e^(2ikx))/2i: a superposition of momentum eigenstates with p = 4ħk and 2ħk. Of the options only 2ħk is a possible outcome.
- Therefore the answer is (C).

FINAL: (C) 2ħ k

SHORTCUT / EXAM TRICK

Orbital energy order for multi-electron atoms by (n+l), tie → lower n; for hydrogen only n matters.

COMMON MISTAKE

Counting the angular node of a p orbital as a radial node; forgetting Z^2 in hydrogen-like ions.

EXAM TIP

Degeneracy of level n in hydrogen = n^2 ($2n^2$ with spin).

MEMORY TRICK

'n−l−1 radial, l angular, n−1 total'.

Why the Other Options Are Wrong

Correct answer: C

A **0**

Why (C) is the key — sin(kx)e^(3ikx) = (e^(4ikx) − e^(2ikx))/2i: a superposition of momentum eigenstates with p = 4ħk and 2ħk. Of the options only 2ħk is a possible outcome.

B **ħ k**

Ruled out: Counting the angular node of a p orbital as a radial node; forgetting Z^2 in hydrogen-like ions.

D **3ħ k**

Ruled out: Degeneracy of level n in hydrogen = n^2 ($2n^2$ with spin).

Q45

Among the following linear combination of atomic orbitals, the CORRECT representation of the lowest unoccupied π-molecular orbital of butadiene is:

A $\Psi = 0.602\varphi_1 - 0.372\varphi_2 - 0.372\varphi_3 + 0.602\varphi_4$

B $\Psi = -0.372\varphi_1 + 0.602\varphi_2 - 0.602\varphi_3 + 0.372\varphi_4$

C $\Psi = 0.602\varphi_1 + 0.372\varphi_2 - 0.372\varphi_3 - 0.602\varphi_4$

D $\Psi = 0.372\varphi_1 + 0.602\varphi_2 + 0.602\varphi_3 + 0.372\varphi_4$

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Atomic Structure – General

PYQ FREQUENCY
Rare · 2 papers

REVISION PRIORITY
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EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'n−l−1 radial, l angular, n−1 total'.

Correct Answer A $\Psi = 0.602\varphi_1 - 0.372\varphi_2 - 0.372\varphi_3 + 0.602\varphi_4$

CONCEPT

Hydrogen-like energies $E_n = -13.6\ Z^2/n^2$ eV; radial nodes $n-l-1$, angular nodes l; quantum numbers n, l, m_l, m_s; Bohr radius $a_0 = 52.9$ pm; de Broglie $\lambda = h/mv$; Heisenberg $\Delta x \Delta p \geq \hbar/2$; Aufbau, Pauli, Hund.

↓

LOGIC / WORKING

- Butadiene ψ_3 (LUMO) has two nodes and coefficients ± 0.602, ∓ 0.372 with the pattern +, −, −, +: $\Psi = 0.602\varphi_1 - 0.372\varphi_2 - 0.372\varphi_3 + 0.602\varphi_4$.
- Therefore the answer is (A).

FINAL: (A) $\Psi = 0.602\varphi_1 - 0.372\varphi_2 - 0.372\varphi_3 + 0.602\varphi_4$

SHORTCUT / EXAM TRICK

Orbital energy order for multi-electron atoms by (n+l), tie → lower n; for hydrogen only n matters.

COMMON MISTAKE

Counting the angular node of a p orbital as a radial node; forgetting Z^2 in hydrogen-like ions.

EXAM TIP

Degeneracy of level n in hydrogen = n^2 ($2n^2$ with spin).

MEMORY TRICK

'n−l−1 radial, l angular, n−1 total'.

Why the Other Options Are Wrong

Correct answer: A

B

$\Psi = -0.372\varphi_1 + 0.602\varphi_2 - 0.602\varphi_3 + 0.372\varphi_4$

Why (A) is the key — Butadiene ψ_3 (LUMO) has two nodes and coefficients ± 0.602, ∓ 0.372 with the pattern +, −, −, +: $\Psi = 0.602\varphi_1 - 0.372\varphi_2 - 0.372\varphi_3 + 0.602\varphi_4$.

