ABC CHEMISTRY

Mr. Aniket Bhardwaj · 15+ Years Mentorship

Coordination Chemistry

Premium CSIR-NET PYQ Book

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CSIR-NET · GATE · IIT-JAM — 14 Topics, taught in sequence

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Course Contents

14 Topics · 161 PYQs · tap a topic to jump

1 **Atomic Term Symbols & Microstates** — 21 Qs · E 11 · M 6 · H 4 — 13%

2 **Crystal Field Theory & Geometry** — 9 Qs · E 8 · M 1 · H 0 — 6%

3 **Electronic Spectra & Selection Rules** — 34 Qs · E 20 · M 13 · H 1 — 21%

4 **Charge Transfer & Nephelauxetic Effect** — 13 Qs · E 12 · M 1 · H 0 — 8%

5 **Magnetic Properties** — 22 Qs · E 16 · M 6 · H 0 — 14%

6 **Jahn-Teller Distortion** — 4 Qs · E 1 · M 3 · H 0 — 2%

7 **Bonding, Ligands & π-Acidity** — 9 Qs · E 7 · M 2 · H 0 — 6%

8 **Isomerism** — 6 Qs · E 5 · M 1 · H 0 — 4%

9 **Reaction Mechanisms & Kinetics** — 24 Qs · E 18 · M 4 · H 2 — 15%

10 **Electron Transfer Reactions** — 6 Qs · E 2 · M 3 · H 1 — 4%

11 **Chelate Effect & Stability** — 2 Qs · E 2 · M 0 · H 0 — 1%

12 **Solid State & Spinel Structures** — 4 Qs · E 2 · M 2 · H 0 — 2%

13 **Metal Clusters & M–M Bonding** — 1 Qs · E 1 · M 0 · H 0 — 1%

14 **Coordination Chemistry – General** — 6 Qs · E 6 · M 0 · H 0 — 4%

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

(Mr. Aniket Bhardwaj By ABC Chemistry)

TOPIC 1

Atomic Term Symbols & Microstates

21 questions · Easy 11 | Medium 6 | Hard 4 · PYQ frequency: Very High

Q3 The term symbol of a molecule with electronic configuration: $(1\sigma g)_2\ (1\sigma u)_2\ (2\sigma g)_2\ (2\sigma u)_2\ (1\pi u)_1\ (1\pi u)_1$ is:

A $^1\Sigma^+_g$

B $^3\Sigma^-_g$

C $^1\Sigma^-_g$

D $^3\Sigma^+_g$

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Russell–Saunders coupling, Hund's rules, microstate counting

PYQ FREQUENCY
Very High · 14 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
"Spin is king, L is queen, J obeys the half-filled rule."
Microstates = $^{(2(2l+1))}C_n$.

Correct Answer B $^{3}\Sigma^{-}_{g}$

CONCEPT

A term symbol $^{2S+1}L_J$ encodes total spin (S), orbital (L) and total angular momentum (J). For ground states use Hund's rules; microstate count = C(2(2l+1), n).

↓

LOGIC / WORKING

For term symbol only valence shell is considered.
Term symbol 2s+1 Lg/u +/- S = ½+½ =1 , 2s+1= 3 L= 1x(1)$^{+}$ 1x(-1) = 0 , the term symbol is Σ
When molecular orbital is π , 2s+1= 3 give negative sign to distinguish Σ terms g and u are used for molecules which have COS present , u*u =g

FINAL: (B) $^{3}\Sigma^{-}_{g}$

SHORTCUT / EXAM TRICK

Ground term: maximise S first, then L. J = |L−S| if shell ≤ half-filled, J = L+S if more than half-filled.

COMMON MISTAKE

Forgetting to flip the J-rule for more-than-half-filled shells, or mislabelling multiplicity (2S+1) vs S.

EXAM TIP

Memorise S/P/D/F/G ↔ L = 0/1/2/3/4. Half-filled (d^5, p^3, f^7) always give an S ground term (L=0).

MEMORY TRICK

“Spin is king, L is queen, J obeys the half-filled rule.”
Microstates = $^{(2(2l+1))}C_n$.

Why the Other Options Are Wrong

Correct answer: **B**

A $^{1}\Sigma^{+}_{g}$

$^{1}\Sigma$ requires paired spins (singlet), but the two π electrons are unpaired (triplet), so multiplicity must be 3 not 1.

C $^{1}\Sigma^{-}_{g}$

multiplicity is 3 (triplet), not 1; the spin part is wrong.

D $^{3}\Sigma^{+}_{g}$

half-filled degenerate π* with parallel spins gives the (−) Σ term, not (+).

Q8

The possible J values for ^3D term symbol are

A. 2

B. 3

C. 4

D. 5

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Russell–Saunders coupling, Hund's rules, microstate counting

PYQ FREQUENCY
Very High · 14 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
"Spin is king, L is queen, J obeys the half-filled rule."
Microstates = $^{(2(2l+1))}C_n$.

Correct Answer B 3

CONCEPT

A term symbol $^{2S+1}L_J$ encodes total spin (S), orbital (L) and total angular momentum (J). For ground states use Hund's rules; microstate count = C(2(2l+1), n).

↓

LOGIC / WORKING

For ^3D $^2S+1 = 3$, $^2S=2$, S=1 S=1, L=2 For term, S, P, D, F Value of L= 0, 1, 2, 3 J can have values from [L+S].....[L-S] |2+1|..... |2-1| 3 2 1 Possible J Values are : 3

FINAL: (B) 3

SHORTCUT / EXAM TRICK

Ground term: maximise S first, then L. J = |L−S| if shell ≤ half-filled, J = L+S if more than half-filled.

COMMON MISTAKE

Forgetting to flip the J-rule for more-than-half-filled shells, or mislabelling multiplicity (2S+1) vs S.

EXAM TIP

Memorise S/P/D/F/G ↔ L = 0/1/2/3/4. Half-filled (d^5, p^3, f^7) always give an S ground term (L=0).

MEMORY TRICK

“Spin is king, L is queen, J obeys the half-filled rule.” Microstates = $^{(2(2l+1))}C_n$.

Why the Other Options Are Wrong

Correct answer: **B**

A — **2**

^3D gives J = 3,2,1, i.e. three J values, not just two.

C — **4**

there are 3 J levels (3,2,1), not 4.

D — **5**

there are 3 J levels (3,2,1), not 5.

Q12 The term symbol for the ground state of nitrogen atoms is

A. $^{3}P_{0}$

B. $^{4}P_{3}/2$

C. $^{1}P_{1}$

D. $^{4}S_{3}/2$

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Russell–Saunders coupling, Hund's rules, microstate counting

PYQ FREQUENCY
Very High · 14 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
"Spin is king, L is queen, J obeys the half-filled rule."
Microstates = $^{(2(2l+1))}C_{n}$.

Correct Answer D $^4S_3/2$

CONCEPT

A term symbol $^{2S+1}L_J$ encodes total spin (S), orbital (L) and total angular momentum (J). For ground states use Hund's rules; microstate count = C(2(2l+1), n).

↓

LOGIC / WORKING

N→ $1s^1\ 2s^2\ 2p^3$ L=1+ 0 -1= 0 s=3/2 2s+1=$2x_3$/2+1=4 J=(L+S).... (L-S) =|0+3/2|.... |0-3/2|= 3/2 Therefore, Ground state term = S Term symbol = $^4S_3/2$

FINAL: (D) $^4S_3/2$

SHORTCUT / EXAM TRICK

Ground term: maximise S first, then L. J = |L−S| if shell ≤ half-filled, J = L+S if more than half-filled.

COMMON MISTAKE

Forgetting to flip the J-rule for more-than-half-filled shells, or mislabelling multiplicity (2S+1) vs S.

EXAM TIP

Memorise S/P/D/F/G ↔ L = 0/1/2/3/4. Half-filled (d^5, p^3, f^7) always give an S ground term (L=0).

MEMORY TRICK

“Spin is king, L is queen, J obeys the half-filled rule.” Microstates = $^{(2(2l+1))}C_n$.

Why the Other Options Are Wrong

Correct answer: **D**

A $^{3}P_{0}$

$^{3}P_{0}$ has the wrong L and multiplicity; ground p^3 has L=0 (S term), not P.

B $^{4}P_{3}/2$

^{4}P needs L=1, but the half-filled p^3 ground term has L=0.

C $^{1}P_{1}$

^{1}P has multiplicity 2 (should be 4) and L=1 (should be 0).

Q22

The correct d-electron configuration showing spin-orbit coupling is

A $t_2g^4\ eg^2$

B $t_2g^6\ eg^0$

C $t_2g^4\ eg^0$

D $t_2g^3\ eg^2$

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Russell–Saunders coupling, Hund's rules, microstate counting

PYQ FREQUENCY
Very High · 14 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
"Spin is king, L is queen, J obeys the half-filled rule."
Microstates = $^{(2(2l+1))}C_n$.

Correct Answer C $t_2g^4\ eg^0$

CONCEPT

A term symbol $^{2S+1}L_J$ encodes total spin (S), orbital (L) and total angular momentum (J). For ground states use Hund's rules; microstate count = C(2(2l+1), n).

↓

LOGIC / WORKING

Spin-orbit coupling of d-electrons takes place in which t_2g orbitals are unsymmetrically filled.

FINAL: (C) $t_2g^4\ eg^0$

SHORTCUT / EXAM TRICK

Ground term: maximise S first, then L. J = |L−S| if shell ≤ half-filled, J = L+S if more than half-filled.

COMMON MISTAKE

Forgetting to flip the J-rule for more-than-half-filled shells, or mislabelling multiplicity (2S+1) vs S.

EXAM TIP

Memorise S/P/D/F/G ↔ L = 0/1/2/3/4. Half-filled (d^5, p^3, f^7) always give an S ground term (L=0).

MEMORY TRICK

“Spin is king, L is queen, J obeys the half-filled rule.” Microstates = $^{(2(2l+1))}C_n$.

Why the Other Options Are Wrong

Correct answer: **C**

A — $t_2g^4\ eg^2$

$t_2g^4eg^2$ (an HS d^6-type) has a symmetric eg^2 and weaker spin-orbit effect than $t_2g^4eg^0$.

B — $t_2g^6\ eg^0$

$t_2g^6eg^0$ is a filled, symmetric t_2g → orbital angular momentum quenched, no spin-orbit coupling.

D — $t_2g^3\ eg^2$

$t_2g^3eg^2$ (half-filled symmetric) gives essentially zero orbital contribution.

Q25

The number of microstates for d^5 electron configuration is:

A. 21×6^3

B. 14×63

C. 7×62

D. 28×63

QUESTION INSIGHTS

ESTIMATED TIME
3–5 min

DIFFICULTY
Hard

CONCEPT TESTED
Russell–Saunders coupling, Hund's rules, microstate counting

PYQ FREQUENCY
Very High · 14 papers

REVISION PRIORITY
★★★★★

EXPECTED LEVEL
Part C (high merit)

MEMORY HOOK
"Spin is king, L is queen, J obeys the half-filled rule."
Microstates = $^{(2(2l+1))}C_n$.

Correct Answer C 7×62

CONCEPT

A term symbol $^{2S+1}L_J$ encodes total spin (S), orbital (L) and total angular momentum (J). For ground states use Hund's rules; microstate count = C(2(2l+1), n).

↓

LOGIC / WORKING

We know that number of microstates= N!(LN)! For d^5, r= 5, l=2 Therefore, n = 2(2l+1)= $2(2x_2+1)$ = 10 OP! Number of microstates = = 252 = 7×6W Q!×Q!

FINAL: (C) 7×62

SHORTCUT / EXAM TRICK

Ground term: maximise S first, then L. J = |L−S| if shell ≤ half-filled, J = L+S if more than half-filled.

COMMON MISTAKE

Forgetting to flip the J-rule for more-than-half-filled shells, or mislabelling multiplicity (2S+1) vs S.

EXAM TIP

Memorise S/P/D/F/G ↔ L = 0/1/2/3/4. Half-filled (d^5, p^3, f^7) always give an S ground term (L=0).

MEMORY TRICK

“Spin is king, L is queen, J obeys the half-filled rule.” Microstates = $^{(2(2l+1))}C_n$.

Why the Other Options Are Wrong

Correct answer: **C**

A — **21×6^3**

21×6^3 is far larger than C(10,5)=252; this miscounts the combinations.

B — **14×63**

$14\times6^3 \neq 252$; incorrect arithmetic for d^5 microstates.

D — **28×63**

28×6^3 overshoots 252; not the correct microstate count.

Q36

One of the excited states of Ti has the electric configuration $[Ar]4s^2\ 3d^1\ 4p^1$. The number of microstates with zero total spin (S) for this configuration is

A) 9

B) 15

C) 27

D) 60

QUESTION INSIGHTS

ESTIMATED TIME
3–5 min

DIFFICULTY
Hard

CONCEPT TESTED
Russell–Saunders coupling, Hund's rules, microstate counting

PYQ FREQUENCY
Very High · 14 papers

REVISION PRIORITY
★★★★★

EXPECTED LEVEL
Part C (high merit)

MEMORY HOOK
"Spin is king, L is queen, J obeys the half-filled rule."
Microstates = $^{(2(2l+1))}C_n$.

Correct Answer B 15

CONCEPT

A term symbol $^{2S+1}L_J$ encodes total spin (S), orbital (L) and total angular momentum (J). For ground states use Hund's rules; microstate count = C(2(2l+1), n).

↓

LOGIC / WORKING

Configuration [Ar]$4s^2 3d^1 4p^1$ → the open shells are $3d^1$ and $4p^1$ ($4s^2$ is closed).
For total spin S = 0, the two electrons must be paired (opposite spins).
3d electron: 5 possible m_l values; 4p electron: 3 possible m_l values.

- Number of S = 0 microstates = 5 × 3 = 15.

FINAL: (B) 15

SHORTCUT / EXAM TRICK

Ground term: maximise S first, then L. J = |L−S| if shell ≤ half-filled, J = L+S if more than half-filled.

COMMON MISTAKE

Forgetting to flip the J-rule for more-than-half-filled shells, or mislabelling multiplicity (2S+1) vs S.

EXAM TIP

Memorise S/P/D/F/G ↔ L = 0/1/2/3/4. Half-filled (d^5, p^3, f^7) always give an S ground term (L=0).

MEMORY TRICK

“Spin is king, L is queen, J obeys the half-filled rule.”
Microstates = $^{(2(2l+1))}C_n$.

Why the Other Options Are Wrong

Correct answer: **B**

A — **9**

9 undercounts; the d(5)×p(3) paired combinations give 15 singlet microstates.

C — **27**

27 counts all spin combinations, not just the S=0 (paired) ones.

D — **60**

60 is the full microstate count for the configuration, not the S=0 subset.

Q40

The Mulliken symbols for the spectroscopic states arising from the free-ion term F are

A $T_2g + Eg$

B $T_1g + T_2g + T_1u$

C $T_1g + T_2g + A_2g$

D $A_1g + T_2g + T_1g$

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Russell–Saunders coupling, Hund's rules, microstate counting

PYQ FREQUENCY
Very High · 14 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
"Spin is king, L is queen, J obeys the half-filled rule."
Microstates = $^{(2(2l+1))}C_n$.

Correct Answer C $T_1g + T_2g + A_2g$

CONCEPT

A term symbol $^{2S+1}L_J$ encodes total spin (S), orbital (L) and total angular momentum (J). For ground states use Hund's rules; microstate count = C(2(2l+1), n).

↓

LOGIC / WORKING

The mulliken symbols for the spectroscopic states arising from free ion term F are $T_1g + T_2g + A_2g$

FINAL: (C) $T_1g + T_2g + A_2g$

SHORTCUT / EXAM TRICK

Ground term: maximise S first, then L. J = |L−S| if shell ≤ half-filled, J = L+S if more than half-filled.

COMMON MISTAKE

Forgetting to flip the J-rule for more-than-half-filled shells, or mislabelling multiplicity (2S+1) vs S.

EXAM TIP

Memorise S/P/D/F/G ↔ L = 0/1/2/3/4. Half-filled (d^5, p^3, f^7) always give an S ground term (L=0).

MEMORY TRICK

“Spin is king, L is queen, J obeys the half-filled rule.” Microstates = $^{(2(2l+1))}C_n$.

Why the Other Options Are Wrong

Correct answer: **C**

A — **T_2g + Eg**

F splits into three terms in Oh ($A_2g+T_2g+T_1g$), not two.

B — **T_1g +T_2g + T_1u**

T_1u is ungerade; the F-derived terms are all gerade (A_2g, T_2g, T_1g).

D — **A_1g +T_2g +T_1g**

A_1g is not among the F-term components; the set is $A_2g+T_2g+T_1g$.

Q49

For an electronic configuration of two non-equivalent π electrons [π^1, π^1], which of the following terms is not possible?

A $^1\Sigma$

B $^3\Sigma$

C $^3\Delta$

D $^3\Phi$

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Russell–Saunders coupling, Hund's rules, microstate counting

PYQ FREQUENCY
Very High · 14 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
"Spin is king, L is queen, J obeys the half-filled rule."
Microstates = $^{(2(2l+1))}C_n$.

Correct Answer D $^3\Phi$

CONCEPT

A term symbol $^{2S+1}L_J$ encodes total spin (S), orbital (L) and total angular momentum (J). For ground states use Hund's rules; microstate count = C(2(2l+1), n).

↓

LOGIC / WORKING

- For two non-equivalent π-electrons [π1, π1] ϕ is not possible.

FINAL: (D) $^3\Phi$

SHORTCUT / EXAM TRICK

Ground term: maximise S first, then L. J = |L−S| if shell ≤ half-filled, J = L+S if more than half-filled.

COMMON MISTAKE

Forgetting to flip the J-rule for more-than-half-filled shells, or mislabelling multiplicity (2S+1) vs S.

EXAM TIP

Memorise S/P/D/F/G ↔ L = 0/1/2/3/4. Half-filled (d^5, p^3, f^7) always give an S ground term (L=0).

MEMORY TRICK

“Spin is king, L is queen, J obeys the half-filled rule.” Microstates = $^{(2(2l+1))}C_n$.

Why the Other Options Are Wrong

Correct answer: **D**

A — **$^{1}\Sigma$**

$^{1}\Sigma$ is a valid term for $[\pi^{1},\pi^{1}]$ (Λ=0 singlet), so it IS possible.

B — **$^{3}\Sigma$**

$^{3}\Sigma$ is allowed (Λ=0 triplet), so it is a possible term.

C — **$^{3}\Delta$**

$^{3}\Delta$ is allowed (Λ=2 triplet), so it is possible; only $^{3}\Phi$ is impossible.

Q59

The term symbol that is NOT allowed for the np_2 configuration is 1

A. ^1D

B. ^3P

C. ^1S

D. ^3D

QUESTION INSIGHTS

ESTIMATED TIME
3–5 min

DIFFICULTY
Hard

CONCEPT TESTED
Russell–Saunders coupling, Hund's rules, microstate counting

PYQ FREQUENCY
Very High · 14 papers

REVISION PRIORITY
★★★★★

EXPECTED LEVEL
Part C (high merit)

MEMORY HOOK
"Spin is king, L is queen, J obeys the half-filled rule."
Microstates = $^{(2(2l+1))}C_n$.

Correct Answer D ^3D

CONCEPT

A term symbol $^{2S+1}L_J$ encodes total spin (S), orbital (L) and total angular momentum (J). For ground states use Hund's rules; microstate count = C(2(2l+1), n).

↓

LOGIC / WORKING

For np_2 configurations (microstates)

The configuration (IV) violets the Pauli's Principle, Hence term symbol ^3D is not possible.

FINAL: (D) ^3D

SHORTCUT / EXAM TRICK

Ground term: maximise S first, then L. J = |L−S| if shell ≤ half-filled, J = L+S if more than half-filled.

COMMON MISTAKE

Forgetting to flip the J-rule for more-than-half-filled shells, or mislabelling multiplicity (2S+1) vs S.

EXAM TIP

Memorise S/P/D/F/G ↔ L = 0/1/2/3/4. Half-filled (d^5, p^3, f^7) always give an S ground term (L=0).

MEMORY TRICK

“Spin is king, L is queen, J obeys the half-filled rule.” Microstates = $^{(2(2l+1))}C_n$.

Why the Other Options Are Wrong

Correct answer: **D**

A — ^{1}D

a bare 'D' is not a complete term symbol and $^{1}D/^{3}D$ possibility must be checked against Pauli.

B — ^{3}P

^{3}P is an allowed p^2 term (it is in fact the ground term).

C — ^{1}S

^{1}S is an allowed p^2 term; only ^{3}D is forbidden by the Pauli principle.

Q65

The S and L values for 15N atom respectively, are

A. 1/2 and 1

B. 1/2 and 0

C. 1 and 0

D. 3/2 and 0

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Russell–Saunders coupling, Hund's rules, microstate counting

PYQ FREQUENCY
Very High · 14 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
"Spin is king, L is queen, J obeys the half-filled rule."
Microstates = $^{(2(2l+1))}C_n$.

Correct Answer D 3/2 and 0

CONCEPT

A term symbol $^{2S+1}L_J$ encodes total spin (S), orbital (L) and total angular momentum (J). For ground states use Hund's rules; microstate count = C(2(2l+1), n).

↓

LOGIC / WORKING

- N=1s 2s 2p L= +1 0 -1 S= 1/2+1/2+1/2=3/2 L=+1+0-1=0

FINAL: (D) 3/2 and 0

SHORTCUT / EXAM TRICK

Ground term: maximise S first, then L. J = |L−S| if shell ≤ half-filled, J = L+S if more than half-filled.

COMMON MISTAKE

Forgetting to flip the J-rule for more-than-half-filled shells, or mislabelling multiplicity (2S+1) vs S.

EXAM TIP

Memorise S/P/D/F/G ↔ L = 0/1/2/3/4. Half-filled (d^5, p^3, f^7) always give an S ground term (L=0).

MEMORY TRICK

“Spin is king, L is queen, J obeys the half-filled rule.” Microstates = $^{(2(2l+1))}C_n$.

Why the Other Options Are Wrong

Correct answer: **D**

A **1/2 and 1**
for p^3 (^{15}N), S=3/2 not 1/2, and L=0 not 1.

B **1/2 and 0**
S is 3/2 (three parallel spins), not 1/2.

C **1 and 0**
S is 3/2, not 1; L is correctly 0 but the spin is wrong.

Q70

The configuration [Ne]$2p^1$ $3p^1$ has a ^3D term. Its levels are
3 3

A $D_3/2$, $D_1/2$

B $^3D_5/2$, $^3D_3/2$, $^3D_1/2$

C $^3D_3$, $^3D_2$, $^3D_1$

D $^3D_3$, $^3D_2$, $^3D_1$, $^3D_0$

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Russell–Saunders coupling, Hund's rules, microstate counting

PYQ FREQUENCY
Very High · 14 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
"Spin is king, L is queen, J obeys the half-filled rule."
Microstates = $^{(2(2l+1))}C_n$.

Correct Answer C $^3D_3$, $^3D_2$, $^3D_1$

CONCEPT

A term symbol $^{2S+1}L_J$ encodes total spin (S), orbital (L) and total angular momentum (J). For ground states use Hund's rules; microstate count = C(2(2l+1), n).

↓

LOGIC / WORKING

[Ne]$2p^1$ $3p^1$ 2s+1=3; 2s=2; s=1 For, D, L=2 J=|L+s|..... |L-s|=|2+1|... |2-1|= 3,2,1 Levels for ^3D are $^3D_3$, $^3D_2$, $^3D_1$

FINAL: (C) $^3D_3$, $^3D_2$, $^3D_1$

SHORTCUT / EXAM TRICK

Ground term: maximise S first, then L. J = |L−S| if shell ≤ half-filled, J = L+S if more than half-filled.

COMMON MISTAKE

Forgetting to flip the J-rule for more-than-half-filled shells, or mislabelling multiplicity (2S+1) vs S.

EXAM TIP

Memorise S/P/D/F/G ↔ L = 0/1/2/3/4. Half-filled (d^5, p^3, f^7) always give an S ground term (L=0).

MEMORY TRICK

“Spin is king, L is queen, J obeys the half-filled rule.” Microstates = $^{(2(2l+1))}C_n$.

Why the Other Options Are Wrong

Correct answer: **C**

A $D_3/2$, $D_1/2$

incomplete/garbled term symbols; ^3D gives J=3,2,1.

B $^3D_5/2$, $^3D_3/2$, $^3D_1/2$

these half-integer J values are for an odd-electron term; ^3D has integer J=3,2,1.

D $^3D_3$, $^3D_2$, $^3D_1$, $^3D_0$

^3D has only J=3,2,1 (three levels); J=0 is not allowed for L=2,S=1.

Q71 The spin-only magnetic moment and the spectroscopic ground state term symbol of manganese center in $[MnF_6]^{3-}$ ion respectively, are

A. 4.9 BM and ^5D

B. 4.9 BM and ^4F

C. 3.9 BM and ^3D

D. 4.9 BM and ^3F

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Russell–Saunders coupling, Hund's rules, microstate counting

PYQ FREQUENCY
Very High · 14 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
"Spin is king, L is queen, J obeys the half-filled rule."
Microstates = $^{(2(2l+1))}C_n$.

Correct Answer A 4.9 BM and ^5D

CONCEPT

A term symbol $^{2S+1}L_J$ encodes total spin (S), orbital (L) and total angular momentum (J). For ground states use Hund's rules; microstate count = C(2(2l+1), n).

↓

LOGIC / WORKING

$[MnF_6]^{3-}$, $Mn^{3+} \rightarrow 3d^4 \rightarrow t2g\ e1g$ (HS)

μ = 4 4 + 2 = 24 = 4.9 S =2 $\rightarrow$ 2s+1 = 2×2+1=5 L=2 $\rightarrow$ D Ground state term symbol ^3D

FINAL: (A) 4.9 BM and ^5D

SHORTCUT / EXAM TRICK

Ground term: maximise S first, then L. J = |L−S| if shell ≤ half-filled, J = L+S if more than half-filled.

COMMON MISTAKE

Forgetting to flip the J-rule for more-than-half-filled shells, or mislabelling multiplicity (2S+1) vs S.

EXAM TIP

Memorise S/P/D/F/G ↔ L = 0/1/2/3/4. Half-filled (d^5, p^3, f^7) always give an S ground term (L=0).

MEMORY TRICK

“Spin is king, L is queen, J obeys the half-filled rule.” Microstates = $^{(2(2l+1))}C_n$.

Why the Other Options Are Wrong

Correct answer: **A**

B **4.9 BM and ^4F**

the ground term of HS d^5 is ^5D... actually $^6S \rightarrow {}^6A_1g$; ^4F is the d^3/d^7 free-ion term, not d^5.

C **3.9 BM and ^3D**

μ for 5 unpaired electrons is 5.9 BM, not 3.9 BM.

D **4.9 BM and ^3F**

^3F is not the d^5 ground term and 4.9 BM corresponds to 4 unpaired, not 5.

Q76

The lowest energy-state of an atom with electronic configuration ns_1np_1 has the term symbol

A $^3P_1$

B $^1P_1$

C $^3P_2$

D $^3P_0$

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Russell–Saunders coupling, Hund's rules, microstate counting

PYQ FREQUENCY
Very High · 14 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
"Spin is king, L is queen, J obeys the half-filled rule."
Microstates = $^{(2(2l+1))}C_n$.

Correct Answer D $^3P_0$

CONCEPT

A term symbol $^{2S+1}L_J$ encodes total spin (S), orbital (L) and total angular momentum (J). For ground states use Hund's rules; microstate count = C(2(2l+1), n).

↓

LOGIC / WORKING

$ns_1\ np_1$ L=1 ≡ *P* S=1 hence, ^{2}S+1=3 For J value, if orbital is less than half filled than J=|L-S|=|1-1|=0 Hence, $^3P_0$

FINAL: (D) $^3P_0$

SHORTCUT / EXAM TRICK

Ground term: maximise S first, then L. J = |L−S| if shell ≤ half-filled, J = L+S if more than half-filled.

COMMON MISTAKE

Forgetting to flip the J-rule for more-than-half-filled shells, or mislabelling multiplicity (2S+1) vs S.

EXAM TIP

Memorise S/P/D/F/G ↔ L = 0/1/2/3/4. Half-filled (d^5, p^3, f^7) always give an S ground term (L=0).

MEMORY TRICK

“Spin is king, L is queen, J obeys the half-filled rule.” Microstates = $^{(2(2l+1))}C_n$.

Why the Other Options Are Wrong

Correct answer: **D**

A $^{3}P_{1}$

for less-than-half-filled, the ground level is the lowest J; $^{3}P_{1}$ is not lowest.

B $^{1}P_{1}$

$^{1}P_{1}$ is a singlet; Hund's rule makes the triplet ^{3}P lower.

C $^{3}P_{2}$

$^{3}P_{2}$ is the highest J of ^{3}P; the ground level is $^{3}P_{0}$ for $s^{1}p^{1}$.

Q80

The term symbol for the first excited state of Be with the electronic configuration $1s^2\ 2s^1\ 3s^1$ is.

A $^3S_1$

B $^3S_0$

C $^1S_0$

D $^2S_1/2$

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Russell–Saunders coupling, Hund's rules, microstate counting

PYQ FREQUENCY
Very High · 14 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
"Spin is king, L is queen, J obeys the half-filled rule."
Microstates = $^{(2(2l+1))}C_n$.

Correct Answer A $^3S_1$

CONCEPT

A term symbol $^{2S+1}L_J$ encodes total spin (S), orbital (L) and total angular momentum (J). For ground states use Hund's rules; microstate count = C(2(2l+1), n).

↓

LOGIC / WORKING

Taking the valence shell configuration Be $2s^1$ $3s^1$ s=1/2+1/2 =1 Multiplicity =^{2}S+1= $2x_1$+1=3 L= 0+0= 0 , S term J= (L+S) = (0+1) = 1 Hence, terms is $^3S_1$

FINAL: (A) $^3S_1$

SHORTCUT / EXAM TRICK

Ground term: maximise S first, then L. J = |L−S| if shell ≤ half-filled, J = L+S if more than half-filled.

COMMON MISTAKE

Forgetting to flip the J-rule for more-than-half-filled shells, or mislabelling multiplicity (2S+1) vs S.

EXAM TIP

Memorise S/P/D/F/G ↔ L = 0/1/2/3/4. Half-filled (d^5, p^3, f^7) always give an S ground term (L=0).

MEMORY TRICK

“Spin is king, L is queen, J obeys the half-filled rule.” Microstates = $^{(2(2l+1))}C_n$.

Why the Other Options Are Wrong

Correct answer: **A**

B $^{3}S_{0}$

^{3}S has J=1 only (L=0,S=1), so $^{3}S_{0}$ is not a valid level.

C $^{1}S_{0}$

the first excited state is the triplet $^{3}S_{1}$, not the singlet $^{1}S_{0}$.

D $^{2}S_{1}/2$

$^{2}S_{1}/_{2}$ is a doublet (one electron), not the two-electron $1s^{2}2s^{1}3s^{1}$ triplet state.

Q91

Possible term symbol(s) of the excited states of Na atom with the electronic configuration [$1s^2\ 2s^2\ 2p^6\ 3p^1$] is/are

A. $^2S_1/2$

B. $^2P_3/2$ and $^2P_1/2$

C. $^1S_0$ and $^1P_1$

D. $^3P_0$ and $^3P_1$

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Russell–Saunders coupling, Hund's rules, microstate counting

PYQ FREQUENCY
Very High · 14 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
"Spin is king, L is queen, J obeys the half-filled rule."
Microstates = $^{(2(2l+1))}C_n$.

Correct Answer B $^2P_3/2$ and $^2P_1/2$

CONCEPT

A term symbol $^{2S+1}L_J$ encodes total spin (S), orbital (L) and total angular momentum (J). For ground states use Hund's rules; microstate count = C(2(2l+1), n).

↓

LOGIC / WORKING

For $[1s_{22}s_2p_6\ 3p^1]$2s+1=2× + 1 = 2 J=|l+s|..... |l-s| =|1+½|.....|1-½| = 3/2 1/2 Term symbol $^2P_3/2$ 2 $P_1/2$

FINAL: (B) $^2P_3/2$ and $^2P_1/2$

SHORTCUT / EXAM TRICK

Ground term: maximise S first, then L. J = |L−S| if shell ≤ half-filled, J = L+S if more than half-filled.

COMMON MISTAKE

Forgetting to flip the J-rule for more-than-half-filled shells, or mislabelling multiplicity (2S+1) vs S.

EXAM TIP

Memorise S/P/D/F/G ↔ L = 0/1/2/3/4. Half-filled (d^5, p^3, f^7) always give an S ground term (L=0).

MEMORY TRICK

“Spin is king, L is queen, J obeys the half-filled rule.” Microstates = $^{(2(2l+1))}C_n$.

Why the Other Options Are Wrong

Correct answer: **B**

A — $^2S_1/2$

a single $^2S_1/_2$ cannot arise from a p^1 excited state; that requires an s electron, and both J levels are needed.

C — $^1S_0$ and $^1P_1$

$^1S/^1P$ are singlets; one p electron gives a doublet (^2P).

D — $^3P_0$ and $^3P_1$

^3P terms are triplets; a single 3p electron gives only the doublet ^2P.

Q94

The number of microstates present in ^{3}F-term is

A. 3

B. 21

C. 9

D. 28

QUESTION INSIGHTS

ESTIMATED TIME
3–5 min

DIFFICULTY
Hard

CONCEPT TESTED
Russell–Saunders coupling, Hund's rules, microstate counting

PYQ FREQUENCY
Very High · 14 papers

REVISION PRIORITY
★★★★★

EXPECTED LEVEL
Part C (high merit)

MEMORY HOOK
"Spin is king, L is queen, J obeys the half-filled rule."
Microstates = $^{(2(2l+1))}C_n$.

Correct Answer B 21

CONCEPT

A term symbol $^{2S+1}L_J$ encodes total spin (S), orbital (L) and total angular momentum (J). For ground states use Hund's rules; microstate count = C(2(2l+1), n).

↓

LOGIC / WORKING

Number of microstate in ^3F is calculated as (^2S + 1) (2L+1)
For F, L=3.
Hence, (3) ($2x_3$+1) =21

FINAL: (B) 21

SHORTCUT / EXAM TRICK

Ground term: maximise S first, then L. J = |L−S| if shell ≤ half-filled, J = L+S if more than half-filled.

COMMON MISTAKE

Forgetting to flip the J-rule for more-than-half-filled shells, or mislabelling multiplicity (2S+1) vs S.

EXAM TIP

Memorise S/P/D/F/G ↔ L = 0/1/2/3/4. Half-filled (d^5, p^3, f^7) always give an S ground term (L=0).

MEMORY TRICK

“Spin is king, L is queen, J obeys the half-filled rule.”
Microstates = $^{(2(2l+1))}C_n$.

Why the Other Options Are Wrong

Correct answer: **B**

A — **3**

3 is far too small; degeneracy of ^3F = (^2S+1)(2L+1)=21.

C — **9**

9 undercounts; the correct microstate count is 21.

D — **28**

28 is the microstate count of a different term; ^3F has 21.

Q96

The lowest energy term for the d^6 configuration is

A. ^2D

B. ^5D

C. ^1P

D. ^1D

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Russell–Saunders coupling, Hund's rules, microstate counting

PYQ FREQUENCY
Very High · 14 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
"Spin is king, L is queen, J obeys the half-filled rule."
Microstates = $^{(2(2l+1))}C_n$.

Correct Answer B ^5D

CONCEPT

A term symbol $^{2S+1}L_J$ encodes total spin (S), orbital (L) and total angular momentum (J). For ground states use Hund's rules; microstate count = C(2(2l+1), n).

↓

LOGIC / WORKING

D_6 = L= ΣML = 5-3 = 2 = D S=2 , $^2S+1=5$ Hence, lowest energy form = ^5D

FINAL: (B) ^5D

SHORTCUT / EXAM TRICK

Ground term: maximise S first, then L. J = |L−S| if shell ≤ half-filled, J = L+S if more than half-filled.

COMMON MISTAKE

Forgetting to flip the J-rule for more-than-half-filled shells, or mislabelling multiplicity (2S+1) vs S.

EXAM TIP

Memorise S/P/D/F/G ↔ L = 0/1/2/3/4. Half-filled (d^5, p^3, f^7) always give an S ground term (L=0).

MEMORY TRICK

“Spin is king, L is queen, J obeys the half-filled rule.” Microstates = $^{(2(2l+1))}C_n$.

Why the Other Options Are Wrong

Correct answer: **B**

A — ^{2}D

^{2}D is a doublet; the d^{6} ground term must maximise spin (quintet) → ^{5}D.

C — ^{1}P

^{1}P is a singlet, far above the high-spin ^{5}D ground term.

D — ^{1}D

^{1}D is a singlet; Hund's rule selects the quintet ^{5}D as lowest.

Q108

The spectroscopic ground state term symbols for the octahedral aqua complexes of Mn(II), Cr(III) and Cu(II), respectively, are 2 4 2

A H , F and D

B ^{6}S, ^{4}F and ^{2}D

C ^{2}H , ^{2}H and ^{2}D

D ^{6}S, ^{4}F and ^{2}P

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Russell–Saunders coupling, Hund's rules, microstate counting

PYQ FREQUENCY
Very High · 14 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
"Spin is king, L is queen, J obeys the half-filled rule."
Microstates = $^{(2(2l+1))}C_n$.

Correct Answer B ^6S, ^4F and ^2D

CONCEPT

A term symbol $^{2S+1}L_J$ encodes total spin (S), orbital (L) and total angular momentum (J). For ground states use Hund's rules; microstate count = C(2(2l+1), n).

↓

LOGIC / WORKING

$[Mn(H_2O_6)]^{2+}$ → H_2O is a weak ligand, No pairing occurs.

S=5/2 , $^2S+1=6$ L=0→ S Term Ground state term → ^6S Cr^{3+} = L= 3→F Term S= 3/2 ; $^2S+1=2x_3/2+1=4$ Ground state term→ ^4F Cu^{2+} = d^9 L= ΣML = 2 →D S=1/2 , $^2S+1=2$ Ground state term → ^2D

FINAL: (B) ^6S, ^4F and ^2D

SHORTCUT / EXAM TRICK

Ground term: maximise S first, then L. J = |L−S| if shell ≤ half-filled, J = L+S if more than half-filled.

COMMON MISTAKE

Forgetting to flip the J-rule for more-than-half-filled shells, or mislabelling multiplicity (2S+1) vs S.

EXAM TIP

Memorise S/P/D/F/G ↔ L = 0/1/2/3/4. Half-filled (d^5, p^3, f^7) always give an S ground term (L=0).

MEMORY TRICK

“Spin is king, L is queen, J obeys the half-filled rule.” Microstates = $^{(2(2l+1))}C_n$.

Why the Other Options Are Wrong

Correct answer: **B**

A **H , F and D**

bare 'H, F, D' are not full term symbols and lack multiplicities.

C **^{2}H , ^{2}H and ^{2}D**

^{2}H/^{2}H multiplicities are incorrect for d^5 (Mn^{2+}) and d^5 (Fe^{3+}) which give ^{6}S.

D **^{6}S, ^{4}F and ^{2}P**

the third term should be ^{2}D (Co^{3+} LS d^6 has $^{1}A_1g$, but free-ion d^6...); ^{2}P is incorrect for the set.

Q129

The lowest energy state of a $1s^1\ 2s^1$ electronic configuration, according to Hund's rule, is:

A $^3S_0$

B $^1S_0$

C $^3S_1$

D $^1S_1$

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Russell–Saunders coupling, Hund's rules, microstate counting

PYQ FREQUENCY
Very High · 14 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
"Spin is king, L is queen, J obeys the half-filled rule."
Microstates = $^{(2(2l+1))}C_n$.

Correct Answer C $^3S_1$

CONCEPT

A term symbol $^{2S+1}L_J$ encodes total spin (S), orbital (L) and total angular momentum (J). For ground states use Hund's rules; microstate count = C(2(2l+1), n).

↓

LOGIC / WORKING

S=1/2+1/2=1 $^2S+1= 2x_1+1=3$ J=|l+s|...|l - s| = |1+0|...|1-0| =1 l=0 → S (term)

S_1

FINAL: (C) $^3S_1$

SHORTCUT / EXAM TRICK

Ground term: maximise S first, then L. J = |L−S| if shell ≤ half-filled, J = L+S if more than half-filled.

COMMON MISTAKE

Forgetting to flip the J-rule for more-than-half-filled shells, or mislabelling multiplicity (2S+1) vs S.

EXAM TIP

Memorise S/P/D/F/G ↔ L = 0/1/2/3/4. Half-filled (d^5, p^3, f^7) always give an S ground term (L=0).

MEMORY TRICK

“Spin is king, L is queen, J obeys the half-filled rule.” Microstates = $^{(2(2l+1))}C_n$.

Why the Other Options Are Wrong

Correct answer: **C**

A $^{3}S_{0}$

^{3}S has J=1 only, so $^{3}S_{0}$ is not a valid level.

B $^{1}S_{0}$

the lowest state is the triplet $^{3}S_{1}$ (Hund), not the singlet $^{1}S_{0}$.

D $^{1}S_{1}$

$^{1}S_{1}$ is not a valid term (singlet S must be J=0); the ground excited state is $^{3}S_{1}$.

Q156

For the d^3 electron configuration, the ground state term symbol is

A. $^4F_{1}/2$

B. $^4F_{3}/2$

C. $^4F_{7}/2$

D. $^4F_{9}/2$

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Russell–Saunders coupling, Hund's rules, microstate counting

PYQ FREQUENCY
Very High · 14 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
"Spin is king, L is queen, J obeys the half-filled rule."
Microstates = $^{(2(2l+1))}C_n$.

Correct Answer B $^4F_3/2$

CONCEPT

A term symbol $^{2S+1}L_J$ encodes total spin (S), orbital (L) and total angular momentum (J). For ground states use Hund's rules; microstate count = C(2(2l+1), n).

↓

LOGIC / WORKING

d -electronic configuration:
L=2+1+0 = 3 i.e. 'F' S= 3 x 1/2 = 3/2 ^{2}S+1 = 2 x 3/2 + 1 = 4 J = less than half filled= L-S= 3-3/2 = 3/2 Thus, ground state term is = ^{2}S+1LJ = $^4F_3/2$

FINAL: (B) $^4F_3/2$

SHORTCUT / EXAM TRICK

Ground term: maximise S first, then L. J = |L−S| if shell ≤ half-filled, J = L+S if more than half-filled.

COMMON MISTAKE

Forgetting to flip the J-rule for more-than-half-filled shells, or mislabelling multiplicity (2S+1) vs S.

EXAM TIP

Memorise S/P/D/F/G ↔ L = 0/1/2/3/4. Half-filled (d^5, p^3, f^7) always give an S ground term (L=0).

MEMORY TRICK

"Spin is king, L is queen, J obeys the half-filled rule." Microstates = $^{(2(2l+1))}C_n$.

Why the Other Options Are Wrong

Correct answer: **B**

A $^4F_1/2$

for d^3 (<half filled) the ground level is the lowest J, but $^4F_1/_2$ is not a valid J for L=3,S=3/2.

C $^4F_7/2$

$^4F_7/_2$ is a higher J level; the ground level is the lowest, $^4F_3/_2$.

D $^4F_9/2$

$^4F_9/_2$ is the highest J; for less-than-half-filled d^3 the ground level is $^4F_3/_2$.

Q161

The term symbol for the ground state of dinitrogen cation radical $(N_2)^+$ is:

A $^2\pi_u$

B $^2\Sigma^+_u$

C $^2\pi_g$

D $^2\Sigma^+_g$

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Russell–Saunders coupling, Hund's rules, microstate counting

PYQ FREQUENCY
Very High · 14 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
"Spin is king, L is queen, J obeys the half-filled rule."
Microstates = $^{(2(2l+1))}C_n$.

Atomic Term Symbols & Microstates

Correct Answer D $^{2}\Sigma^{+}_{g}$

CONCEPT

A term symbol $^{2S+1}L_J$ encodes total spin (S), orbital (L) and total angular momentum (J). For ground states use Hund's rules; microstate count = C(2(2l+1), n).

↓

LOGIC / WORKING

N_2 = σ 1s σ 1s* σ22s σ22s* π22px = π22py σ12pz 2 2 σ12pz = gerade Λ = 0 i.e. Σ S=½ ^{2}S+1 = 2 × 1/2 + 1 = 2 As σ12pz orbital is symmetric, (+) is used.
Thus, term symbol of N^{2+}, is Λ. 2 . g/u = Σ

FINAL: (D) $^{2}\Sigma^{+}_{g}$

SHORTCUT / EXAM TRICK

Ground term: maximise S first, then L. J = |L−S| if shell ≤ half-filled, J = L+S if more than half-filled.

COMMON MISTAKE

Forgetting to flip the J-rule for more-than-half-filled shells, or mislabelling multiplicity (2S+1) vs S.

EXAM TIP

Memorise S/P/D/F/G ↔ L = 0/1/2/3/4. Half-filled (d^5, p^3, f^7) always give an S ground term (L=0).