C

$\Psi = 0.602\varphi_1 + 0.372\varphi_2 - 0.372\varphi_3 - 0.602\varphi_4$

Ruled out: Counting the angular node of a p orbital as a radial node; forgetting Z^2 in hydrogen-like ions.

D

$\Psi = 0.372\varphi_1 + 0.602\varphi_2 + 0.602\varphi_3 + 0.372\varphi_4$

Ruled out: Degeneracy of level n in hydrogen = n^2 ($2n^2$ with spin).

Q46

The % error (rounded off to two decimal places) in the ground state energy of a particle in a one dimensional box of length 'a' described by a trial variation function varphi = x(a - x), where 0 ≤ x ≤ a, is _____ (Given: The true ground state energy of the above system is $h^2/8ma^2$; $\int_0^a varphi^*varphi\, d\tau = a^5/30$) (Numerical answer type — write the value.)

ANSWER: 1.32 %

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Atomic Structure – General

PYQ FREQUENCY
Rare · 2 papers

REVISION PRIORITY
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EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
⟨H⟩ for φ = x(a − x) is $5h^2/(4\pi^2ma^2) = (10/\pi^2)(h^2/8ma^2)$ = 1.0132 × E_0 → 1.32 % above the exact energy.

Q47

Acceptable wavefunction for a quantum particle must be;

A. even

B. single – valued

C. odd

D. continuous

ANSWER: (b) and (d)

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Atomic Structure – General

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REVISION PRIORITY
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EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
Acceptable wavefunctions must be single-valued, continuous (with continuous first derivative) and square-integrable; they need not be even or odd.

Q48 **Given that the radius of the first Bohr orbit of hydrogen atom is 53 pm, the radius of its third Bohr orbit is ____ pm. (Round off to the nearest integer) (IIT JAM-2020)**
(Numerical answer type — write the value.)

ANSWER: 477 pm

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Atomic Structure – General

PYQ FREQUENCY
Rare · 2 papers

REVISION PRIORITY
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EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
$r_n = n^2 a_0 \rightarrow r_3 = 9 \times 53 = 477$ pm.

Q49

The ratio of the 2p → 1s transition energy in He^+ to that in the H atom is closest to

A) 1

B) 2

C) 4

D) 8

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Atomic Structure – General

PYQ FREQUENCY
Rare · 2 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
'n−l−1 radial, l angular, n−1 total'.

Correct Answer C 4

CONCEPT

Hydrogen-like energies $E_n = -13.6\ Z^2/n^2$ eV; radial nodes $n-l-1$, angular nodes l; quantum numbers n, l, m_l, m_s; Bohr radius $a_0 = 52.9$ pm; de Broglie $\lambda = h/mv$; Heisenberg $\Delta x \Delta p \geq \hbar/2$; Aufbau, Pauli, Hund.

↓

LOGIC / WORKING

- Transition energies scale as Z^2: He^+ ($Z = 2$) gives 4 × the hydrogen value.
- Therefore the answer is (C).

FINAL: (C) 4

SHORTCUT / EXAM TRICK

Orbital energy order for multi-electron atoms by (n+l), tie → lower n; for hydrogen only n matters.

COMMON MISTAKE

Counting the angular node of a p orbital as a radial node; forgetting Z^2 in hydrogen-like ions.

EXAM TIP

Degeneracy of level n in hydrogen = n^2 ($2n^2$ with spin).

MEMORY TRICK

'n−l−1 radial, l angular, n−1 total'.

Why the Other Options Are Wrong

Correct answer: C

A

1

Why (C) is the key — Transition energies scale as Z^2: He^+ (Z = 2) gives 4 × the hydrogen value.

B

2

Ruled out: Counting the angular node of a p orbital as a radial node; forgetting Z^2 in hydrogen-like ions.

D

8

Ruled out: Degeneracy of level n in hydrogen = n^2 ($2n^2$ with spin).