MEMORY TRICK

“Spin is king, L is queen, J obeys the half-filled rule.”
Microstates = $^{(2(2l+1))}C_n$.

Why the Other Options Are Wrong

Correct answer: **D**

A $^{2}\pi_{u}$

removing an electron from the σ-type HOMO gives a Σ (not π) ground state.

B $^{2}\Sigma^{+}_{u}$

the singly-occupied σg orbital makes the term gerade (g), so Σu^{+} has the wrong parity.

C $^{2}\pi_{g}$

the ground term is a Σ state (Λ=0), not a π state (Λ=1).

TOPIC REVISION

Atomic Term Symbols & Microstates

21 PYQs · Last-minute revision

TOPIC SUMMARY

A term symbol $^{2S+1}L_J$ encodes total spin (S), orbital (L) and total angular momentum (J). For ground states use Hund's rules; microstate count = C(2(2l+1), n).

IMPORTANT FORMULA SHEET

Multiplicity = 2S + 1

Microstates = $^{(2(2l+1))}C_n$ (n = electrons)

Ground J = |L−S| (≤ half) ; L+S (> half)

- Total degeneracy of a term = (2S+1)(2L+1)

FREQUENTLY ASKED CONCEPTS

Hund's rule of maximum multiplicity

L, S, J coupling

Pauli-allowed terms

- Ground-state term derivation

COMMON MISTAKES & QUICK NOTES

Watch out:

Forgetting to flip the J-rule for more-than-half-filled shells, or mislabelling multiplicity (2S+1) vs S.

Last-minute:

Ground term: maximise S first, then L. J = |L−S| if shell ≤ half-filled, J = L+S if more than half-filled.

MOST-REPEATED PYQs & EXPECTED IN EXAM

PYQs in this topic: Q3 Q8 Q12 Q22 Q25 Q36 Q40 Q49 Q59 Q65 Q70 Q71 Q76 Q80 Q91 Q94 Q96 Q108 Q129 Q156 Q161

Expect **3 question(s)** next session on **Russell–Saunders coupling, Hund's rules, microstate counting.**

TOPIC 2

Crystal Field Theory & Geometry

9 questions · Easy 8 | Medium 1 | Hard 0 · PYQ frequency: Moderate

Q18

The correct order of d-orbital splitting in a trigonal bipyramidal geometry is: 2 2

A $dz^2 > dxz > d\ x\text{-}y\ ,\ dxy$

B $dxz\ ,\ dyz > d\ x_2\text{-}y_2,\ dxy > dz^2$

C $d\ x_2\text{-}y_2,\ dxy > dz^2 > dxz\ ,\ dyz$

D $dz^2 > d\ x_2\text{-}y_2 > dxy > dxz\ ,\ dyz$

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
d-orbital splitting, CFSE, geometry prediction

PYQ FREQUENCY
Moderate · 7 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
Spectrochemical series: "I < Br < Cl < F < OH < ox < H_2O < NCS < NH_3 < en < NO_2 < CN < CO".

Correct Answer D $dz^2 > d\,x_2\text{-}y_2 > dxy > dxz\ ,\ dyz$

CONCEPT

Ligands split d-orbitals by electrostatic field. Δo (octahedral), Δt = 4/9 Δo (tetrahedral). CFSE depends on d-electron count and field strength.

↓

LOGIC / WORKING

In trigonal bipyramidal geometry, two ligands lie along the z-axis and three in the xy-plane.
dz^2 points directly at the two axial ligands → highest energy.
$dx^2\text{-}y^2$ and dxy lie in the equatorial plane (between ligands) → intermediate energy.
dxz, dyz have nodes between the axes → lowest energy.
Order: $dz^2 > dx^2\text{-}y^2 > dxy > dxz, dyz$.

FINAL: (D) $dz^2 > d\,x_2\text{-}y_2 > dxy > dxz\ ,\ dyz$

SHORTCUT / EXAM TRICK

Octahedral CFSE = $(-0.4\ t_2g + 0.6\ eg)\ \Delta o$ + pairing.
Tetrahedral is always high-spin (Δt small).

COMMON MISTAKE

Using Δo splitting pattern (t_2g below eg) for tetrahedral, where the order inverts (e below t_2).

EXAM TIP

Strong field (CN^-, CO) → low spin; weak field (halides, H_2O) → high spin. Square planar favoured by d^8 + strong field.

MEMORY TRICK

Spectrochemical series: "I < Br < Cl < F < OH < ox < H_2O < NCS < NH_3 < en < NO_2 < CN < CO".

Why the Other Options Are Wrong

Correct answer: **D**

A

$dz^2 > dxz > d\ x\text{-}y\ ,\ dxy$

dxz is not the second-highest; in TBP $dx^2–y^2$/dxy lie above the dxz,dyz pair.

B

$dxz\ ,\ dyz > d\ x_2\text{-}y_2,\ dxy > dz^2$

this inverts the order; dz^2 (pointing at axial ligands) must be highest, not lowest.

C

$d\ x_2\text{-}y_2,\ dxy > dz^2 > dxz\ ,\ dyz$

dz^2 is the highest orbital in TBP, so it cannot lie below the equatorial set here.

Q20

The coordination number and geometry of cerium in $[Ce(NO_3)_6]^{2-}$ are respectively,

A. 6 and octahedron

B. 6 and trigonal prism

C. 8 and cubic

D. 12 and icosahedron

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
d-orbital splitting, CFSE, geometry prediction

PYQ FREQUENCY
Moderate · 7 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
Spectrochemical series: "I < Br < Cl < F < OH < ox < H_2O < NCS < NH_3 < en < NO_2 < CN < CO".

Correct Answer D 12 and icosahedron

CONCEPT

Ligands split d-orbitals by electrostatic field. Δo (octahedral), Δt = 4/9 Δo (tetrahedral). CFSE depends on d-electron count and field strength.

↓

LOGIC / WORKING

For Ce^{4+} ions NO_3^- behaves as bidentate ligand. Thus C.N. for $[Ce(NO_3)_6]^{2-}$ is 12 and shape corresponding to C.N=12 is icosahedron.

FINAL: (D) 12 and icosahedron

SHORTCUT / EXAM TRICK

Octahedral CFSE = (−0.4 t_2g + 0.6 eg) Δo + pairing. Tetrahedral is always high-spin (Δt small).

COMMON MISTAKE

Using Δo splitting pattern (t_2g below eg) for tetrahedral, where the order inverts (e below t_2).

EXAM TIP

Strong field (CN^-, CO) → low spin; weak field (halides, H_2O) → high spin. Square planar favoured by d^8 + strong field.

MEMORY TRICK

Spectrochemical series: "I < Br < Cl < F < OH < ox < H_2O < NCS < NH_3 < en < NO_2 < CN < CO".

Why the Other Options Are Wrong

Correct answer: **D**

A **6 and octahedron**

each NO_3^- is bidentate, so 6 nitrates give CN=12, not 6.

B **6 and trigonal prism**

CN is 12 (bidentate nitrates); trigonal prism is a CN=6 geometry.

C **8 and cubic**

CN is 12, not 8; cubic geometry corresponds to CN=8.

Q33 In the solid state, the $CuCl_5$ ion has two types of bonds. These are

A. Three long and two short

B. Two long and three short

C. One long and four short

D. Four long and one short

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
d-orbital splitting, CFSE, geometry prediction

PYQ FREQUENCY
Moderate · 7 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
Spectrochemical series: "I < Br < Cl < F < OH < ox < H_2O < NCS < NH_3 < en < NO_2 < CN < CO".

Correct Answer A Three long and two short

CONCEPT

Ligands split d-orbitals by electrostatic field. Δo (octahedral), Δt = 4/9 Δo (tetrahedral). CFSE depends on d-electron count and field strength.

↓

LOGIC / WORKING

- In trigonal bipyramidal complexes, the two ligands lie on z-axis and the three in xy plane somewhere in between the axes. In xy plane, there are four electrons and on z-axis there is only one electron in dZ [orbital Electronic Configuration, d\Z W = d]Z W < d\] , =d\W[ ] [<dZW[

FINAL: (A) Three long and two short

SHORTCUT / EXAM TRICK

Octahedral CFSE = (−0.4 t_2g + 0.6 eg) Δo + pairing. Tetrahedral is always high-spin (Δt small).

COMMON MISTAKE

Using Δo splitting pattern (t_2g below eg) for tetrahedral, where the order inverts (e below t_2).

EXAM TIP

Strong field (CN^-, CO) → low spin; weak field (halides, H_2O) → high spin. Square planar favoured by d^8 + strong field.

MEMORY TRICK

Spectrochemical series: "I < Br < Cl < F < OH < ox < H_2O < NCS < NH_3 < en < NO_2 < CN < CO".

Why the Other Options Are Wrong

Correct answer: **A**

B **Two long and three short**
this reverses the TBP pattern; the two axial bonds are the long ones, three equatorial are short.

C **One long and four short**
$CuCl_5^{3-}$ is 5-coordinate TBP, not a 4+1 set, so 'one long, four short' is incorrect.

D **Four long and one short**
there are two long (axial) and three short (equatorial) bonds, not four long.

Q41 **Which of the pairs will generally result in tetrahedral coordination complexes, when ligands are Cl- or OH-.**

A Be(II), Ba(II)

B Ba(II), Co(II)

C Co(II), Zn(II)

D Be(II), Zn(II)

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
d-orbital splitting, CFSE, geometry prediction

PYQ FREQUENCY
Moderate · 7 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
Spectrochemical series: "I < Br < Cl < F < OH < ox < H_2O < NCS < NH_3 < en < NO_2 < CN < CO".

Correct Answer C Co(II), Zn(II)

CONCEPT

Ligands split d-orbitals by electrostatic field. Δo (octahedral), Δt = 4/9 Δo (tetrahedral). CFSE depends on d-electron count and field strength.

↓

LOGIC / WORKING

Co(II), Zn(II) and Be(II) form tetrahedral complexes with Cl- or OH-.
Be(II) has no d-orbitals, therefore it form tetrahedral complexes.

- Co(II) and Zn(II) form tetrahedral complexes with halides and OH-.

FINAL: (C) Co(II), Zn(II)

SHORTCUT / EXAM TRICK

Octahedral CFSE = (−0.4 t_2g + 0.6 eg) Δo + pairing.
Tetrahedral is always high-spin (Δt small).

COMMON MISTAKE

Using Δo splitting pattern (t_2g below eg) for tetrahedral, where the order inverts (e below t_2).

EXAM TIP

Strong field (CN^-, CO) → low spin; weak field (halides, H_2O) → high spin. Square planar favoured by d^8 + strong field.

MEMORY TRICK

Spectrochemical series: "I < Br < Cl < F < OH < ox < H_2O < NCS < NH_3 < en < NO_2 < CN < CO".

Why the Other Options Are Wrong

Correct answer: **C**

A **Be(II), Ba(II)**

Ba^{2+} is large and prefers high coordination, not tetrahedral with Cl^-/OH^-.

B **Ba(II), Co(II)**

Ba^{2+} again disfavours tetrahedral geometry due to its large size.

D **Be(II), Zn(II)**

Be^{2+} does form tetrahedral, but the pairing with Zn (option C) is the reliably tetrahedral set here.

Q47 The Δt of the following complexes

A $[Co(Cl_4)]^{2-}$

B $[Co(Br_4)]^{2-}$

C $[Co(NCS_4)]^{2-}$ follows the order

D C>A>B

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
d-orbital splitting, CFSE, geometry prediction

PYQ FREQUENCY
Moderate · 7 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
Spectrochemical series: "I < Br < Cl < F < OH < ox < H_2O < NCS < NH_3 < en < NO_2 < CN < CO".

Correct Answer A $[Co(Cl_4)]^{2-}$

CONCEPT

Ligands split d-orbitals by electrostatic field. Δo (octahedral), Δt = 4/9 Δo (tetrahedral). CFSE depends on d-electron count and field strength.

↓

LOGIC / WORKING

As strong field ligand have high crystal field stabilisation energy, according to spec trochemical series of ligand, the given ligand in order Br- < Cl- < NCS- Thus, Δ t of given complexes follow the order: $[Co(NCS_4)]^{2-}$ >$[Co(Cl_4)]^{2-}$ > $[Co(Br_4)]^{2-}$

FINAL: (A) $[Co(Cl_4)]^{2-}$

SHORTCUT / EXAM TRICK

Octahedral CFSE = (−0.4 t_2g + 0.6 eg) Δo + pairing. Tetrahedral is always high-spin (Δt small).

COMMON MISTAKE

Using Δo splitting pattern (t_2g below eg) for tetrahedral, where the order inverts (e below t_2).

EXAM TIP

Strong field (CN^-, CO) → low spin; weak field (halides, H_2O) → high spin. Square planar favoured by d^8 + strong field.

MEMORY TRICK

Spectrochemical series: "I < Br < Cl < F < OH < ox < H_2O < NCS < NH_3 < en < NO_2 < CN < CO".

Why the Other Options Are Wrong

Correct answer: **A**

B **$[Co(Br_4)]^{2-}$**

this order ignores the spectrochemical series; NCS^- is the strongest, not Cl^-.

C **$[Co(NCS_4)]^{2-}$ follows the order**

Br^- is the weakest field ligand, so it gives the smallest Δt, not the largest.

D **C>A>B**

the order should follow $NCS^->Cl^->Br^-$, i.e. C>A>B, not this sequence.

Q114 The relative rates of water exchange for the hydrated complexes of (1) Ni^{2+} (2) V^{2+} and (3) Cr^{3}+ ions follows the trend:

A (1) > (2) > (3)

B (1) < (2) < (3)

C (1) > (2) < (3)

D (1) < (2) > (3)

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
d-orbital splitting, CFSE, geometry prediction

PYQ FREQUENCY
Moderate · 7 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
Spectrochemical series: "I < Br < Cl < F < OH < ox < H_2O < NCS < NH_3 < en < NO_2 < CN < CO".

Correct Answer A (1) > (2) > (3)

CONCEPT

Ligands split d-orbitals by electrostatic field. Δo (octahedral), Δt = 4/9 Δo (tetrahedral). CFSE depends on d-electron count and field strength.

↓

LOGIC / WORKING

Change in CFSE on going for Oh to five coordinate intermediate for ions is as follows.
V^{2+} (d^3) = -2.00 Cr^{3+} (d^3) = -2.00 Ni^{2+} (d^8) = -2.00

FINAL: (A) (1) > (2) > (3)

SHORTCUT / EXAM TRICK

Octahedral CFSE = (−0.4 t_2g + 0.6 eg) Δo + pairing.
Tetrahedral is always high-spin (Δt small).

COMMON MISTAKE

Using Δo splitting pattern (t_2g below eg) for tetrahedral, where the order inverts (e below t_2).

EXAM TIP

Strong field (CN^-, CO) → low spin; weak field (halides, H_2O) → high spin. Square planar favoured by d^8 + strong field.

MEMORY TRICK

Spectrochemical series: "I < Br < Cl < F < OH < ox < H_2O < NCS < NH_3 < en < NO_2 < CN < CO".

Why the Other Options Are Wrong

Correct answer: **A**

B

(1) < (2) < (3)

this reverses the trend; Jahn-Teller-labilised Cu^{2+}/aqua exchanges fastest, so (1) is largest.

C

(1) > (2) < (3)

the order is monotonic decreasing (1)>(2)>(3), not a dip in the middle.

D

(1) < (2) > (3)

the correct sequence is strictly (1)>(2)>(3).

Q120 The geometry around Cu and its spin state for K_3CuF_6 and $KCuL_2$, [H_2L= H_2 NCONHCONH$_2$], respectively are:

A (octahedral, high-spin) and (square planar, low-spin)

B (octahedral, low-spin) and (square planar, low-spin)

C (trigonal prismatic, high-spin) and (tetrahedral, high-spin)

D (trigonal prismatic, low-spin) and (tetrahedral, high-spin)

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
d-orbital splitting, CFSE, geometry prediction

PYQ FREQUENCY
Moderate · 7 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
Spectrochemical series: "I < Br < Cl < F < OH < ox < H_2O < NCS < NH_3 < en < NO_2 < CN < CO".

Correct Answer A (octahedral, high-spin) and (square planar, low-spin)

CONCEPT

Ligands split d-orbitals by electrostatic field. Δo (octahedral), Δt = 4/9 Δo (tetrahedral). CFSE depends on d-electron count and field strength.

↓

LOGIC / WORKING

K_2CuF_6 = 3K $[CuF_6]^{3-}$ oxidation state of Cu^{3+} = $3d^8$ Thus, Cu^{3+} (Oh) ,d^8 $KCuL_2$ oxidation state of Cu = 1 + x - 4 = 0 => x=+3 Cu^{3+} (d^8)

- Hence, square planar low spin

FINAL: (A) (octahedral, high-spin) and (square planar, low-spin)

SHORTCUT / EXAM TRICK

Octahedral CFSE = (−0.4 t_2g + 0.6 eg) Δo + pairing. Tetrahedral is always high-spin (Δt small).

COMMON MISTAKE

Using Δo splitting pattern (t_2g below eg) for tetrahedral, where the order inverts (e below t_2).

EXAM TIP

Strong field (CN^-, CO) → low spin; weak field (halides, H_2O) → high spin. Square planar favoured by d^8 + strong field.

MEMORY TRICK

Spectrochemical series: "I < Br < Cl < F < OH < ox < H_2O < NCS < NH_3 < en < NO_2 < CN < CO".

Why the Other Options Are Wrong

Correct answer: **A**

B **(octahedral, low-spin) and (square planar, low-spin)**
the fluoride complex is high-spin (weak field F^-), not low-spin octahedral.

C **(trigonal prismatic, high-spin) and (tetrahedral, high-spin)**
the geometries are octahedral and square planar, not trigonal-prismatic/tetrahedral.

D **(trigonal prismatic, low-spin) and (tetrahedral, high-spin)**
neither centre is trigonal prismatic; the correct pair is octahedral HS and square-planar LS.

Q126

The total degeneracy of the ground term of Co(II) (high spin) in octahedral geometry is:

A. 18

B. 12

C. 28

D. 9

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
d-orbital splitting, CFSE, geometry prediction

PYQ FREQUENCY
Moderate · 7 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
Spectrochemical series: "I < Br < Cl < F < OH < ox < H_2O < NCS < NH_3 < en < NO_2 < CN < CO".

Correct Answer C 28

CONCEPT

Ligands split d-orbitals by electrostatic field. Δo (octahedral), Δt = 4/9 Δo (tetrahedral). CFSE depends on d-electron count and field strength.

↓

LOGIC / WORKING

Co (high spin) → $3d^7$ $4s^0$ S=1/2+1/2+1/2=3/2 L=4+2-0-1-2 L=3 Degeneracy for d-orbital = $(^2S+1)(2L+1)=(2x_3/2+1)(2x_3+1)=4\times7=28$

FINAL: (C) 28

SHORTCUT / EXAM TRICK

Octahedral CFSE = (−0.4 t_2g + 0.6 eg) Δo + pairing. Tetrahedral is always high-spin (Δt small).

COMMON MISTAKE

Using Δo splitting pattern (t_2g below eg) for tetrahedral, where the order inverts (e below t_2).

EXAM TIP

Strong field (CN^-, CO) → low spin; weak field (halides, H_2O) → high spin. Square planar favoured by d^8 + strong field.

MEMORY TRICK

Spectrochemical series: "I < Br < Cl < F < OH < ox < H_2O < NCS < NH_3 < en < NO_2 < CN < CO".

Why the Other Options Are Wrong

Correct answer: **C**

A **18**

18 is not the full degeneracy of the ^4F-derived ground manifold.

B **12**

12 is the degeneracy of the ^4T_1g component only, not the total ^4F term.

D **9**

9 undercounts; total degeneracy of the ^4F free-ion term is 28.

Q136 The correct set of electronic configurations for metal ions in octahedral coordination geometry for strong Jahn-Teller distortion is 6 1 3 1 6 3

A t 2g e g , t 2g e g , t 2g e g

B t_2g^1 , t_2g^3 eg^2 , t_2g^6 eg^1

C t_2g^3 , t_2g^3 eg^1 , t_2g^3 eg^2

D t_2g^3 eg^2 , t_2g^6 eg^2 , t_2g^6 eg^3

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
d-orbital splitting, CFSE, geometry prediction

PYQ FREQUENCY
Moderate · 7 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
Spectrochemical series: "I < Br < Cl < F < OH < ox < H_2O < NCS < NH_3 < en < NO_2 < CN < CO".

Correct Answer A t 2g e g , t 2g e g , t 2g e g

CONCEPT

Ligands split d-orbitals by electrostatic field. Δo (octahedral), Δt = 4/9 Δo (tetrahedral). CFSE depends on d-electron count and field strength.

↓

LOGIC / WORKING

For strong Jahn-Teller distortion eg orbital must be assymetrical filled.
$t_2g^6\ eg^1$, $t_2g^3\ eg^1$, $t_2g^6\ eg^3$

FINAL: (A) t 2g e g , t 2g e g , t 2g e g

SHORTCUT / EXAM TRICK

Octahedral CFSE = (−0.4 t_2g + 0.6 eg) Δo + pairing. Tetrahedral is always high-spin (Δt small).

COMMON MISTAKE

Using Δo splitting pattern (t_2g below eg) for tetrahedral, where the order inverts (e below t_2).

EXAM TIP

Strong field (CN^-, CO) → low spin; weak field (halides, H_2O) → high spin. Square planar favoured by d^8 + strong field.

MEMORY TRICK

Spectrochemical series: "I < Br < Cl < F < OH < ox < H_2O < NCS < NH_3 < en < NO_2 < CN < CO".

Why the Other Options Are Wrong

Correct answer: **A**

B t_2g^1 , $t_2g^3\ eg^2$, $t_2g^6\ eg^1$

these configurations (e.g. t_2g^1) do not match the correct d-electron counts for the stated ions.

C t_2g^3 , $t_2g^3\ eg^1$, $t_2g^3\ eg^2$

the occupancies given are inconsistent with the metal oxidation states.

D $t_2g^3\ eg^2$, $t_2g^6\ eg^2$, $t_2g^6\ eg^3$

eg^3 and similar over-filled sets are impossible for these ions.

TOPIC REVISION

Crystal Field Theory & Geometry

9 PYQs · Last-minute revision

TOPIC SUMMARY

Ligands split d-orbitals by electrostatic field. Δo (octahedral), Δt = 4/9 Δo (tetrahedral). CFSE depends on d-electron count and field strength.

IMPORTANT FORMULA SHEET

$\Delta t = (4/9)\ \Delta o$

CFSE(oct) = $(-0.4 \cdot n_t_2g + 0.6 \cdot n_eg)\ \Delta o$

Octahedral: t_2g (lower), eg (upper)

Tetrahedral: e (lower), t_2 (upper)

FREQUENTLY ASKED CONCEPTS

Spectrochemical series
High vs low spin
CFSE calculation
Square-planar d^8

COMMON MISTAKES & QUICK NOTES

Watch out:
Using Δo splitting pattern (t_2g below eg) for tetrahedral, where the order inverts (e below t_2).

Last-minute:
Octahedral CFSE = $(-0.4\ t_2g + 0.6\ eg)\ \Delta o$ + pairing. Tetrahedral is always high-spin (Δt small).

MOST-REPEATED PYQs & EXPECTED IN EXAM

PYQs in this topic: Q18 Q20 Q33 Q41 Q47 Q114 Q120 Q126 Q136

Expect **2 question(s)** next session on **d-orbital splitting, CFSE, geometry prediction.**

TOPIC 3

Electronic Spectra & Selection Rules

34 questions · Easy 20 | Medium 13 | Hard 1 · PYQ frequency: Very High

Q5 The complex $[Mn(H_2O)_6]^{2+}$ has very light pink colour. The best reason for it is

A the complex does not have a charge transfer transition.

B d-d transitions here are orbital forbidden but spin allowed.

C d-d transitions here are orbital allowed but spin forbidden.

D d-d transitions here are both orbital forbidden and spin forbidden.

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Selection rules, band assignment, Orgel/Tanabe–Sugano

PYQ FREQUENCY
Very High · 19 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
"Same spin, change parity" = allowed. Break either rule → forbidden (weak).

Correct Answer D d-d transitions here are both orbital forbidden and spin forbidden.

CONCEPT

d–d transitions are governed by spin ($\Delta S = 0$) and Laporte ($g \leftrightarrow u$) selection rules. Band energies map to Δo via Orgel / Tanabe–Sugano diagrams.

↓

LOGIC / WORKING

For a d^5 octahedral complex $[Mn(H_2O)_6]^{2+}$ all transitions are Laporte forbidden (orbital forbidden) as well as spin forbidden. Absorptions associated with doubly forbidden transitions are extremely weak, so it is very lightly coloured.

FINAL: (D) d-d transitions here are both orbital forbidden and spin forbidden.

SHORTCUT / EXAM TRICK

Lowest-energy spin-allowed band ≈ Δo (for d^3, d^8 octahedral). Spin-forbidden bands are very weak and sharp.

COMMON MISTAKE

Calling a spin-changing (e.g. quartet → doublet) transition allowed, or mis-assigning the ground term.

EXAM TIP

Centrosymmetric (octahedral) complexes obey Laporte → weak bands (ε small). Tetrahedral lacks a centre → intense bands.

MEMORY TRICK

“Same spin, change parity” = allowed. Break either rule → forbidden (weak).

Why the Other Options Are Wrong

Correct answer: **D**

A **the complex does not have a charge transfer transition.**
the pale colour is not from absence of CT; it is due to the d-d bands being extremely weak.

B **d-d transitions here are orbital forbidden but spin allowed.**
for d^5 the transitions are also spin-forbidden (not spin-allowed); 'spin allowed' is incorrect.

C **d-d transitions here are orbital allowed but spin forbidden.**
d-d here are orbital (Laporte) forbidden as well, not orbitally allowed.

Q10

Cis and trans complexes of the type $[PtA^2X^2]$ are distinguished by

A. Chromyl chloride test

B. Carbylamine test

C. Kurnakov test

D. Ring test

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Selection rules, band assignment, Orgel/Tanabe–Sugano

PYQ FREQUENCY
Very High · 19 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
"Same spin, change parity" = allowed. Break either rule → forbidden (weak).

Correct Answer C Kurnakov test

CONCEPT

d–d transitions are governed by spin (ΔS = 0) and Laporte (g↔u) selection rules. Band energies map to Δo via Orgel / Tanabe–Sugano diagrams.

↓

LOGIC / WORKING

Kurnakov test is used to distinguish between cisplatin and transplatin, by using thiourea as a reagent.

- Cisplatin+ Aqueous thiourea → deep yellow solution and on crystallisation it gives yellow needle shape crystal of tetrakis(thiourea) platinum (II) chloride Transplatin + aqueous thiourea →Colourless solution on crystallisation it gives white needle shape crystal of trans-bis(thiourea)diaammine platinum (II) chloride

FINAL: (C) Kurnakov test

SHORTCUT / EXAM TRICK

Lowest-energy spin-allowed band ≈ Δo (for d^3, d^8 octahedral). Spin-forbidden bands are very weak and sharp.

COMMON MISTAKE

Calling a spin-changing (e.g. quartet→doublet) transition allowed, or mis-assigning the ground term.

EXAM TIP

Centrosymmetric (octahedral) complexes obey Laporte → weak bands (ε small). Tetrahedral lacks a centre → intense bands.

MEMORY TRICK

“Same spin, change parity” = allowed. Break either rule → forbidden (weak).

Why the Other Options Are Wrong

Correct answer: **C**

A **Chromyl chloride test**
chromyl chloride test detects chloride/chromium, not cis/trans Pt isomers.

B **Carbylamine test**
the carbylamine test identifies primary amines, unrelated to Pt geometry.

D **Ring test**
the ring test is for nitrate ion, not Pt geometric isomers.

Q13 The complex that absorbs light of shortest wavelength is

A. $[CoF_6]^{3-}$

B. $[Co(H_2O)_6]^{3+}$

C. $[Co(NH_3)_6]^{3+}$

D. $[Co(ox)_3]^{3-}$ (ox=$C_2O_4^{2-}$)

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Selection rules, band assignment, Orgel/Tanabe–Sugano

PYQ FREQUENCY
Very High · 19 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
"Same spin, change parity" = allowed. Break either rule → forbidden (weak).

Correct Answer C $[Co(NH_3)_6]^{3+}$

CONCEPT

d–d transitions are governed by spin ($\Delta S = 0$) and Laporte ($g \leftrightarrow u$) selection rules. Band energies map to Δo via Orgel / Tanabe–Sugano diagrams.

↓

LOGIC / WORKING

$[Co(NH_3)_6]^{3+}$ highest value of $\Delta 0$ Highest energy (v) or lowest value of wavelength is absorbed

FINAL: (C) $[Co(NH_3)_6]^{3+}$

SHORTCUT / EXAM TRICK

Lowest-energy spin-allowed band ≈ Δo (for d^3, d^8 octahedral). Spin-forbidden bands are very weak and sharp.

COMMON MISTAKE

Calling a spin-changing (e.g. quartet → doublet) transition allowed, or mis-assigning the ground term.

EXAM TIP

Centrosymmetric (octahedral) complexes obey Laporte → weak bands (ε small). Tetrahedral lacks a centre → intense bands.

MEMORY TRICK

“Same spin, change parity” = allowed. Break either rule → forbidden (weak).

Why the Other Options Are Wrong

Correct answer: **C**

A $[CoF_6]^{3-}$

F^- is a weak-field ligand, giving the smallest Δo and longest-wavelength absorption.

B $[Co(H_2O)_6]^{3+}$

H_2O is weaker than NH_3, so it absorbs at longer wavelength (lower energy).

D $[Co(ox)_3]^{3-}$ $(ox=C_2O_4^{2-})$

oxalate is weaker than NH_3, so its Δo and absorption energy are lower.

Q15

Observe the following electronic transition of a diatomic molecule.

A $^1\Sigma^+_g \rightarrow {}^3\Sigma^+_g$

B $^1\Sigma^+_u \rightarrow {}^1\Sigma^+_g$

C $^1\Delta_u \rightarrow {}^1\Sigma^+_g$

D $^1\pi_g \rightarrow {}^1\Sigma^+_u$

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Selection rules, band assignment, Orgel/Tanabe–Sugano

PYQ FREQUENCY
Very High · 19 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
“Same spin, change parity” = allowed. Break either rule → forbidden (weak).

Correct Answer B $^1\Sigma^+_u \rightarrow {}^1\Sigma^+_g$

CONCEPT

d–d transitions are governed by spin (ΔS = 0) and Laporte (g↔u) selection rules. Band energies map to Δo via Orgel / Tanabe–Sugano diagrams.

↓

LOGIC / WORKING

For allowed transition : a)Spin multiplicity should be same or ΔS = 0 Therefore (a) is not allowed as ΔS ≠ 0 b) ΔL = 0, ± 1 , for allowed transition Therefore (c) is not allowed as ΔL ≠ 0, ± 1 c) u → g (allowed)
g→ g (not allowed)

- Therefore (b) is correct option.

FINAL: (B) $^1\Sigma^+_u \rightarrow {}^1\Sigma^+_g$

SHORTCUT / EXAM TRICK

Lowest-energy spin-allowed band ≈ Δo (for d^3, d^8 octahedral). Spin-forbidden bands are very weak and sharp.

COMMON MISTAKE

Calling a spin-changing (e.g. quartet→doublet) transition allowed, or mis-assigning the ground term.

EXAM TIP

Centrosymmetric (octahedral) complexes obey Laporte → weak bands (ε small). Tetrahedral lacks a centre → intense bands.

MEMORY TRICK

“Same spin, change parity” = allowed. Break either rule → forbidden (weak).

Why the Other Options Are Wrong

Correct answer: **B**

A

$^1\Sigma^+_g \rightarrow {}^3\Sigma^+_g$

$^1\Sigma \rightarrow {}^3\Sigma$ changes spin ($\Delta S \neq 0$), so it is spin-forbidden.

C

$^1\Delta_u \rightarrow {}^1\Sigma^+_g$

$^1\Delta \rightarrow {}^1\Sigma$ has $\Delta\Lambda = 2$, violating $\Delta\Lambda = 0, \pm 1$; forbidden.

D

$^1\pi_g \rightarrow {}^1\Sigma^+_u$

this transition is actually allowed, so listing it as forbidden is incorrect (it should be included).

Q16

The electronic spectrum of $[CrF_6]^{3-}$ shows three bands at 14, 900 cm^{-1} , 22400 cm^{-1} and 34, 800 cm^{-1}. The value of Δo in this case is:

A. 5,500 cm^{-1}

B. 14,900 cm^{-1}

C. 22,400 cm^{-1}

D. 34,800 cm^{-1}

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Selection rules, band assignment, Orgel/Tanabe–Sugano

PYQ FREQUENCY
Very High · 19 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
"Same spin, change parity" = allowed. Break either rule → forbidden (weak).

Correct Answer B 14,900 cm^{-1}

CONCEPT

d–d transitions are governed by spin ($\Delta S = 0$) and Laporte ($g \leftrightarrow u$) selection rules. Band energies map to Δo via Orgel / Tanabe–Sugano diagrams.

↓

LOGIC / WORKING

For d^3 and d^8 , the lowest transition gives the value of Δo

FINAL: (B) 14,900 cm^{-1}

SHORTCUT / EXAM TRICK

Lowest-energy spin-allowed band ≈ Δo (for d^3, d^8 octahedral). Spin-forbidden bands are very weak and sharp.

COMMON MISTAKE

Calling a spin-changing (e.g. quartet → doublet) transition allowed, or mis-assigning the ground term.

EXAM TIP

Centrosymmetric (octahedral) complexes obey Laporte → weak bands (ε small). Tetrahedral lacks a centre → intense bands.

MEMORY TRICK

“Same spin, change parity” = allowed. Break either rule → forbidden (weak).

Why the Other Options Are Wrong

Correct answer: **B**

A **5,500 cm^{-1}**

5,500 cm^{-1} does not match any observed band; Δo equals the lowest band energy.

C **22,400 cm^{-1}**

22,400 cm^{-1} is the second transition ($^4T_1g \leftarrow {}^4A_2g$), not Δo.

D **34,800 cm^{-1}**

34,800 cm^{-1} is the highest-energy band, not Δo.

Q24

The number of spin-allowed ligand field transitions for octahedral Ni(II) complexes with ^3A_2g, ground state is:

A. Two

B. Three

C. One

D. Four

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Selection rules, band assignment, Orgel/Tanabe–Sugano

PYQ FREQUENCY
Very High · 19 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
"Same spin, change parity" = allowed. Break either rule → forbidden (weak).

Correct Answer B Three

CONCEPT

d–d transitions are governed by spin (ΔS = 0) and Laporte (g↔u) selection rules. Band energies map to Δo via Orgel / Tanabe–Sugano diagrams.

↓

LOGIC / WORKING

For Ni^{2+} ion in free state, the thus having same spin multiplicity as ^3F and ^3P. In octahedral field, ^3F splits into ^3A_2g , ^3T_2g and ^3T_1g terms but ^3P does not split but it transforms into ^3T_1g (P).

Therefore orgel diagram is.

Three electronic transitions are $^3T_2g \leftarrow {}^3A_2g$, $^3T_1g \leftarrow {}^3A_2g$, ^3T_1g (P) $\leftarrow {}^3A_2g$

FINAL: (B) Three

SHORTCUT / EXAM TRICK

Lowest-energy spin-allowed band ≈ Δo (for d^3, d^8 octahedral). Spin-forbidden bands are very weak and sharp.

COMMON MISTAKE

Calling a spin-changing (e.g. quartet→doublet) transition allowed, or mis-assigning the ground term.

EXAM TIP

Centrosymmetric (octahedral) complexes obey Laporte → weak bands (ε small). Tetrahedral lacks a centre → intense bands.

MEMORY TRICK

“Same spin, change parity” = allowed. Break either rule → forbidden (weak).

Why the Other Options Are Wrong

Correct answer: **B**

A **Two**

d^8 octahedral (^3A_2g) has three spin-allowed bands, not two.

C **One**

there are three spin-allowed transitions (to ^3T_2g, $^3T_1g(F)$, $^3T_1g(P)$), not one.

D **Four**

only three transitions are spin-allowed; the fourth would be spin-forbidden.

Q26

The set of allowed electronic transitions among the following is: 4 2 3 3 1 1 2 2 (A) Σ → Π (B) Σ→ Π (C) Δ→ Δ (D) Π→ Π (E) Σ→^{3}Δ 3

A. A, B, E

B. A, C, E

C. B, C, D

D. C, D, E

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Selection rules, band assignment, Orgel/Tanabe–Sugano

PYQ FREQUENCY
Very High · 19 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
“Same spin, change parity” = allowed. Break either rule → forbidden (weak).

Correct Answer C B, C, D

CONCEPT

d–d transitions are governed by spin (ΔS = 0) and Laporte (g↔u) selection rules. Band energies map to Δo via Orgel / Tanabe–Sugano diagrams.

↓

LOGIC / WORKING

For allowed transition :

- (a) Spin multiplicity should be same or ΔS = 0 A is not allowed transition as ΔS ≠ 0 (b) ΔL = +/-1 , 0 for allowed transition as ΔL ≠ 0, ± 1 therefore E transition not allowed as ΔL ≠ 0, ± 1 B, C, D are allowed .

FINAL: (C) B, C, D

SHORTCUT / EXAM TRICK

Lowest-energy spin-allowed band ≈ Δo (for d^3, d^8 octahedral). Spin-forbidden bands are very weak and sharp.

COMMON MISTAKE

Calling a spin-changing (e.g. quartet→doublet) transition allowed, or mis-assigning the ground term.

EXAM TIP

Centrosymmetric (octahedral) complexes obey Laporte → weak bands (ε small). Tetrahedral lacks a centre → intense bands.

MEMORY TRICK

“Same spin, change parity” = allowed. Break either rule → forbidden (weak).

Why the Other Options Are Wrong

Correct answer: **C**

A

A, B, E

set includes spin-changing or $\Delta\Lambda=2$ transitions that are forbidden.

B

A, C, E

includes a forbidden transition (spin or $\Delta\Lambda$ violation), so the set is invalid.

D

C, D, E

contains $\Delta\Lambda=2$ (e.g. $\Sigma \rightarrow \Delta$) which is forbidden.

Q31

The electric dipole allowed transition in a d^2 atomic system is 3 1

A. F→ D

B. $^3F \rightarrow {}^1P$

C. $^3F \rightarrow {}^3D$

D. $^3F \rightarrow {}^3P$

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Selection rules, band assignment, Orgel/Tanabe–Sugano

PYQ FREQUENCY
Very High · 19 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
"Same spin, change parity" = allowed. Break either rule → forbidden (weak).

Correct Answer C $^3F \rightarrow {}^3D$

CONCEPT

d–d transitions are governed by spin (ΔS = 0) and Laporte (g↔u) selection rules. Band energies map to Δo via Orgel / Tanabe–Sugano diagrams.

↓

LOGIC / WORKING

Electric dipole allowed transition in d^2 For electronic transition selection rule, spin multiplicity ΔS=0; Δl= ±1, ΔJ = 0, ±1 $F \rightarrow {}^3D$ is allowed transition because ΔS=0, Δl = -1

FINAL: (C) $^3F \rightarrow {}^3D$

SHORTCUT / EXAM TRICK

Lowest-energy spin-allowed band ≈ Δo (for d^3, d^8 octahedral). Spin-forbidden bands are very weak and sharp.

COMMON MISTAKE

Calling a spin-changing (e.g. quartet→doublet) transition allowed, or mis-assigning the ground term.

EXAM TIP

Centrosymmetric (octahedral) complexes obey Laporte → weak bands (ε small). Tetrahedral lacks a centre → intense bands.

MEMORY TRICK

“Same spin, change parity” = allowed. Break either rule → forbidden (weak).

Why the Other Options Are Wrong

Correct answer: **C**

A — **F → D**

$^3F \rightarrow {}^1D$ changes spin ($\Delta S \neq 0$); spin-forbidden.

B — **$^3F \rightarrow {}^1P$**

$^3F \rightarrow {}^1P$ is spin-forbidden ($\Delta S \neq 0$).

D — **$^3F \rightarrow {}^3P$**

$^3F \rightarrow {}^3P$ has $\Delta L = 2$, violating $\Delta L = 0, \pm 1$; forbidden.

Q39

The electronic transition responsible for the colour of the transition metal ions is

A. $d\pi \rightarrow d\sigma$

B. $d\pi \rightarrow d\sigma^*$

C. $d\pi \rightarrow d\pi^*$

D. $d\sigma \rightarrow d\pi^*$

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Selection rules, band assignment, Orgel/Tanabe–Sugano

PYQ FREQUENCY
Very High · 19 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
"Same spin, change parity" = allowed. Break either rule → forbidden (weak).

Correct Answer B $d\pi \rightarrow d\sigma^*$

CONCEPT

d–d transitions are governed by spin ($\Delta S = 0$) and Laporte ($g \leftrightarrow u$) selection rules. Band energies map to Δo via Orgel / Tanabe–Sugano diagrams.

↓

LOGIC / WORKING

- The electronic transition responsible for the colour of the transition metal ions is $d\pi \rightarrow d\sigma^*$ which is in according to LFT.

FINAL: (B) $d\pi \rightarrow d\sigma^*$

SHORTCUT / EXAM TRICK

Lowest-energy spin-allowed band ≈ Δo (for d^3, d^8 octahedral). Spin-forbidden bands are very weak and sharp.

COMMON MISTAKE

Calling a spin-changing (e.g. quartet → doublet) transition allowed, or mis-assigning the ground term.

EXAM TIP

Centrosymmetric (octahedral) complexes obey Laporte → weak bands (ε small). Tetrahedral lacks a centre → intense bands.

MEMORY TRICK

“Same spin, change parity” = allowed. Break either rule → forbidden (weak).

Why the Other Options Are Wrong

Correct answer: **B**

A **dπ →dσ**

dπ→dσ (t_2g→eg without antibonding character) is not the standard LFT label for the colour transition.

C **dπ→ dπ***

the eg set is σ* (dσ*), not π*; dπ→dπ* mislabels the acceptor orbital.

D **dσ → dπ***

the donor is the t_2g (dπ) set, not dσ; dσ→dπ* is the wrong assignment.

Q42 **Silica gel contains $[Co(Cl_4)]^{2-}$ as an indicator. When activated , silica gel becomes dark blue while upon absorption of moisture, its colour changes to pale pink This is because,**

A. Co (II) changes its coordination from tetrahedral to octahedral.

B. Co(II) changes its oxidation state to Co(III)

C. Tetrahedral crystal field splitting is NOT equal to octahedral crystal field splitting

D. Co(II) forms kinetically labile while Co(III) forms kinetically inert complexes.

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Selection rules, band assignment, Orgel/Tanabe–Sugano

PYQ FREQUENCY
Very High · 19 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
“Same spin, change parity” = allowed. Break either rule → forbidden (weak).

Correct Answer A Co (II) changes its coordination from tetrahedral to octahedral.

CONCEPT

d–d transitions are governed by spin (ΔS = 0) and Laporte (g↔u) selection rules. Band energies map to Δo via Orgel / Tanabe–Sugano diagrams.

↓

LOGIC / WORKING

$[CoCl_4]^{2-} + {}^{6}H_2O(blue) \leftrightarrow [Co(H_2O)_6]^{2+} + 4Cl^-$ (blue, tetrahedral) (Light pink, octahedral)

FINAL: (A) Co (II) changes its coordination from tetrahedral to octahedral.

SHORTCUT / EXAM TRICK

Lowest-energy spin-allowed band ≈ Δo (for d^3, d^8 octahedral). Spin-forbidden bands are very weak and sharp.

COMMON MISTAKE

Calling a spin-changing (e.g. quartet→doublet) transition allowed, or mis-assigning the ground term.

EXAM TIP

Centrosymmetric (octahedral) complexes obey Laporte → weak bands (ε small). Tetrahedral lacks a centre → intense bands.

MEMORY TRICK

“Same spin, change parity” = allowed. Break either rule → forbidden (weak).

Why the Other Options Are Wrong

Correct answer: **A**

B **Co(II) changes its oxidation state to Co(III)**
the colour change is a geometry/oxidation environment change, not a simple oxidation-state change of Co.

C **Tetrahedral crystal field splitting is NOT equal to octahedral crystal field splitting**
although $\Delta t \neq \Delta o$, the operative reason is the Td ↔ Oh interconversion on hydration.

D **Co(II) forms kinetically labile while Co(III) forms kinetically inert complexes.**
lability/inertness of oxidation states is not what drives the reversible colour change.

Q43

Intense band at 15000 cm^{-1} in the UV-visible spectrum of $[Bu_4N]2\ Re_2\ Cl_8$ is due to the transition

A) $\pi \rightarrow \pi^*$

B) $\delta \rightarrow \delta^*$

C) $\delta \rightarrow \pi^*$

D) $\pi \rightarrow \delta^*$ Correct answer is (b)

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Selection rules, band assignment, Orgel/Tanabe–Sugano

PYQ FREQUENCY
Very High · 19 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
"Same spin, change parity" = allowed. Break either rule → forbidden (weak).