TOPIC REVISION

Atomic Structure – General

49 PYQs · Last-minute revision

TOPIC SUMMARY

Hydrogen-like energies $E_n = -13.6\ Z^2/n^2$ eV; radial nodes n−l−1, angular nodes l; quantum numbers n, l, m_l, m_s; Bohr radius a_0 = 52.9 pm; de Broglie λ = h/mv; Heisenberg ΔxΔp ≥ ħ/2; Aufbau, Pauli, Hund.

IMPORTANT FORMULA SHEET

- $E_n = -13.6\ Z^2/n^2$ eV = $-RhcZ^2/n^2$
- $1/\lambda = R_H\ Z^2(1/n_1^2 - 1/n_2^2)$
- $r_n = a_0 n^2/Z$; $v_n = 2.19\times10^6\ Z/n$ m s^{-1}
- Nodes: radial n−l−1, angular l, total n−1
- λ = h/√(2mE)

FREQUENTLY ASKED CONCEPTS

- Number of nodes in 3p, 4d, 2s
- Series limits (Lyman, Balmer)
- Ionisation energy of He^+, Li^{2+}
- Most probable radius of 1s = a_0
- Slater's rules and Z_eff

COMMON MISTAKES & QUICK NOTES

Watch out:
Counting the angular node of a p orbital as a radial node; forgetting Z^2 in hydrogen-like ions.
Degeneracy of level n in hydrogen = n^2 ($2n^2$ with spin).

MOST-REPEATED PYQs & EXPECTED IN EXAM

PYQs in this topic: Q1 Q2 Q3 Q4 Q5 Q6 Q7 Q8 Q9 Q10 Q11 Q12 Q13 Q14 …

Expect 24 question(s) next session on Atomic Structure – General.

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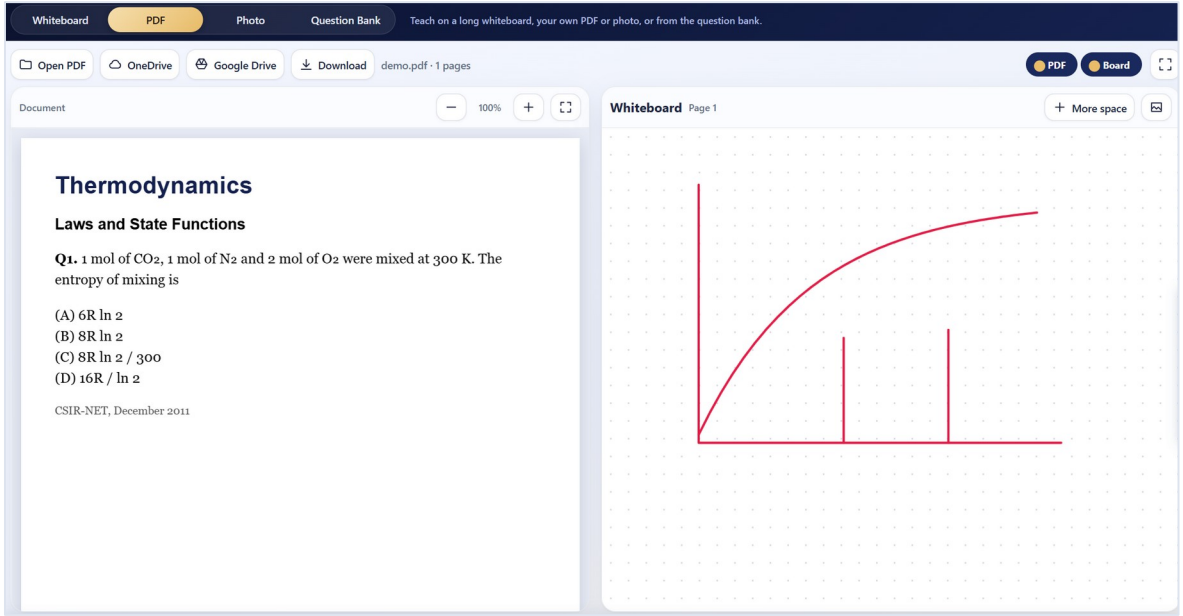
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