Correct Answer B δ → δ*

CONCEPT

d–d transitions are governed by spin (ΔS = 0) and Laporte (g ↔ u) selection rules. Band energies map to Δo via Orgel / Tanabe–Sugano diagrams.

↓

LOGIC / WORKING

$[Bu_4N]2\ Re_2\ Cl_8$

FINAL: (B) δ → δ*

SHORTCUT / EXAM TRICK

Lowest-energy spin-allowed band ≈ Δo (for d^3, d^8 octahedral). Spin-forbidden bands are very weak and sharp.

COMMON MISTAKE

Calling a spin-changing (e.g. quartet → doublet) transition allowed, or mis-assigning the ground term.

EXAM TIP

Centrosymmetric (octahedral) complexes obey Laporte → weak bands (ε small). Tetrahedral lacks a centre → intense bands.

MEMORY TRICK

“Same spin, change parity” = allowed. Break either rule → forbidden (weak).

Why the Other Options Are Wrong

Correct answer: **B**

A **π → π***

π → π* is higher energy; the visible band of $Re_2Cl_8^{2-}$ is the low-energy δ → δ*.

C **δ → π***

δ → π* is not the assigned low-energy transition; it is δ → δ*.

D **π → δ* Correct answer is (b)**

π → δ* is not the characteristic band; the metal-metal δ → δ* is.

Q46

Three bands in the electronic spectrum of $[Cr(NH_3)_6]^{3+}$ are due to the following transitions

A $^4A_{2g} \rightarrow {}^4T_{1g}$ (B) $^4A_{2g} \rightarrow {}^4T_{2g}$ (C) $^4A_{2g} \rightarrow {}^2E_g$ Identify the correct statement about them

B Intensity of (A) is lowest

C Intensity of (C) is lowest

D Intensitites of (A), (B) and (C) are similar

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Selection rules, band assignment, Orgel/Tanabe–Sugano

PYQ FREQUENCY
Very High · 19 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
“Same spin, change parity” = allowed. Break either rule → forbidden (weak).

Correct Answer B Intensity of (A) is lowest

CONCEPT

d–d transitions are governed by spin ($\Delta S = 0$) and Laporte ($g \leftrightarrow u$) selection rules. Band energies map to Δo via Orgel / Tanabe–Sugano diagrams.

↓

LOGIC / WORKING

Intensity of C $^4A\ 2g \rightarrow {}^2E\ g$ is lowest, since it is spin forbidden.

FINAL: (B) Intensity of (A) is lowest

SHORTCUT / EXAM TRICK

Lowest-energy spin-allowed band ≈ Δo (for d^3, d^8 octahedral). Spin-forbidden bands are very weak and sharp.

COMMON MISTAKE

Calling a spin-changing (e.g. quartet → doublet) transition allowed, or mis-assigning the ground term.

EXAM TIP

Centrosymmetric (octahedral) complexes obey Laporte → weak bands (ε small). Tetrahedral lacks a centre → intense bands.

MEMORY TRICK

“Same spin, change parity” = allowed. Break either rule → forbidden (weak).

Why the Other Options Are Wrong

Correct answer: **B**

A — **$^4A\ 2g \rightarrow {}^4T\ 1g$ (B) $^4A\ 2g \rightarrow {}^4T\ 2g$ (C) $^4A\ 2g \rightarrow {}^2E\ g$ Identify the correct statement about them**

band (A) is spin-allowed and Laporte-forbidden, of moderate (not lowest) intensity.

C — **Intensity of (C) is lowest**

the three bands are not of similar intensity; the spin-forbidden one is much weaker.

D — **Intensitites of (A), (B) and (C) are similar**

(B) is spin-allowed while (C) is spin-forbidden, so their intensities differ greatly.

Q50

Among the following, the correct combination of complex and its colour is:

A $[Co(CN)_4]^{2-}$ — Red

B $[Co(Cl)_4]^{2-}$ — Orange

C $[Co(CNS)_4]^{2-}$ — Blue

D $[Co(F)_4]^{2-}$ — Yellow

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Selection rules, band assignment, Orgel/Tanabe–Sugano

PYQ FREQUENCY
Very High · 19 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
“Same spin, change parity” = allowed. Break either rule → forbidden (weak).

Correct Answer C $[Co(CNS)_4]^{2-}$ — Blue

CONCEPT

d–d transitions are governed by spin ($\Delta S = 0$) and Laporte ($g \leftrightarrow u$) selection rules. Band energies map to Δo via Orgel / Tanabe–Sugano diagrams.

↓

LOGIC / WORKING

Order of ligand is spectro chemical series SCN- < Cl- < F- < CN- From above it is clear that CN- will produce highest energy difference, followed by F-, Cl-, SCN-. As colour of complex is complementary colour of absorbed light.
Thus $[Co(CN_4)]^{2-}$ absorbs orange colour radiation which complementary colour is blue therefore colour of $[Co(CN_4)]^{2-}$ is blue.

- The other combination according to energy are mismatched. Hence, only option (c) is correct.

FINAL: (C) $[Co(CNS)_4]^{2-}$ — Blue

SHORTCUT / EXAM TRICK

Lowest-energy spin-allowed band ≈ Δo (for d^3, d^8 octahedral). Spin-forbidden bands are very weak and sharp.

COMMON MISTAKE

Calling a spin-changing (e.g. quartet → doublet) transition allowed, or mis-assigning the ground term.

EXAM TIP

Centrosymmetric (octahedral) complexes obey Laporte → weak bands (ε small). Tetrahedral lacks a centre → intense bands.

MEMORY TRICK

“Same spin, change parity” = allowed. Break either rule → forbidden (weak).

Why the Other Options Are Wrong

Correct answer: **C**

A **$[Co(CN)_4]^{2-}$ — Red**

$[Co(CN)_4]^{2-}$ has a very large field (CN^-), absorbing in UV/violet → appears yellow, not red.

B **$[Co(Cl)_4]^{2-}$ — Orange**

$[Co(Cl)_4]^{2-}$ is blue/violet (weak field), not orange.

D **$[Co(F)_4]^{2-}$ — Yellow**

$[Co(F)_4]^{2-}$ matching is incorrect; the reliably blue tetrahedral species is the thiocyanate.

Q57

$[CoL_6]^{3+}$ is red in colour whereas $[CoL'6]^{3+}$ is green. L. and L' respectively corresponds to,

A. NH_3 and H_2O

B. NH_3 and 1, 10-phenanthroline

C. H_2O and 1, 10-phenanthroline

D. H_2O and NH_3

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Selection rules, band assignment, Orgel/Tanabe–Sugano

PYQ FREQUENCY
Very High · 19 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
"Same spin, change parity" = allowed. Break either rule → forbidden (weak).

Correct Answer A NH_3 and H_2O

CONCEPT

d–d transitions are governed by spin ($\Delta S = 0$) and Laporte ($g \leftrightarrow u$) selection rules. Band energies map to Δo via Orgel / Tanabe–Sugano diagrams.

↓

LOGIC / WORKING

$[CoL_6]^{3+}$ → red colour → absorbs green radiations $[CoL'6]^{3+}$ → green colour → absorbs red radiations.
Energy of green radiations > energy of red radiations, Therefore, L will be stronger ligand than L'. Thus, L and L' are NH_3 and H_2O respectively.

FINAL: (A) NH_3 and H_2O

SHORTCUT / EXAM TRICK

Lowest-energy spin-allowed band ≈ Δo (for d^3, d^8 octahedral). Spin-forbidden bands are very weak and sharp.

COMMON MISTAKE

Calling a spin-changing (e.g. quartet → doublet) transition allowed, or mis-assigning the ground term.

EXAM TIP

Centrosymmetric (octahedral) complexes obey Laporte → weak bands (ε small). Tetrahedral lacks a centre → intense bands.

MEMORY TRICK

“Same spin, change parity” = allowed. Break either rule → forbidden (weak).

Why the Other Options Are Wrong

Correct answer: **A**

B — **NH_3 and 1, 10-phenanthroline**

phen is a stronger-field ligand giving a different colour; the green complex is the weaker-field H_2O.

C — **H_2O and 1, 10-phenanthroline**

the red complex needs the stronger field (NH_3), not H_2O.

D — **H_2O and NH_3**

this reverses the colours; NH_3 gives the red (higher-energy) complex, H_2O the green.

Q58

In its electronic spectrum, $[V(H_2O)_6]^{3+}$ exihibits two absorption bands, one at 17,800 (v_1) and the second at 25, 700 (v_2) cm. The correct assignment of these bands, respectively, is

A $v_1 = {}^3T_1g\,(F) \rightarrow {}^3T_2g\,(F)$, $v_2 = {}^3T_1g\,(F) \rightarrow {}^3T_1g\,(P)$

B $v_1 = {}^3T_1g\,(F) \rightarrow {}^3T_1g\,(P)$, $v_2 = {}^3T_1g\,(F) \rightarrow {}^3T_2g\,(P)$

C $v_1 = {}^3A_2g \rightarrow {}^3T_1g\,(F)$, $v_2 = {}^3A_2g \rightarrow {}^3T_2g\,(F)$

D $v_1 = {}^3A_2g \rightarrow {}^3T_2g\,(F)$, $v_2 = {}^3A_2g \rightarrow {}^3T_1g\,(\,(F)$

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Selection rules, band assignment, Orgel/Tanabe–Sugano

PYQ FREQUENCY
Very High · 19 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
“Same spin, change parity” = allowed. Break either rule → forbidden (weak).

Correct Answer A $v_1 = {}^3T_1g\,(F) \rightarrow {}^3T_2g\,(F),\ v_2 = {}^3T_1g\,(F) \rightarrow {}^3T_1g\,(P)$

CONCEPT

d–d transitions are governed by spin ($\Delta S = 0$) and Laporte ($g \leftrightarrow u$) selection rules. Band energies map to Δo via Orgel / Tanabe–Sugano diagrams.

↓

LOGIC / WORKING

$[V(H_2O)_6]^{3+} \rightarrow V^{3+} \rightarrow 3d^2 \rightarrow t_2\ eg^o$ Two transition $V_1 = {}^3T_1g\,(F) \rightarrow {}^3T_2g\,(F)$; $V_2 = {}^3T_1g\,(F) \rightarrow {}^3T_1g\,(P)$

FINAL: (A) $v_1 = {}^3T_1g\,(F) \rightarrow {}^3T_2g\,(F),\ v_2 = {}^3T_1g\,(F) \rightarrow {}^3T_1g\,(P)$

SHORTCUT / EXAM TRICK

Lowest-energy spin-allowed band ≈ Δo (for d^3, d^8 octahedral). Spin-forbidden bands are very weak and sharp.

COMMON MISTAKE

Calling a spin-changing (e.g. quartet → doublet) transition allowed, or mis-assigning the ground term.

EXAM TIP

Centrosymmetric (octahedral) complexes obey Laporte → weak bands (ε small). Tetrahedral lacks a centre → intense bands.

MEMORY TRICK

“Same spin, change parity” = allowed. Break either rule → forbidden (weak).

Why the Other Options Are Wrong

Correct answer: **A**

B

$v_1 = {}^3T_1g\ (F) \rightarrow {}^3T_1g\ (P)$, $v_2 = {}^3T_1g\ (F) \rightarrow {}^3T_2g\ (P)$

V^{3+} is d^2, so the ground state is ${}^3T_1g(F)$, and v_2 goes to ${}^3T_1g(P)$, not ${}^3T_2g(P)$.

C

$v_1 = {}^3A_2g \rightarrow {}^3T_1g\ (F)$, $v_2 = {}^3A_2g \rightarrow {}^3T_2g\ (F)$

the ground term for d^2 is ${}^3T_1g(F)$, not ${}^3A_2g$ (that is the d^3/d^8 ground term).

D

$v_1 = {}^3A_2g \rightarrow {}^3T_2g\ (F)$, $v_2 = {}^3A_2g \rightarrow {}^3T_1g\ (F)$

again the ground term is ${}^3T_1g(F)$ for d^2, so ${}^3A_2g$ assignments are incorrect.

Q68

An aqueous solution of $[Mn(H_2O)_6]^{2+}$ complex is pale pink in colour. The probable reasons for it are

A. Presence of ^6A_1g ground state

B. Disallowed transition by spin selection rule

C. Presence of ^2T_2g ground state

D. Charge transfer transition The correct answer is

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Selection rules, band assignment, Orgel/Tanabe–Sugano

PYQ FREQUENCY
Very High · 19 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
"Same spin, change parity" = allowed. Break either rule → forbidden (weak).

Correct Answer A Presence of $^{6}A_{1}g$ ground state

CONCEPT

d–d transitions are governed by spin (ΔS = 0) and Laporte (g↔u) selection rules. Band energies map to Δo via Orgel / Tanabe–Sugano diagrams.

↓

LOGIC / WORKING

- Explanation There is spin change during electron transition. Therefore, transition is spin disallowed

FINAL: (A) Presence of $^{6}A_{1}g$ ground state

SHORTCUT / EXAM TRICK

Lowest-energy spin-allowed band ≈ Δo (for d^3, d^8 octahedral). Spin-forbidden bands are very weak and sharp.

COMMON MISTAKE

Calling a spin-changing (e.g. quartet→doublet) transition allowed, or mis-assigning the ground term.

EXAM TIP

Centrosymmetric (octahedral) complexes obey Laporte → weak bands (ε small). Tetrahedral lacks a centre → intense bands.

MEMORY TRICK

“Same spin, change parity” = allowed. Break either rule → forbidden (weak).

Why the Other Options Are Wrong

Correct answer: **A**

B **Disallowed transition by spin selection rule**

although transitions are spin-forbidden, the precise reason cited (ground state ^6A_1g) is the ground-state symmetry basis; option B alone is incomplete.

C **Presence of ^2T_2g ground state**

the ground state of HS d^5 is ^6A_1g, not ^2T_2g.

D **Charge transfer transition The correct answer is**

the pale colour is not from CT; CT bands would be intense, unlike the very weak d-d here.

Q75

The electric-dipole allowed transition among the following is 3 3

A. S → D

B. $^3S \rightarrow {}^3P$

C. $^3S \rightarrow {}^1D$

D. $^3S \rightarrow {}^1F$

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Selection rules, band assignment, Orgel/Tanabe–Sugano

PYQ FREQUENCY
Very High · 19 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
"Same spin, change parity" = allowed. Break either rule → forbidden (weak).

Correct Answer B $^3S \rightarrow {}^3P$

CONCEPT

d–d transitions are governed by spin (ΔS = 0) and Laporte (g↔u) selection rules. Band energies map to Δo via Orgel / Tanabe–Sugano diagrams.

↓

LOGIC / WORKING

For allowed transition : a)Spin multiplicity should be same or ΔS = 0 Option c and d (incorrect) as ΔS ≠ 0 b) ΔL = ±1 , for allowed transition $^3S \rightarrow {}^3P$ ΔS = 3-3=0 ΔL= 1-0= 1

FINAL: (B) $^3S \rightarrow {}^3P$

SHORTCUT / EXAM TRICK

Lowest-energy spin-allowed band ≈ Δo (for d^3, d^8 octahedral). Spin-forbidden bands are very weak and sharp.

COMMON MISTAKE

Calling a spin-changing (e.g. quartet→doublet) transition allowed, or mis-assigning the ground term.

EXAM TIP

Centrosymmetric (octahedral) complexes obey Laporte → weak bands (ε small). Tetrahedral lacks a centre → intense bands.

MEMORY TRICK

“Same spin, change parity” = allowed. Break either rule → forbidden (weak).

Why the Other Options Are Wrong

Correct answer: **B**

A

S → D

bare 'S→D' is incomplete and the multiplicities are not specified.

C

^{3}S → ^{1}D

^{3}S→^{1}D changes spin (ΔS≠0); forbidden.

D

^{3}S → ^{1}F

^{3}S→^{1}F changes spin and ΔL>1; doubly forbidden.

Q84

Identify the complex ions in sequential order when ferroin is used as an indicator in the titration of iron(II) with potassium dichromate, (phen = 1, 10-phenathroline)$^{2+}$ 3+

A. $[Fe(phen)_3]$ and $[Fe(phen)_3]$

B. $[Fe\ (phen)_3]^{3+}$ and $[Fe(phen)_3\ ]^{2+}$

C. $[Fe(CN)_6]^{4-}$ and $[Fe(CN)_6]^{3-}$

D. $[Fe(CN)_6]^{3-}$ and $[Fe(CN)_6]^{4-}$

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Selection rules, band assignment, Orgel/Tanabe–Sugano

PYQ FREQUENCY
Very High · 19 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
“Same spin, change parity” = allowed. Break either rule → forbidden (weak).

Correct Answer A [Fe(phen)$_3$] and [Fe(phen)$_3$]

CONCEPT

d–d transitions are governed by spin (ΔS = 0) and Laporte (g↔u) selection rules. Band energies map to Δo via Orgel / Tanabe–Sugano diagrams.

↓

LOGIC / WORKING

$[Fe(phen)_3]^{2+} \rightarrow [Fe(phen)_3]^{3+} + e^-$ (Red) (Blue)

In presence of oxidising agent like $K_2Cr_2O_7$, $[Fe(phen)_3]^{2+}$ changes it colours from red to blue hence, they are used in redox titration.

FINAL: (A) [Fe(phen)$_3$] and [Fe(phen)$_3$]

SHORTCUT / EXAM TRICK

Lowest-energy spin-allowed band ≈ Δo (for d^3, d^8 octahedral). Spin-forbidden bands are very weak and sharp.

COMMON MISTAKE

Calling a spin-changing (e.g. quartet→doublet) transition allowed, or mis-assigning the ground term.

EXAM TIP

Centrosymmetric (octahedral) complexes obey Laporte → weak bands (ε small). Tetrahedral lacks a centre → intense bands.

MEMORY TRICK

“Same spin, change parity” = allowed. Break either rule → forbidden (weak).

Why the Other Options Are Wrong

Correct answer: **A**

B **$[Fe(phen)_3]^{3+}$ and $[Fe(phen)_3]^{2+}$**
the oxidation/colour sequence is reversed; ferroin starts as Fe(II) (red) then oxidises to Fe(III).

C **$[Fe(CN)_6]^{4-}$ and $[Fe(CN)_6]^{3-}$**
the indicator is the phen (ferroin) system, not the cyanide complex.

D **$[Fe(CN)_6]^{3-}$ and $[Fe(CN)_6]^{4-}$**
again cyanide complexes are not the ferroin indicator couple.

Q89 Choose the correct statements about Tanabe-Sugano diagrams

A E/B is plotted against Δ0/B.

B The zero energy is taken as that of the lowest term

C Terms of the same symmetry cross each other

D Two terms of the same symmetry upon increases of ligand field strength bend apart from each other. Correct answer is

QUESTION INSIGHTS

ESTIMATED TIME
3–5 min

DIFFICULTY
Hard

CONCEPT TESTED
Selection rules, band assignment, Orgel/Tanabe–Sugano

PYQ FREQUENCY
Very High · 19 papers

REVISION PRIORITY
★★★★★

EXPECTED LEVEL
Part C (high merit)

MEMORY HOOK
"Same spin, change parity" = allowed. Break either rule → forbidden (weak).

Correct Answer C Terms of the same symmetry cross each other

CONCEPT

d–d transitions are governed by spin (ΔS = 0) and Laporte (g↔u) selection rules. Band energies map to Δo via Orgel / Tanabe–Sugano diagrams.

↓

LOGIC / WORKING

Tanabe-Sugano are useful in interpretation of spectra of both high spin and low spin complexes of d^2- d^8 metal cation.
In Tanabe-Sugano, the energy of excited sate (expressed as E/B) are plotted against ligand field strength (expressed as (Δ0 /B).

- Zero energy is taken for the lowest term and also two form of same symmetry never cross each other and they bent for apart from each other due to repulsion.

FINAL: (C) Terms of the same symmetry cross each other

SHORTCUT / EXAM TRICK

Lowest-energy spin-allowed band ≈ Δo (for d^3, d^8 octahedral). Spin-forbidden bands are very weak and sharp.

COMMON MISTAKE

Calling a spin-changing (e.g. quartet→doublet) transition allowed, or mis-assigning the ground term.

EXAM TIP

Centrosymmetric (octahedral) complexes obey Laporte → weak bands (ε small). Tetrahedral lacks a centre → intense bands.

MEMORY TRICK

“Same spin, change parity” = allowed. Break either rule → forbidden (weak).

Why the Other Options Are Wrong

Correct answer: **C**

A **E/B is plotted against Δ0/B.**
this is a TRUE statement about Tanabe-Sugano diagrams, so it is not the incorrect one.

B **The zero energy is taken as that of the lowest term**
this is also TRUE (zero energy = lowest term), so not the false statement.

D **Two terms of the same symmetry upon increases of ligand field strength bend apart from each other. Correct answer is**
same-symmetry terms bending apart on increasing field is true; the FALSE statement is that they cross.

Q90

Three electronic transitions at 14900, 22700 and 34400 cm^{-1} are observed in the absorption spectrum of $[CrF_6]^{3-}$, The Δ0 value (in cm^{-1}) and the corresponding transition are 4 4

A 7800 and $A_2g \rightarrow T_2g$

B 14900 and $^4A_2g \rightarrow {}^4T_2g$

C 14900 and $^4T_1g \rightarrow {}^4T_1g$ (F)

D 7800 and $^4T_2g \rightarrow {}^3T_1g$ (F)

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Selection rules, band assignment, Orgel/Tanabe–Sugano

PYQ FREQUENCY
Very High · 19 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
“Same spin, change parity” = allowed. Break either rule → forbidden (weak).

Correct Answer B 14900 and $^4A_2g \rightarrow {}^4T_2g$

CONCEPT

d–d transitions are governed by spin (ΔS = 0) and Laporte (g↔u) selection rules. Band energies map to Δo via Orgel / Tanabe–Sugano diagrams.

↓

LOGIC / WORKING

$[CrF_6]^{3-}$ = d^3 Orgel diagram for d^3. ground state= ^4F First excited state = ^4P $A_2g \rightarrow {}^4T_2g$ (Δ0)
v_1 = 14900 cm^{-1} ; v_2 = 22700 cm^{-1} ; v_3 = 34400 cm^{-1} Since, ^4T_1g (P) and ^4T_1g (F) have no fix energy therefore, they will not provide accurate value of Δ0.
Thus, energy difference between $^4A_2g \rightarrow {}^4T_2g$ 14900 cm^{-1} will be correspond to Δ0

FINAL: (B) 14900 and $^4A_2g \rightarrow {}^4T_2g$

SHORTCUT / EXAM TRICK

Lowest-energy spin-allowed band ≈ Δo (for d^3, d^8 octahedral). Spin-forbidden bands are very weak and sharp.

COMMON MISTAKE

Calling a spin-changing (e.g. quartet→doublet) transition allowed, or mis-assigning the ground term.

EXAM TIP

Centrosymmetric (octahedral) complexes obey Laporte → weak bands (ε small). Tetrahedral lacks a centre → intense bands.

MEMORY TRICK

“Same spin, change parity” = allowed. Break either rule → forbidden (weak).

Why the Other Options Are Wrong

Correct answer: **B**

A

7800 and $A_2g \rightarrow T_2g$

7800 cm^{-1} is not the band position; the lowest band (=Δo) is 14900 cm^{-1} for this d^3 ion.

C

14900 and $^4T_1g \rightarrow {}^4T_1g$ (F)

the lowest transition is $^4A_2g \rightarrow {}^4T_2g$, not a $^4T_1g \rightarrow {}^4T_1g$ process.

D

7800 and $^4T_2g \rightarrow {}^3T_1g$ (F)

the band energy and a spin-changing (quartet→triplet) assignment are both incorrect.

Q92 The symmetry-allowed atomic transition among the following is

A $^3F \rightarrow {}^1D$

B $^3F \rightarrow {}^3D$

C $^3F \rightarrow {}^1P$

D $^3F \rightarrow {}^3P$

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Selection rules, band assignment, Orgel/Tanabe–Sugano

PYQ FREQUENCY
Very High · 19 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
“Same spin, change parity” = allowed. Break either rule → forbidden (weak).

Correct Answer B $^3F \rightarrow {}^3D$

CONCEPT

d–d transitions are governed by spin (ΔS = 0) and Laporte (g↔u) selection rules. Band energies map to Δo via Orgel / Tanabe–Sugano diagrams.

↓

LOGIC / WORKING

$F \rightarrow {}^3D$ Since, for allowed transition (atomic), ΔS=0, ΔL=0,±1 In option a and c spin multiplicity is not same therefore incorrect In option d , ΔL=2 therefore incorrect.

FINAL: (B) $^3F \rightarrow {}^3D$

SHORTCUT / EXAM TRICK

Lowest-energy spin-allowed band ≈ Δo (for d^3, d^8 octahedral). Spin-forbidden bands are very weak and sharp.

COMMON MISTAKE

Calling a spin-changing (e.g. quartet→doublet) transition allowed, or mis-assigning the ground term.

EXAM TIP

Centrosymmetric (octahedral) complexes obey Laporte → weak bands (ε small). Tetrahedral lacks a centre → intense bands.

MEMORY TRICK

“Same spin, change parity” = allowed. Break either rule → forbidden (weak).

Why the Other Options Are Wrong

Correct answer: **B**

A $^3F \rightarrow {}^1D$

$^3F \rightarrow {}^1D$ changes spin ($\Delta S \neq 0$); forbidden.

C $^3F \rightarrow {}^1P$

$^3F \rightarrow {}^1P$ is spin-forbidden ($\Delta S \neq 0$).

D $^3F \rightarrow {}^3P$

$^3F \rightarrow {}^3P$ has $\Delta L = 2$, violating $\Delta L = 0, \pm 1$.

Q93

$[NiIIIL_6]$ n+ or n- shows absorption bands at 8500, 15400, and 26000 cm^{-1} whereas [NiII L′6] n+ or n- at 10750, 17500 and 28200 cm^{-1} . L and L' are respectively -1 1

A. OH and **N**3

B. Cl^{1-} and I^{1-}

C. NCS-1 and RC**O1** 2

D. H_2O and NH_3

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Selection rules, band assignment, Orgel/Tanabe–Sugano

PYQ FREQUENCY
Very High · 19 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
“Same spin, change parity” = allowed. Break either rule → forbidden (weak).

Correct Answer D H_2O and NH_3

CONCEPT

d–d transitions are governed by spin (ΔS = 0) and Laporte (g↔u) selection rules. Band energies map to Δo via Orgel / Tanabe–Sugano diagrams.

↓

LOGIC / WORKING

$[NiIIL_6]$ n+ or n- has shows absorption bands at 8500, 15400, and 26000 cm^{-1} [NiII L'6] n+ or n- at 10750, 17500 and 28200 cm^{-1} as for first complex absorptions bands are at low energy i.e. it has weak splitting therefore, it has weak ligand and for II complex high energy absorption bands corresponds to strong ligand.Thus, L is weak and L' is strong ligand.

FINAL: (D) H_2O and NH_3

SHORTCUT / EXAM TRICK

Lowest-energy spin-allowed band ≈ Δo (for d^3, d^8 octahedral). Spin-forbidden bands are very weak and sharp.

COMMON MISTAKE

Calling a spin-changing (e.g. quartet→doublet) transition allowed, or mis-assigning the ground term.

EXAM TIP

Centrosymmetric (octahedral) complexes obey Laporte → weak bands (ε small). Tetrahedral lacks a centre → intense bands.

MEMORY TRICK

“Same spin, change parity” = allowed. Break either rule → forbidden (weak).

Why the Other Options Are Wrong

Correct answer: **D**

A **OH and N3**

OH^-/N_3^- here are not the pair giving the largest field; H_2O and NH_3 are the intended match.

B **Cl^{1-} and I^{1-}**

halides Cl^-/I^- are weak-field; they do not fit the required assignment.

C **NCS-1 and RCO1 2**

NCS^-/RCO_2^- do not match; the correct pair is H_2O and NH_3.

Q97

The first excited state of hydrogen molecule is

A $^1\Sigma_g$

B $^1\Sigma_u$

C $^3\Sigma_g$

D $^3\Sigma_u$

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Selection rules, band assignment, Orgel/Tanabe–Sugano

PYQ FREQUENCY
Very High · 19 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
“Same spin, change parity” = allowed. Break either rule → forbidden (weak).

Correct Answer D $^3\Sigma_u$

CONCEPT

d–d transitions are governed by spin (ΔS = 0) and Laporte (g↔u) selection rules. Band energies map to Δo via Orgel / Tanabe–Sugano diagrams.

↓

LOGIC / WORKING

H_2 (excited state)

L=0=Σ S=1/2+1/2= 1 , 2s+1=3 gxu=u = $^3\Sigma$. u For half filled.

FINAL: (D) $^3\Sigma_u$

SHORTCUT / EXAM TRICK

Lowest-energy spin-allowed band ≈ Δo (for d^3, d^8 octahedral). Spin-forbidden bands are very weak and sharp.

COMMON MISTAKE

Calling a spin-changing (e.g. quartet→doublet) transition allowed, or mis-assigning the ground term.

EXAM TIP

Centrosymmetric (octahedral) complexes obey Laporte → weak bands (ε small). Tetrahedral lacks a centre → intense bands.

MEMORY TRICK

“Same spin, change parity” = allowed. Break either rule → forbidden (weak).

Why the Other Options Are Wrong

Correct answer: **D**

A $^{1}\Sigma_{g}$

$^{1}\Sigma g^{+}$ is the ground state of H_2, not the first excited state.

B $^{1}\Sigma_{u}$

$^{1}\Sigma u^{+}$ is a singlet; the first excited state is the lower-lying triplet.

C $^{3}\Sigma_{g}$

the gerade triplet $^{3}\Sigma g^{+}$ is not the first excited state; promotion gives the ungerade $^{3}\Sigma u^{+}$.

Q98

Complex $[Cr(bipyridyl)_3]^{3+}$, shows red phosphorescence due to transition

A $^4T_2g \leftarrow {}^4A_2g$

B $^4T_1g \leftarrow {}^4A_2g$

C $^4A_2g \leftarrow {}^2Eg$

D $^2Eg \leftarrow {}^4A_2g$

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Selection rules, band assignment, Orgel/Tanabe–Sugano

PYQ FREQUENCY
Very High · 19 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
“Same spin, change parity” = allowed. Break either rule → forbidden (weak).

Correct Answer C $^4A_2g \leftarrow {}^2Eg$

CONCEPT

d–d transitions are governed by spin ($\Delta S = 0$) and Laporte ($g \leftrightarrow u$) selection rules. Band energies map to Δo via Orgel / Tanabe–Sugano diagrams.

↓

LOGIC / WORKING

$[Cr(bipyridyl)_3]^{3+} \rightarrow d^3 = {}^4F$ (ground state term)

As phosphorescence is spin-forbidden transition and also occurs when electron comes from excited to ground state. Hence, transition $^4A_2g \leftarrow {}^2Eg$ is responsible for the phosphorescence.

FINAL: (C) $^4A_2g \leftarrow {}^2Eg$

SHORTCUT / EXAM TRICK

Lowest-energy spin-allowed band ≈ Δo (for d^3, d^8 octahedral). Spin-forbidden bands are very weak and sharp.

COMMON MISTAKE

Calling a spin-changing (e.g. quartet → doublet) transition allowed, or mis-assigning the ground term.

EXAM TIP

Centrosymmetric (octahedral) complexes obey Laporte → weak bands (ε small). Tetrahedral lacks a centre → intense bands.

MEMORY TRICK

“Same spin, change parity” = allowed. Break either rule → forbidden (weak).

Why the Other Options Are Wrong

Correct answer: **C**

A $^4T_2g \leftarrow {}^4A_2g$

$^4T_2g \leftarrow {}^4A_2g$ is a spin-allowed absorption, not the spin-forbidden emissive transition.

B $^4T_1g \leftarrow {}^4A_2g$

$^4T_1g \leftarrow {}^4A_2g$ is also a spin-allowed band, not the phosphorescent emission.

D $^2Eg \leftarrow {}^4A_2g$

the direction is emission ($^2Eg \rightarrow {}^4A_2g$), i.e. $^4A_2g \leftarrow {}^2Eg$; $^2Eg \leftarrow {}^4A_2g$ is the absorption direction.

Q102

The HOMO (highest occupied molecular orbital) to LUMO (lowest unoccupied molecular orbital) electronic transition responsible for the observed colours of halogen molecules (gas) is

A) $\pi^* \rightarrow \sigma^*$

B) $\pi^* \rightarrow \pi^*$

C) $\sigma \rightarrow \sigma^*$

D) $\pi \rightarrow \sigma^*$

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Selection rules, band assignment, Orgel/Tanabe–Sugano

PYQ FREQUENCY
Very High · 19 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
"Same spin, change parity" = allowed. Break either rule → forbidden (weak).

Correct Answer A $\pi^* \rightarrow \sigma^*$

CONCEPT

d–d transitions are governed by spin ($\Delta S = 0$) and Laporte ($g \leftrightarrow u$) selection rules. Band energies map to Δo via Orgel / Tanabe–Sugano diagrams.

↓

LOGIC / WORKING

- In halogen molecules, the $\pi^* \rightarrow \sigma^*$ transitions are responsible for their colours as evident from the following figure

FINAL: (A) $\pi^* \rightarrow \sigma^*$

SHORTCUT / EXAM TRICK

Lowest-energy spin-allowed band ≈ Δo (for d^3, d^8 octahedral). Spin-forbidden bands are very weak and sharp.

COMMON MISTAKE

Calling a spin-changing (e.g. quartet → doublet) transition allowed, or mis-assigning the ground term.

EXAM TIP

Centrosymmetric (octahedral) complexes obey Laporte → weak bands (ε small). Tetrahedral lacks a centre → intense bands.

MEMORY TRICK

“Same spin, change parity” = allowed. Break either rule → forbidden (weak).

Why the Other Options Are Wrong

Correct answer: **A**

B **π* → π***

π*→π* does not describe the donor-acceptor CT; the pyridine HOMO is n, not π*.

C **σ → σ***

σ→σ* is not the lowest CT; the transition is from the iodine/pyridine HOMO to the σ* acceptor.

D **π→ σ***

the donor orbital is the nitrogen lone pair (n), giving n→σ*, not π→σ*.

Q105

The $^2Eg \leftarrow {}^4A_2g$ transition in the electronic spectrum of $[Cr(NH_3)_6]^{3+}$ occurs nearly at

A. 650 nm

B. 450 nm

C. 350 nm

D. 200 nm

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Selection rules, band assignment, Orgel/Tanabe–Sugano

PYQ FREQUENCY
Very High · 19 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
"Same spin, change parity" = allowed. Break either rule → forbidden (weak).

Correct Answer A 650 nm

CONCEPT

d–d transitions are governed by spin (ΔS = 0) and Laporte (g↔u) selection rules. Band energies map to Δo via Orgel / Tanabe–Sugano diagrams.

↓

LOGIC / WORKING

The Eg ← A_2g transition in the electronic spectrum of $[Cr(NH_3)_6]^{3+}$ occurs nearly at 650 nm.

- 2 4

FINAL: (A) 650 nm

SHORTCUT / EXAM TRICK

Lowest-energy spin-allowed band ≈ Δo (for d^3, d^8 octahedral). Spin-forbidden bands are very weak and sharp.

COMMON MISTAKE

Calling a spin-changing (e.g. quartet→doublet) transition allowed, or mis-assigning the ground term.

EXAM TIP

Centrosymmetric (octahedral) complexes obey Laporte → weak bands (ε small). Tetrahedral lacks a centre → intense bands.

MEMORY TRICK

“Same spin, change parity” = allowed. Break either rule → forbidden (weak).

Why the Other Options Are Wrong

Correct answer: **A**

B **450 nm**

450 nm corresponds to a much higher energy than the spin-forbidden ^2Eg band of Cr^{3+}.

C **350 nm**

350 nm is in the UV, far from the $^2Eg \leftarrow {}^4A_2g$ transition energy.

D **200 nm**

200 nm is deep UV (CT region), not the low-energy spin-forbidden d-d band.

Q112 The highest molecular orbitals for an excited electronic configuration of the oxygen molecule are [1πg]1 [3σu]1. A possible molecular term symbol for oxygen with this electronic configuration is

A) 1π

B) $^3\Sigma$

C) $^1\Delta$

D) $^1\Sigma$

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Selection rules, band assignment, Orgel/Tanabe–Sugano

PYQ FREQUENCY
Very High · 19 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
"Same spin, change parity" = allowed. Break either rule → forbidden (weak).

Correct Answer A 1π

CONCEPT

d–d transitions are governed by spin (ΔS = 0) and Laporte (g↔u) selection rules. Band energies map to Δo via Orgel / Tanabe–Sugano diagrams.

↓

LOGIC / WORKING

The arrangements for [1πg]1 [3σu]1configurations are S= 1, ^{2}S+1=3 L=1→ πTerm Spectroscopic Term = 3π L=1→ πTerm S=0, ^{2}S+1= 1 Spectroscopic Term → ^{1}S Thus one of possible moleculer term symbol is 1π

FINAL: (A) 1π

SHORTCUT / EXAM TRICK

Lowest-energy spin-allowed band ≈ Δo (for d^3, d^8 octahedral). Spin-forbidden bands are very weak and sharp.

COMMON MISTAKE

Calling a spin-changing (e.g. quartet→doublet) transition allowed, or mis-assigning the ground term.

EXAM TIP

Centrosymmetric (octahedral) complexes obey Laporte → weak bands (ε small). Tetrahedral lacks a centre → intense bands.

MEMORY TRICK

“Same spin, change parity” = allowed. Break either rule → forbidden (weak).

Why the Other Options Are Wrong

Correct answer: **A**

B — $^3\Sigma$

$^3\Sigma$ is not the highest occupied set described; the excited config places electrons in π and σ* type orbitals.

C — $^1\Delta$

$^1\Delta$ does not match the stated singly-occupied π* + σ* description.

D — $^1\Sigma$

$^1\Sigma$ is the ground-state symmetry; the excited highest orbitals are π/σ* type.

Q118 Match the items in the three columns. The correct answer is

(A) A-II-X; B-I-Z; C-III-Y

(B) A-III-Y: B^{1-}-Z; C-II-X

(C) A-I-X; B-II-Y; C-III-Z

(D) A-I-X; B-II-Z; C-III-Y

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Selection rules, band assignment, Orgel/Tanabe–Sugano

PYQ FREQUENCY
Very High · 19 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
"Same spin, change parity" = allowed. Break either rule → forbidden (weak).

Correct Answer A A-II-X; B-I-Z; C-III-Y

CONCEPT

d–d transitions are governed by spin (ΔS = 0) and Laporte (g↔u) selection rules. Band energies map to Δo via Orgel / Tanabe–Sugano diagrams.

↓

LOGIC / WORKING

Thus, order for energy absorption is 675 (A) < 615 (B) < 565 (C)
Δ0 increases as the ligand field strength increases H_2O < NH_3 < en Complementary colour of blue → Orange , green →Red, Violet → Yellow Energy order for absorbed light is yellow > orange > red Thus, A absorbs red hence it is green B absorbs orange hence it is blue C absorbs yellow hence it is violet

FINAL: (A) A-II-X; B-I-Z; C-III-Y

SHORTCUT / EXAM TRICK

Lowest-energy spin-allowed band ≈ Δo (for d^3, d^8 octahedral). Spin-forbidden bands are very weak and sharp.

COMMON MISTAKE

Calling a spin-changing (e.g. quartet→doublet) transition allowed, or mis-assigning the ground term.

EXAM TIP

Centrosymmetric (octahedral) complexes obey Laporte → weak bands (ε small). Tetrahedral lacks a centre → intense bands.

MEMORY TRICK

“Same spin, change parity” = allowed. Break either rule → forbidden (weak).

Why the Other Options Are Wrong

Correct answer: **A**

B

A-III-Y: B^{1-}-Z; C-II-X

the three-column matches are scrambled (A pairs with II-X, not III-Y).

C

A-I-X; B-II-Y; C-III-Z

A-I-X is incorrect; A should map to II-X.

D

A-I-X; B-II-Z; C-III-Y

B-II-Z is incorrect; the correct mapping is B-I-Z.

Q123 For high spin and low spin d^6 octahedral complexes (ML_6), the generally observed spin allowed transitions respectively, are

A. two and one

B. one and two

C. zero and one

D. two and two

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Selection rules, band assignment, Orgel/Tanabe–Sugano

PYQ FREQUENCY
Very High · 19 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
"Same spin, change parity" = allowed. Break either rule → forbidden (weak).

Correct Answer B one and two

CONCEPT

d–d transitions are governed by spin (ΔS = 0) and Laporte (g↔u) selection rules. Band energies map to Δo via Orgel / Tanabe–Sugano diagrams.

↓

LOGIC / WORKING

For d (high spin) there is one spin allowed transition from $^5T_2g \rightarrow {}^5Eg$ In case of d^6 low spin commonly two spin allowed transitions are observed.
$A_1g \rightarrow {}^1T_1g$ $A_1g \rightarrow {}^1T_2g$ there are additional spin allowed transitions at higher energy but they are marked by allowed transitions.

- Hence, are not observed

FINAL: (B) one and two

SHORTCUT / EXAM TRICK

Lowest-energy spin-allowed band ≈ Δo (for d^3, d^8 octahedral). Spin-forbidden bands are very weak and sharp.

COMMON MISTAKE

Calling a spin-changing (e.g. quartet→doublet) transition allowed, or mis-assigning the ground term.

EXAM TIP

Centrosymmetric (octahedral) complexes obey Laporte → weak bands (ε small). Tetrahedral lacks a centre → intense bands.

MEMORY TRICK

“Same spin, change parity” = allowed. Break either rule → forbidden (weak).

Why the Other Options Are Wrong

Correct answer: **B**

A — **two and one**

the counts are reversed; HS d^6 has the smaller/larger unpaired set opposite to this.

C — **zero and one**

'zero and one' miscounts the unpaired electrons of the LS/HS pair.

D — **two and two**

'two and two' does not match the actual HS vs LS unpaired electron counts.

Q132 The allowed electronic transition in fluorine molecule (F_2) is:

A $\Sigma^+_g \rightarrow \Sigma^+_g$

B $\Sigma^-_g \rightarrow \Sigma^+_g$

C $\Sigma_g \rightarrow \pi_u$

D $\Sigma_g \rightarrow \Delta_u$

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Selection rules, band assignment, Orgel/Tanabe–Sugano

PYQ FREQUENCY
Very High · 19 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
"Same spin, change parity" = allowed. Break either rule → forbidden (weak).

Correct Answer C $\Sigma_g \rightarrow \pi_u$

CONCEPT

d–d transitions are governed by spin (ΔS = 0) and Laporte (g↔u) selection rules. Band energies map to Δo via Orgel / Tanabe–Sugano diagrams.

↓

LOGIC / WORKING

For allowed transition : a)Spin multiplicity should be same or ΔS = 0 b) ΔL = 0, ± 1 , for allowed transition Therefore (4) is not allowed as ΔL ≠ 0, ± 1 c) u → g (allowed)
g→ g (not allowed)

- Therefore (1, 2) are not allowed [+ → -] → forbidden so, therefore (1, 2) are not allowed [+ → +] → allowed

FINAL: (C) $\Sigma_g \rightarrow \pi_u$

SHORTCUT / EXAM TRICK

Lowest-energy spin-allowed band ≈ Δo (for d^3, d^8 octahedral). Spin-forbidden bands are very weak and sharp.

COMMON MISTAKE

Calling a spin-changing (e.g. quartet→doublet) transition allowed, or mis-assigning the ground term.

EXAM TIP

Centrosymmetric (octahedral) complexes obey Laporte → weak bands (ε small). Tetrahedral lacks a centre → intense bands.

MEMORY TRICK

“Same spin, change parity” = allowed. Break either rule → forbidden (weak).

Why the Other Options Are Wrong

Correct answer: **C**

A

$\Sigma^+_g \rightarrow \Sigma^+_g$

$\Sigma g^+ \rightarrow \Sigma g^+$ is g → g, violating the parity (g ↔ u) selection rule.

B

$\Sigma^-_g \rightarrow \Sigma^+_g$

$\Sigma g^- \rightarrow \Sigma g^+$ is g → g and changes the ± label; forbidden.

D

$\Sigma_g \rightarrow \Delta_u$

$\Sigma g \rightarrow \Delta u$ has $\Delta\Lambda=2$, violating $\Delta\Lambda=0,\pm1$.

Q137 The correct order of intensity of the d-d transitions in the complexes of a 3d-transition metal ion

A cis-$[M(H_2O)_4Cl_2]$ > trans-$[M(H_2O)_4Cl_2]$ > $[M(H_2O)_6]^{2+}$

B $[M(H_2O)_6]^{2+}$ > cis-$[M(H_2O)_4Cl_2]$ > trans-$[M(H_2O)_4Cl_2]$

C trans-$[M(H_2O)_4Cl_2]$ > cis-$[M(H_2O)_4Cl_2]$ > $[M(H_2O)_6]^{2+}$

D $[M(H_2O)_6]^{2+}$ > cis-$[M(H_2O)_4Cl_2]$ > trans-$[M(H_2O)_4Cl_2]$

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Selection rules, band assignment, Orgel/Tanabe–Sugano

PYQ FREQUENCY
Very High · 19 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
“Same spin, change parity” = allowed. Break either rule → forbidden (weak).

Correct Answer A cis-$[M(H_2O)_4Cl_2]$ > trans-$[M(H_2O)_4Cl_2]$ > $[M(H_2O)_6]^{2+}$

CONCEPT

d–d transitions are governed by spin ($\Delta S = 0$) and Laporte ($g \leftrightarrow u$) selection rules. Band energies map to Δo via Orgel / Tanabe–Sugano diagrams.

↓

LOGIC / WORKING

The correct order of intensity of d-d transitions in the complexes follows order cis-$[M(H_2O)_4Cl_2]$ > trans-$[M(H_2O)_4Cl_2]$ > $[M(H_2O)_6]^{2+}$

FINAL: (A) **cis-$[M(H_2O)_4Cl_2]$ > trans-$[M(H_2O)_4Cl_2]$ > $[M(H_2O)_6]^{2+}$**

SHORTCUT / EXAM TRICK

Lowest-energy spin-allowed band ≈ Δo (for d^3, d^8 octahedral). Spin-forbidden bands are very weak and sharp.

COMMON MISTAKE

Calling a spin-changing (e.g. quartet → doublet) transition allowed, or mis-assigning the ground term.

EXAM TIP

Centrosymmetric (octahedral) complexes obey Laporte → weak bands (ε small). Tetrahedral lacks a centre → intense bands.

MEMORY TRICK

“Same spin, change parity” = allowed. Break either rule → forbidden (weak).

Why the Other Options Are Wrong

Correct answer: **A**

B

$[M(H_2O)_6]^{2+}$ > cis-$[M(H_2O)_4Cl_2]$ > trans-$[M(H_2O)_4Cl_2]$

the centrosymmetric $[M(H_2O)_6]^{2+}$ has the LOWEST ε (strict Laporte), so it cannot be highest.

C

trans-$[M(H_2O)_4Cl_2]$ > cis-$[M(H_2O)_4Cl_2]$ > $[M(H_2O)_6]^{2+}$

cis is lower symmetry than trans and gives higher ε; placing trans above cis is wrong.

D

$[M(H_2O)_6]^{2+}$ > cis-$[M(H_2O)_4Cl_2]$ > trans-$[M(H_2O)_4Cl_2]$

the octahedral hexaaqua complex has the smallest ε, not the largest.

Q143

Consider the following statements regarding electronic spectra of high spin complexes

A Ti^{3+} complexes exhibit one sharp band.

B Co^{2+} and Cr^{3+} complexes exhibit two broad bands.

C Mn^{2+} complexes exhibit a series of very weak and sharp bands.

D Ni^{2+} complexes exhibit three broad bands . The correct statements are

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Selection rules, band assignment, Orgel/Tanabe–Sugano

PYQ FREQUENCY
Very High · 19 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
“Same spin, change parity” = allowed. Break either rule → forbidden (weak).

Correct Answer C Mn^{2+} complexes exhibit a series of very weak and sharp bands.

CONCEPT

d–d transitions are governed by spin (ΔS = 0) and Laporte (g ↔ u) selection rules. Band energies map to Δo via Orgel / Tanabe–Sugano diagrams.

↓

LOGIC / WORKING

Ti →d complex: t_2g^1 eg^0 +3 1 Ti^{3+} complex exhibit one broad band due to (i) Vibronic coupling (ii) Jahn-Teller distortion (iii) Spin-orbit coupling Co^{2+} → d^7 complex Exhibit three broad bands due to following transitions:
T_1g →^4T_2g ; ^4T_1g → ^4A_2g ; ^4T_1g → 4 T_1g(P) •Cr^{3+} →d^3 complex Exhibit three broad bands due to following transitions:
A_2g →^4T_2g ; ^4A_2g → ^4T_1g(F) ; ^4A_2g → 4 T_1g(P)
•Mn^{2+} complex→ d^5 complex exhibit a series of very weak (spin forbidden, Laporte forbidden and sharp bands).
•Ni^{2+} →d^8 exhibit three broad bands due to following transitions:
A_2g → ^3T_2g ; ^3A_2g → ^3T_1g (F); ^3A_2g → 3 T_1g(P)

FINAL: (C) Mn^{2+} complexes exhibit a series of very weak and sharp bands.

SHORTCUT / EXAM TRICK

Lowest-energy spin-allowed band ≈ Δo (for d^3, d^8 octahedral). Spin-forbidden bands are very weak and sharp.

COMMON MISTAKE

Calling a spin-changing (e.g. quartet→doublet) transition allowed, or mis-assigning the ground term.

EXAM TIP

Centrosymmetric (octahedral) complexes obey Laporte → weak bands (ε small). Tetrahedral lacks a centre → intense bands.

MEMORY TRICK

“Same spin, change parity” = allowed. Break either rule → forbidden (weak).

Why the Other Options Are Wrong

Correct answer: **C**

A **Ti^{3+} complexes exhibit one sharp band.**

Ti^{3+} shows one broad (not sharp) d-d band that is often split by Jahn-Teller.

B **Co^{2+} and Cr^{3+} complexes exhibit two broad bands.**

Co^{2+}/Cr^{3+} show three (not two) spin-allowed broad bands.

D **Ni^{2+} complexes exhibit three broad bands . The correct statements are**

Ni^{2+} does show three bands, but the asked-for correct statement is the very weak sharp bands of Mn^{2+}.

Q147 Correct order of molar extinction coefficient values of the visible absorption bands for the following species is:

A $[Cr(H_2O)_6]^{2+} > [Mn(H_2O)_6]^{2+} >$ Chlorophyll $> [NiCl_4]^{2-}$

B Chlorophyll $> [NiCl_4]^{2-} > [Cr(H_2O)_6]^{2+} > [Mn(H_2O)_6]^{2+}$

C $[NiCl_4]^{2-} >$ Chlorophyll $> [Cr(H_2O)_6]^{2+} > [Mn(H_2O)_6]^{2+}$

D Chlorophyll $> [Cr(H_2O)_6]^{2+} > [NiCl_4]^{2-} > [Mn(H_2O)_6]^{2+}$

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Selection rules, band assignment, Orgel/Tanabe–Sugano

PYQ FREQUENCY
Very High · 19 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
"Same spin, change parity" = allowed. Break either rule → forbidden (weak).

Correct Answer B Chlorophyll > $[NiCl_4]^{2-}$ > $[Cr(H_2O)_6]^{2+}$ > $[Mn(H_2O)_6]^{2+}$

CONCEPT

d–d transitions are governed by spin (ΔS = 0) and Laporte (g↔u) selection rules. Band energies map to Δo via Orgel / Tanabe–Sugano diagrams.

↓

LOGIC / WORKING

In chlorophyll, visible absorption band arise from excitation of electron from the π-HOMO to π* LUMO, thus, has maximum value of molar extinction coefficient value.
$[NiCl_4]^{2-}$ is a tetrahedral comples, thus, p-d mixing will be there, hence, Laporte partially allowed and spin allowed transition.
In $[Cr(H_2O)_6]^{2+}$, d-d transition will be there. hence, Laporte forbidden and spin allowed transition.
In $[Mn(H_2O)_6]^{2+}$ transition is both Laporte and spin forbidden.
So, the order of molar extinction coefficient value is:
Chlorophyll > $[NiCl_4]^{2-}$ > $[Cr(H_2O)_6]^{2+}$ > $[Mn(H_2O)_6]^{2+}$

FINAL: (B) Chlorophyll > $[NiCl_4]^{2-}$ > $[Cr(H_2O)_6]^{2+}$ > $[Mn(H_2O)_6]^{2+}$

SHORTCUT / EXAM TRICK

Lowest-energy spin-allowed band ≈ Δo (for d^3, d^8 octahedral). Spin-forbidden bands are very weak and sharp.

COMMON MISTAKE

Calling a spin-changing (e.g. quartet→doublet) transition allowed, or mis-assigning the ground term.

EXAM TIP

Centrosymmetric (octahedral) complexes obey Laporte → weak bands (ε small). Tetrahedral lacks a centre → intense bands.

MEMORY TRICK

“Same spin, change parity” = allowed. Break either rule → forbidden (weak).

Why the Other Options Are Wrong

Correct answer: **B**

A $[Cr(H_2O)_6]^{2+} > [Mn(H_2O)_6]^{2+} >$ Chlorophyll $> [NiCl_4]^{2-}$

the centrosymmetric hexaaqua ions have the lowest ε; they cannot top the order.

C $[NiCl_4]^{2-} >$ Chlorophyll $> [Cr(H_2O)_6]^{2+} > [Mn(H_2O)_6]^{2+}$

chlorophyll's intense band is highest, but $[NiCl_4]^{2-}$ should rank below it, not above.

D Chlorophyll $> [Cr(H_2O)_6]^{2+} > [NiCl_4]^{2-} > [Mn(H_2O)_6]^{2+}$

the ordering of the aqua complexes vs $NiCl_4^{2-}$ is incorrect here.

Q158

The number of expected electronic transitions in $[Cr(en)_3]^{3+}$ and trans-$[Cr(en)^2F]^+$ at 4 K is, respectively (en = ethylenediamine)

A. 3 and 3

B. 3 and 4

C. 3 and 5

D. 3 and 6

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Selection rules, band assignment, Orgel/Tanabe–Sugano

PYQ FREQUENCY
Very High · 19 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
“Same spin, change parity” = allowed. Break either rule → forbidden (weak).

Correct Answer D 3 and 6

CONCEPT

d–d transitions are governed by spin (ΔS = 0) and Laporte (g↔u) selection rules. Band energies map to Δo via Orgel / Tanabe–Sugano diagrams.

↓

LOGIC / WORKING

In $[Cr(en)_3]^{3+}$, which is an octahedral complex, three spin allowed electronic transitions are observed.
Trans-$[Cr(en)^2F_2]^+$ is a tetragonal complex. Therefore, there is splitting of ^4T_2g , ^4T_1g, and ^4T_1g (P) states.
A_2g term does not split. Thus, 6 electronic transitions are observed.

FINAL: (D) 3 and 6

SHORTCUT / EXAM TRICK

Lowest-energy spin-allowed band ≈ Δo (for d^3, d^8 octahedral). Spin-forbidden bands are very weak and sharp.

COMMON MISTAKE

Calling a spin-changing (e.g. quartet→doublet) transition allowed, or mis-assigning the ground term.

EXAM TIP

Centrosymmetric (octahedral) complexes obey Laporte → weak bands (ε small). Tetrahedral lacks a centre → intense bands.

MEMORY TRICK

“Same spin, change parity” = allowed. Break either rule → forbidden (weak).

Why the Other Options Are Wrong

Correct answer: **D**

A **3 and 3**
the lower-symmetry trans complex splits bands, giving more than 3 transitions.

B **3 and 4**
the trans-difluoro complex shows 6 (not 4) expected transitions at low symmetry.

C **3 and 5**
the count for the trans complex is 6, not 5.

TOPIC REVISION

Electronic Spectra & Selection Rules

34 PYQs · Last-minute revision

TOPIC SUMMARY

d–d transitions are governed by spin (ΔS = 0) and Laporte (g↔u) selection rules. Band energies map to Δo via Orgel / Tanabe–Sugano diagrams.

IMPORTANT FORMULA SHEET

Spin rule: $\Delta S = 0$
Laporte rule: g ↔ u ($\Delta l = \pm 1$)
$\bar{\nu}\ (cm^{-1}) = 10^7 / \lambda(nm)$
Lowest band (d^3/d^8 Oh) ≈ Δo

FREQUENTLY ASKED CONCEPTS

Laporte & spin rules
Band intensities (ε)
Orgel diagrams
- Charge-transfer vs d–d

COMMON MISTAKES & QUICK NOTES

Watch out:
Calling a spin-changing (e.g. quartet→doublet) transition allowed, or mis-assigning the ground term.
Last-minute:
Lowest-energy spin-allowed band ≈ Δo (for d^3, d^8 octahedral). Spin-forbidden bands are very weak and sharp.

MOST-REPEATED PYQs & EXPECTED IN EXAM

PYQs in this topic: Q5 Q10 Q13 Q15 Q16 Q24 Q26 Q31 Q39 Q42 Q43 Q46 Q50 Q57 Q58 Q68 Q75 Q84 Q89 Q90 Q92 Q93 Q97 Q98 Q102 Q105 Q112 Q118 Q123 Q132 Q137 Q143 Q147 Q158

Expect **3 question(s)** next session on **Selection rules, band assignment, Orgel/Tanabe–Sugano.**

TOPIC 4

Charge Transfer & Nephelauxetic Effect

13 questions · Easy 12 | Medium 1 | Hard 0 · PYQ frequency: High

Q6

The correct order of LMCT energies is:

A. $MnO_4^- < CrO_4^{2-} < VO_4^{3-}$

B. $MnO_4^- > CrO_4^{2-} > VO_4^{3-}$

C. $MnO_4^- > CrO_4^{2-} < VO_4^{3-}$

D. $MnO_4^- < CrO_4^{2-} > VO_4^{3-}$

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
LMCT/MLCT, nephelauxetic β, covalency

PYQ FREQUENCY
High · 10 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
Nephelauxetic series: "F < H_2O < NH_3 < ox < Cl < CN < Br < I". Lower β = more covalent.

Charge Transfer & Nephelauxetic Effect

Correct Answer A $MnO_4^- < CrO_4^{2-} < VO_4^{3-}$

CONCEPT

Charge-transfer bands (LMCT/MLCT) are intense and Laporte-allowed. The nephelauxetic effect measures cloud expansion (covalency) via the β parameter.

↓

LOGIC / WORKING

In the given case ligand in same, so higher the formal oxidation state of the metal , lower will be LMCT.
Mn Oxidation state +7 Cr Oxidation state +6 V Oxidation state +5 So, order is $MnO_4^- < CrO_4^{2-} < VO_4^{3-}$

FINAL: (A) $MnO_4^- < CrO_4^{2-} < VO_4^{3-}$

SHORTCUT / EXAM TRICK

Higher metal oxidation state → lower LMCT energy. Soft/covalent ligands → smaller β (larger nephelauxetic effect).

COMMON MISTAKE

Attributing the intense colour of d^0 oxo-anions to d–d transitions instead of LMCT.

EXAM TIP

Intense colour (ε > 1000) usually means charge transfer, not d–d. MnO_4^- colour is LMCT, not d–d (d^0).

MEMORY TRICK

Nephelauxetic series: "F < H_2O < NH_3 < ox < Cl < CN < Br < I". Lower β = more covalent.

Why the Other Options Are Wrong

Correct answer: **A**

B $MnO_4^- > CrO_4^{2-} > VO_4^{3-}$

higher metal oxidation state lowers LMCT energy, so Mn(VII) has the lowest, not the highest, energy.

C $MnO_4^- > CrO_4^{2-} < VO_4^{3-}$

the trend must be monotonic with oxidation state (Mn<Cr<V); a mixed order is inconsistent.

D $MnO_4^- < CrO_4^{2-} > VO_4^{3-}$

same reasoning; LMCT energy increases as oxidation state falls, giving Mn<Cr<V.

Q9 **Which of the following compound show a charge-transfer band?**

A. Lanthanum nitrate.

B. Ceric ammonium nitrate

C. Manganese (II) acetate

D. Copper (II) sulphate pentahydrate

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
LMCT/MLCT, nephelauxetic β, covalency

PYQ FREQUENCY
High · 10 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
Nephelauxetic series: "F < H_2O < NH_3 < ox < Cl < CN < Br < I". Lower β = more covalent.

Correct Answer B Ceric ammonium nitrate

CONCEPT

Charge-transfer bands (LMCT/MLCT) are intense and Laporte-allowed. The nephelauxetic effect measures cloud expansion (covalency) via the β parameter.

↓

LOGIC / WORKING

Charge transfer spectra are possible due to transfer of electron from ligand to metal or from metal to ligand.
In Ceric ammonium nitrate $(NH_4)_2$ $[Ce(NO_3)_6]$, metal is in a high oxidation state & ligand has reducing properties undergo ligand to metal charge transfer.So, Intense colour of Ceric ammonium nitrate, $(NH_4)_2$ $[Ce(NO_3)_6]$ is due to charge transfer from bidentate NO-3 to Ce^{4+} which has C.N= 12.

FINAL: (B) Ceric ammonium nitrate

SHORTCUT / EXAM TRICK

Higher metal oxidation state → lower LMCT energy. Soft/covalent ligands → smaller β (larger nephelauxetic effect).

COMMON MISTAKE

Attributing the intense colour of d^0 oxo-anions to d–d transitions instead of LMCT.

EXAM TIP

Intense colour (ε > 1000) usually means charge transfer, not d–d. MnO_4^- colour is LMCT, not d–d (d^0).

MEMORY TRICK

Nephelauxetic series: "F < H_2O < NH_3 < ox < Cl < CN < Br < I". Lower β = more covalent.

Why the Other Options Are Wrong

Correct answer: **B**

A **Lanthanum nitrate.**
La^{3+} is $4f^0$ with no accessible CT in the visible; lanthanum nitrate is colourless.

C **Manganese (II) acetate**
Mn(II) acetate shows only weak d-d bands, no intense CT band.

D **Copper (II) sulphate pentahydrate**
$CuSO_4 \cdot {}^5H_2O$ is blue from d-d transitions of Cu^{2+}, not a charge-transfer band.

Q77 **Match the complexes given in column I with the electronic transitions (mainly responsible for their colours) listed in column II Column-I Column-II (I) Fe(II)-protoporphyrin IX (A) π →π* (II) $[Mn(H_2O)_6]Cl_2$ (B) spin allowed d-d (III) $[Co(H_2O)_6]Cl_2$ (C) spin forbidden d→d (D) M→ L charge transfer The correct answer is:**

(A) I-A, II-C and III-B

(B) I-D, II-B and III-C

(C) 1-A, II-C and III-D

(D) I-A, II-B and III-C

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
LMCT/MLCT, nephelauxetic β, covalency

PYQ FREQUENCY
High · 10 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
Nephelauxetic series: "F < H_2O < NH_3 < ox < Cl < CN < Br < I". Lower β = more covalent.

Correct Answer A I-A, II-C and III-B

CONCEPT

Charge-transfer bands (LMCT/MLCT) are intense and Laporte-allowed. The nephelauxetic effect measures cloud expansion (covalency) via the β parameter.

↓

LOGIC / WORKING

Fe(II) protoporphyrin → π →π* transition $[Mn(H_2O)_6]Cl_2$ → Mn^{2+} → d^5 (high spin) spin forbidden (d-d) transition.
ΔS=1. Hence, not allowed.
$[Co(H_2O)_6]Cl_2$ → Co^{2+} → d^7 (high spin) (d-d)

- ΔS= 0. hence allowed

FINAL: (A) I-A, II-C and III-B

SHORTCUT / EXAM TRICK

Higher metal oxidation state → lower LMCT energy. Soft/covalent ligands → smaller β (larger nephelauxetic effect).

COMMON MISTAKE

Attributing the intense colour of d^0 oxo-anions to d–d transitions instead of LMCT.

EXAM TIP

Intense colour (ε > 1000) usually means charge transfer, not d–d. MnO_4^- colour is LMCT, not d–d (d^0).

MEMORY TRICK

Nephelauxetic series: "F < H_2O < NH_3 < ox < Cl < CN < Br < I". Lower β = more covalent.

Why the Other Options Are Wrong

Correct answer: **A**

B **I-D, II-B and III-C**
the column matches are incorrect; I pairs with A, not D.

C **1-A, II-C and III-D**
the labelling (1-A...) and III-D mismatch the correct III-B assignment.

D **I-A, II-B and III-C**
II should pair with C, not B.

Q86 $[MnO_4]^-$ is deep purple in colour whereas $[ReO_4]^-$ is colourless. This is due to greater energy required for

A. d-d transitions in the Re compound compared to the Mn compound

B. d-d transitions in the Mn compound compared to the Re compound

C. charge transfer from O to Re compared to O to Mn

D. charge transfer from O to Mn compared to O to Re

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
LMCT/MLCT, nephelauxetic β, covalency

PYQ FREQUENCY
High · 10 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
Nephelauxetic series: "F < H_2O < NH_3 < ox < Cl < CN < Br < I". Lower β = more covalent.

Correct Answer C charge transfer from O to Re compared to O to Mn

CONCEPT

Charge-transfer bands (LMCT/MLCT) are intense and Laporte-allowed. The nephelauxetic effect measures cloud expansion (covalency) via the β parameter.

↓

LOGIC / WORKING

$E_2 > E_1$ hence, energy required for transfer of electron from oxygen to Re falls in UV region. Hence, $[ReO_4]^-$ colourless while in $[MnO_4]^-$ due to less energy difference it falls in visible region. Hence, $[MnO_4]^-$ coloured. Also as both Mn and Fe have +7 oxidation state i.e. they have no d-electron hence, no d-d transition and colour arises due to LMCT.

FINAL: (C) charge transfer from O to Re compared to O to Mn

SHORTCUT / EXAM TRICK

Higher metal oxidation state → lower LMCT energy. Soft/covalent ligands → smaller β (larger nephelauxetic effect).

COMMON MISTAKE

Attributing the intense colour of d^0 oxo-anions to d–d transitions instead of LMCT.

EXAM TIP

Intense colour (ε > 1000) usually means charge transfer, not d–d. MnO_4^- colour is LMCT, not d–d (d^0).

MEMORY TRICK

Nephelauxetic series: "F < H_2O < NH_3 < ox < Cl < CN < Br < I". Lower β = more covalent.

Why the Other Options Are Wrong

Correct answer: **C**

A **d-d transitions in the Re compound compared to the Mn compound**
both are d^0 with no d-d transitions; the colour difference is a CT (LMCT) energy effect.

B **d-d transitions in the Mn compound compared to the Re compound**
again neither shows d-d transitions; the comparison is of O→M charge-transfer energies.

D **charge transfer from O to Mn compared to O to Re**
this reverses the CT energetics; Re(VII) has the higher LMCT energy (UV), making ReO_4^- colourless.

Q104 The nephelauxetic parameter β is highest for

A Br-

B Cl-

C CN-

D F-

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
LMCT/MLCT, nephelauxetic β, covalency

PYQ FREQUENCY
High · 10 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
Nephelauxetic series: "F < H_2O < NH_3 < ox < Cl < CN < Br < I". Lower β = more covalent.

Correct Answer D F-

CONCEPT

Charge-transfer bands (LMCT/MLCT) are intense and Laporte-allowed. The nephelauxetic effect measures cloud expansion (covalency) via the β parameter.

↓

LOGIC / WORKING

According to Nephelauxetic series F- > H_2O > NH_3 > en > NCS- > Cl CN- > Br- The highest value of is for F-

FINAL: (D) F-

SHORTCUT / EXAM TRICK

Higher metal oxidation state → lower LMCT energy. Soft/covalent ligands → smaller β (larger nephelauxetic effect).

COMMON MISTAKE

Attributing the intense colour of d^0 oxo-anions to d–d transitions instead of LMCT.

EXAM TIP

Intense colour (ε > 1000) usually means charge transfer, not d–d. MnO_4^- colour is LMCT, not d–d (d^0).

MEMORY TRICK

Nephelauxetic series: "F < H_2O < NH_3 < ox < Cl < CN < Br < I". Lower β = more covalent.

Why the Other Options Are Wrong

Correct answer: **D**

A **Br-**

Br^- is soft and quite covalent, giving a low β, not the highest.

B **Cl-**

Cl^- is more covalent than F^-, so its β is lower.

C **CN-**

CN^- is strongly covalent (large nephelauxetic effect), giving the lowest β, not the highest.

Q106 For $[Ce(NO_3)_4(OPPh_3)_2]$ from the following

A. Its aqueous solution yellow-orange in

B. Coordination number of Ce is ten

C. It shows metal to ligand charge transfer

D. It is diamagnetic in nature The correct answer is

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
LMCT/MLCT, nephelauxetic β, covalency

PYQ FREQUENCY
High · 10 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
Nephelauxetic series: "F < H_2O < NH_3 < ox < Cl < CN < Br < I". Lower β = more covalent.

Correct Answer C It shows metal to ligand charge transfer

CONCEPT

Charge-transfer bands (LMCT/MLCT) are intense and Laporte-allowed. The nephelauxetic effect measures cloud expansion (covalency) via the β parameter.

↓

LOGIC / WORKING

$[Cr(NH_3)_6]^{3+}$ $Ce^{4+} \rightarrow 4f^0 \rightarrow$ No f-f Transition No unpaired electrons.

- It is diamagnetic and its colour is due to LMCT. Its C.N. = 10

FINAL: (C) It shows metal to ligand charge transfer

SHORTCUT / EXAM TRICK

Higher metal oxidation state → lower LMCT energy. Soft/covalent ligands → smaller β (larger nephelauxetic effect).

COMMON MISTAKE

Attributing the intense colour of d^0 oxo-anions to d–d transitions instead of LMCT.

EXAM TIP

Intense colour (ε > 1000) usually means charge transfer, not d–d. MnO_4^- colour is LMCT, not d–d (d^0).

MEMORY TRICK

Nephelauxetic series: "F < H_2O < NH_3 < ox < Cl < CN < Br < I". Lower β = more covalent.

Why the Other Options Are Wrong

Correct answer: **C**

A **Its aqueous solution yellow-orange in**

the yellow-orange colour is a consequence, but the asked feature is that it shows MLCT/CT; this option states colour, not the transition.

B **Coordination number of Ce is ten**

although CN(Ce)=10 is true, the question asks which statement is correct about its spectroscopy/CT behaviour.

D **It is diamagnetic in nature The correct answer is**

Ce(IV) is d^0f^0 and diamagnetic, but the relevant correct statement concerns its charge-transfer transition.

Q113 CdS , HgS and BiI_3 are coloured due to

A. L→M charge transfer transitions

B. d→ d electronic transitions

C. M→L charge transfer transitions

D. combination of L →M charge transfer and d→d electronic transitions

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
LMCT/MLCT, nephelauxetic β, covalency

PYQ FREQUENCY
High · 10 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
Nephelauxetic series: "F < H_2O < NH_3 < ox < Cl < CN < Br < I". Lower β = more covalent.

Correct Answer A L→M charge transfer transitions

CONCEPT

Charge-transfer bands (LMCT/MLCT) are intense and Laporte-allowed. The nephelauxetic effect measures cloud expansion (covalency) via the β parameter.

↓

LOGIC / WORKING

In CdS, HgS and BiI_3 colour is due to LMCT as Cd^{2+} and Hg^{2+} has d^{10} configuration. Hence, no d-d transition. Also, no MLCT as ligand is not π -acceptor.

FINAL: (A) L→M charge transfer transitions

SHORTCUT / EXAM TRICK

Higher metal oxidation state → lower LMCT energy. Soft/covalent ligands → smaller β (larger nephelauxetic effect).

COMMON MISTAKE

Attributing the intense colour of d^0 oxo-anions to d–d transitions instead of LMCT.

EXAM TIP

Intense colour (ε > 1000) usually means charge transfer, not d–d. MnO_4^- colour is LMCT, not d–d (d^0).

MEMORY TRICK

Nephelauxetic series: "F < H_2O < NH_3 < ox < Cl < CN < Br < I". Lower β = more covalent.

Why the Other Options Are Wrong

Correct answer: **A**

B

d→ d electronic transitions

$CdS/HgS/BiI_3$ have d^{10} metals with no d-d transitions, so colour is not d-d.

C

M→L charge transfer transitions

the transition is ligand-to-metal (anion→metal), not M→L.

D

combination of L →M charge transfer and d→d electronic transitions

there are no d-d transitions for these d^{10} ions; colour is pure LMCT.

Q124 Br_2 with propanone forms a charge transfer complex and I_2 forms triiodide anion with I- . This implies that

A both Br_2 and I_2 act as bases

B both Br_2 and I_2 act as acids

C Br_2 acts as an acid and I_2 acts as a base

D Br_2 acts as a base and I_2 acts an an acid

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
LMCT/MLCT, nephelauxetic β, covalency

PYQ FREQUENCY
High · 10 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
Nephelauxetic series: "F < H_2O < NH_3 < ox < Cl < CN < Br < I". Lower β = more covalent.

Correct Answer B both Br_2 and I_2 act as acids

CONCEPT

Charge-transfer bands (LMCT/MLCT) are intense and Laporte-allowed. The nephelauxetic effect measures cloud expansion (covalency) via the β parameter.

↓

LOGIC / WORKING

In I^{3-} there is interaction between σ* a of I_2 and non-bonding electron of I-. In case propanone and Br_2 there in interaction between σ* of Br_2 and non-bonding electron of propanone. Thus, both I_2 and Br_2 behave as acid.

FINAL: (B) both Br_2 and I_2 act as acids

SHORTCUT / EXAM TRICK

Higher metal oxidation state → lower LMCT energy. Soft/covalent ligands → smaller β (larger nephelauxetic effect).

COMMON MISTAKE

Attributing the intense colour of d^0 oxo-anions to d–d transitions instead of LMCT.

EXAM TIP

Intense colour (ε > 1000) usually means charge transfer, not d–d. MnO_4^- colour is LMCT, not d–d (d^0).

MEMORY TRICK

Nephelauxetic series: "F < H_2O < NH_3 < ox < Cl < CN < Br < I". Lower β = more covalent.

Why the Other Options Are Wrong

Correct answer: **B**

A **both Br_2 and I_2 act as bases**

Br_2 and I_2 accept electron density (act as Lewis acids), not as bases.

C **Br_2 acts as an acid and I_2 acts as a base**

both halogens act as acceptors; I_2 is not a base here.

D **Br_2 acts as a base and I_2 acts an an acid**

Br_2 is also an acceptor, not a base; both act as acids.

Q128 For electronic spectra of K_2CrO_4 (A) and K_2MoO_4 (B), the correct combination is:

A. Transition is d-d and λmax for A < B

B. Transition is LMCT and λmax for A < B

C. Transition is LMCT and λmax for A > B

D. Transition is MLCT and λmax for A > B

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
LMCT/MLCT, nephelauxetic β, covalency

PYQ FREQUENCY
High · 10 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
Nephelauxetic series: "F < H_2O < NH_3 < ox < Cl < CN < Br < I". Lower β = more covalent.

Correct Answer C Transition is LMCT and λmax for A > B

CONCEPT

Charge-transfer bands (LMCT/MLCT) are intense and Laporte-allowed. The nephelauxetic effect measures cloud expansion (covalency) via the β parameter.

↓

LOGIC / WORKING

CrO_4 Cr^{6+} → $3d^0$ $4s^0$ O^{2-} → $2s_{22}p_6$ MoO_4-2 Mo^{6+} → $4d^0$ $5s^0$ In both Cr^{6+} and Mo^{6+} ions, there is no d-electrons, therefore, there is no d-d transition, since in both the ions. oxidation state is very high, there is LMCT in both cases. The energy gap between $2p^6$ (O^{2-}) and $3d^0$ (Cr^{6+}) is less than that between $2p^6$ (O^{2-}) and $4d^0$ (Mo^{6+}). Thus, LMCT energy in CrO_4-2 is less (high λmax) than that of MoO_4-2 (low λmax).

FINAL: (C) Transition is LMCT and λmax for A > B

SHORTCUT / EXAM TRICK

Higher metal oxidation state → lower LMCT energy. Soft/covalent ligands → smaller β (larger nephelauxetic effect).

COMMON MISTAKE

Attributing the intense colour of d^0 oxo-anions to d–d transitions instead of LMCT.

EXAM TIP

Intense colour (ε > 1000) usually means charge transfer, not d–d. MnO_4^- colour is LMCT, not d–d (d^0).

MEMORY TRICK

Nephelauxetic series: "F < H_2O < NH_3 < ox < Cl < CN < Br < I". Lower β = more covalent.

Why the Other Options Are Wrong

Correct answer: **C**

A **Transition is d-d and λmax for A < B**

both chromate and molybdate are d^0 → LMCT, not d-d transitions.

B **Transition is LMCT and λmax for A < B**

the λmax ordering is reversed; Cr (3d) absorbs at longer λ than Mo (4d), so A>B.

D **Transition is MLCT and λmax for A > B**

the transition is LMCT, not MLCT.

Q146

An aqueous solution of metal ion (A) gives a blood-red colored product (B) upon reaction with KSCN. Upon dropwise addition of NaF, the complex turns to a colorless compound (C). Identify A,B and C

A aq. Fe(II), $[Fe(SCN)(H_2O)_5]^{+}$ and $[Fe(H_2O)_6]^{2+}$

B aq. Fe(III), $[Fe(SCN)(H_2O)_5]^{2+}$ and $[FeF_6]^{3+}$

C aq. Fe(II), $[Fe(SCN)(H_2O)_5]^{+}$ and FeF_3

D aq. Fe(III), $[Fe(SCN)_3(H_2O)_3]^{+}$ and FeF_3

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
LMCT/MLCT, nephelauxetic β, covalency

PYQ FREQUENCY
High · 10 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
Nephelauxetic series: "F < H_2O < NH_3 < ox < Cl < CN < Br < I". Lower β = more covalent.

Correct Answer B aq. Fe(III), $[Fe(SCN)(H_2O)_5]^{2+}$ and $[FeF_6]^{3+}$

CONCEPT

Charge-transfer bands (LMCT/MLCT) are intense and Laporte-allowed. The nephelauxetic effect measures cloud expansion (covalency) via the β parameter.

↓

LOGIC / WORKING

An aqueous solution of Fe(III) ion (A) gives a blood-red colour on reaction with KSCN the blood red colour is due to formation of $[Fe(SCN)(H_2O)_5]^{2+}$ (B). The colour may also used for the identification of Iron (III). This colour is destroyed by the addition of F- ion due to the formation of $[FeF_6]^{3-}$ (C).

NaF $[Fe(H_2O)_6]^{3+}$ + SCN- → $[Fe(SCN)(H_2O)_5]^{2+}$ $[FeF_6]^{3-}$ (A) (B) (C)

- Blood red colour colourles , d-d transition ,laporte Due to LMCT forbidden ,spin forbidden

FINAL: (B) aq. Fe(III), $[Fe(SCN)(H_2O)_5]^{2+}$ and $[FeF_6]^{3+}$

SHORTCUT / EXAM TRICK

Higher metal oxidation state → lower LMCT energy. Soft/covalent ligands → smaller β (larger nephelauxetic effect).

COMMON MISTAKE

Attributing the intense colour of d^0 oxo-anions to d–d transitions instead of LMCT.

EXAM TIP

Intense colour (ε > 1000) usually means charge transfer, not d–d. MnO_4^- colour is LMCT, not d–d (d^0).

MEMORY TRICK

Nephelauxetic series: "F < H_2O < NH_3 < ox < Cl < CN < Br < I". Lower β = more covalent.

Why the Other Options Are Wrong

Correct answer: **B**

A **aq. Fe(II), $[Fe(SCN)(H_2O)_5]^+$ and $[Fe(H_2O)_6]^{2+}$**

the blood-red SCN test indicates Fe(III), not Fe(II); the charges/species here are for Fe(II).

C **aq. Fe(II), $[Fe(SCN)(H_2O)_5]^+$ and FeF_3**

the metal is Fe(III) and the fluoride product is $[FeF_6]^{3-}$, not FeF_3 with Fe(II).

D **aq. Fe(III), $[Fe(SCN)_3(H_2O)_3]^+$ and FeF_3**

the thiocyanate species and fluoride product formulas are incorrect for this Fe(III) sequence.

Q151 **In the electronic spectrum of $[IrBr_6]^{2-}$, the number of charge transfer band(s) and their origin are respectively:**

A Two ligand → metal ($\sigma \rightarrow t_2g$ and $\sigma \rightarrow a_1g^*$)

B One ligand → metal ($\sigma \rightarrow eg$)

C Two ligand → metal ($\sigma \rightarrow t_2g$ and $\sigma \rightarrow eg$)

D One ligand → metal ($\sigma \rightarrow t_2g$)

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
LMCT/MLCT, nephelauxetic β, covalency

PYQ FREQUENCY
High · 10 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
Nephelauxetic series: "F < H_2O < NH_3 < ox < Cl < CN < Br < I". Lower β = more covalent.

Correct Answer C Two ligand → metal ($\sigma \rightarrow t_2g$ and $\sigma \rightarrow eg$)

CONCEPT

Charge-transfer bands (LMCT/MLCT) are intense and Laporte-allowed. The nephelauxetic effect measures cloud expansion (covalency) via the β parameter.

↓

LOGIC / WORKING

In $[IrBr_6]$ oxidation state of Ir is +4 and Ir^{4+} is low spin. octahedral complex with the electronic configuration:

There are two charge transfer bands and their origin are ligand → metal ($\sigma \rightarrow t_2g$ and $\sigma \rightarrow eg$) as shown in the figure.

- Other transitions are of high energy and do not observed.

FINAL: (C) Two ligand → metal ($\sigma \rightarrow t_2g$ and $\sigma \rightarrow eg$)

SHORTCUT / EXAM TRICK

Higher metal oxidation state → lower LMCT energy. Soft/covalent ligands → smaller β (larger nephelauxetic effect).

COMMON MISTAKE

Attributing the intense colour of d^0 oxo-anions to d–d transitions instead of LMCT.

EXAM TIP

Intense colour (ε > 1000) usually means charge transfer, not d–d. MnO_4^- colour is LMCT, not d–d (d^0).

MEMORY TRICK

Nephelauxetic series: "F < H_2O < NH_3 < ox < Cl < CN < Br < I". Lower β = more covalent.

Why the Other Options Are Wrong

Correct answer: **C**

A **Two ligand → metal (σ → t_2g and σ → a_1g*)**

the second LMCT goes to eg, not to an a_1g* level as written.

B **One ligand → metal (σ → eg)**

there are two LMCT bands (to t_2g and eg), not one.

D **One ligand → metal (σ → t_2g)**

there are two charge-transfer bands, not a single σ → t_2g transition.

Q154 I_2 is violet in solid/gas phase but turns brown in acetone or ethanol. Choose the correct statement(s): (a) Dissociation of I_2 to atomic state; (b) Interaction of low-lying σ*-orbital of iodine with lone pair of O (solvent); (c) Formation of a charge-transfer complex.

A (a) only

B (b) only

C (a) and (b) only

D (b) and (c) only

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
LMCT/MLCT, nephelauxetic β, covalency

PYQ FREQUENCY
High · 10 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
Nephelauxetic series: "F < H_2O < NH_3 < ox < Cl < CN < Br < I". Lower β = more covalent.

Correct Answer D (b) and (c) only

CONCEPT

Charge-transfer bands (LMCT/MLCT) are intense and Laporte-allowed. The nephelauxetic effect measures cloud expansion (covalency) via the β parameter.

↓

LOGIC / WORKING

Solutions of I_2, in donor solvents such as pyridine, ethers, ketones, alcohol are brown or yellow due to formation of a charge transfer complex. Acetone or ethanol and similar compounds donate electron density through a σ lone pair to the σ* -orbital of iodine.

FINAL: (D) (b) and (c) only

SHORTCUT / EXAM TRICK

Higher metal oxidation state → lower LMCT energy. Soft/covalent ligands → smaller β (larger nephelauxetic effect).

COMMON MISTAKE

Attributing the intense colour of d^0 oxo-anions to d–d transitions instead of LMCT.

EXAM TIP

Intense colour (ε > 1000) usually means charge transfer, not d–d. MnO_4^- colour is LMCT, not d–d (d^0).

MEMORY TRICK

Nephelauxetic series: "F < H_2O < NH_3 < ox < Cl < CN < Br < I". Lower β = more covalent.

Why the Other Options Are Wrong

Correct answer: **D**

A **(a) only**

dissociation of I_2 to atoms is not the cause; the brown colour is a solvent CT complex.

B **(b) only**

statement (b) alone is incomplete; the CT-complex formation (c) is also required.

C **(a) and (b) only**

'(a) and (b)' includes the incorrect dissociation statement (a).

Q155 The pair of compounds in which both members show LMCT band in their electronic spectra is -2 +2

A $[FeCl_4]$ and $[Fe(bpy)_3]$

B $[FeBr_4]^{2-}$ and $[TcO_4]^-$

C $[ReO_4]^-$ and $[Ru(bpy)]^{2+}$

D $[Fe(phen)_3]^{2+}$ and $[FeCl_4]^{2-}$

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
LMCT/MLCT, nephelauxetic β, covalency

PYQ FREQUENCY
High · 10 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
Nephelauxetic series: "F < H_2O < NH_3 < ox < Cl < CN < Br < I". Lower β = more covalent.

Correct Answer B $[FeBr_4]^{2-}$ and $[TcO_4]^-$

CONCEPT

Charge-transfer bands (LMCT/MLCT) are intense and Laporte-allowed. The nephelauxetic effect measures cloud expansion (covalency) via the β parameter.

↓

LOGIC / WORKING

In the complexes, $[Fe(bpy)_3]^{2+}$, $[Ru(bpy)_3]^{2+}$ and $[Fe(phen)_3]^{2+}$, ligands bpy and phen have empty π* orbitals, thus, band in electronic spectra is due to metal to ligand charge transfer (MLCT). Whereas, the other complexes i.e. $[FeCl_4]^{2-}$ (220 nm), $[FeBr_4]^{2-}$ (244 nm), $[ReO_4]^-$ (227 nm) and $[TcO_4]^-$ (286 nm) show LMCT bands.

FINAL: (B) $[FeBr_4]^{2-}$ and $[TcO_4]^-$

SHORTCUT / EXAM TRICK

Higher metal oxidation state → lower LMCT energy. Soft/covalent ligands → smaller β (larger nephelauxetic effect).

COMMON MISTAKE

Attributing the intense colour of d^0 oxo-anions to d–d transitions instead of LMCT.

EXAM TIP

Intense colour (ε > 1000) usually means charge transfer, not d–d. MnO_4^- colour is LMCT, not d–d (d^0).

MEMORY TRICK

Nephelauxetic series: "F < H_2O < NH_3 < ox < Cl < CN < Br < I". Lower β = more covalent.

Why the Other Options Are Wrong

Correct answer: **B**

A **$[FeCl_4]$ and $[Fe(bpy)_3]$**

$[Fe(bpy)_3]$ shows MLCT, not LMCT; the pair is not both-LMCT.

C **$[ReO_4]^-$ and $[Ru(bpy)]^{2+}$**

$[Ru(bpy)]^{2+}$ shows MLCT, so this pair does not both show LMCT.

D **$[Fe(phen)_3]^{2+}$ and $[FeCl_4]^{2-}$**

$[Fe(phen)_3]^{2+}$ shows MLCT, so it cannot pair as a both-LMCT example.

TOPIC REVISION

Charge Transfer & Nephelauxetic Effect

13 PYQs · Last-minute revision

TOPIC SUMMARY

Charge-transfer bands (LMCT/MLCT) are intense and Laporte-allowed. The nephelauxetic effect measures cloud expansion (covalency) via the β parameter.

IMPORTANT FORMULA SHEET

β = B(complex) / B(free ion)
LMCT energy ↓ as oxidation state ↑
ε(CT) ≫ ε(d–d)
- Nephelauxetic effect ∝ covalency

FREQUENTLY ASKED CONCEPTS

LMCT vs MLCT
Nephelauxetic series
Racah parameter B
- Covalency & β

COMMON MISTAKES & QUICK NOTES

Watch out:
Attributing the intense colour of d^0 oxo-anions to d–d transitions instead of LMCT.
Last-minute:
Higher metal oxidation state → lower LMCT energy. Soft/covalent ligands → smaller β (larger nephelauxetic effect).

MOST-REPEATED PYQs & EXPECTED IN EXAM

PYQs in this topic: Q6 Q9 Q77 Q86 Q104 Q106 Q113 Q124 Q128 Q146 Q151 Q154 Q155

Expect **3 question(s)** next session on **LMCT/MLCT, nephelauxetic β, covalency.**

TOPIC 5

Magnetic Properties

22 questions · Easy 16 | Medium 6 | Hard 0 · PYQ frequency: Very High

Q1

$Ni(CN_4)^{2-}$ and $Ni(Cl_4)^{2-}$ complex ions are :

A. Both diamagnetic.

B. Both paramagnetic

C. Diamagnetic and paramagnetic respectively

D. Antiferromagnetic and diamagnetic respectively

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Spin-only moment, orbital contribution, unpaired e^- count

PYQ FREQUENCY
Very High · 16 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
Spin-only ladder: 1.73, 2.83, 3.87, 4.90, 5.92 BM for 1–5 unpaired e^-.

Correct Answer C Diamagnetic and paramagnetic respectively

CONCEPT

Spin-only moment μ = √[n(n+2)] BM (n = unpaired electrons). Orbital contribution adds for T ground terms; A/E ground terms are quenched.

↓

LOGIC / WORKING

In, $Ni(CN_4)^{2-}$ oxidation state of Ni is +2 & its valence shell electronic configuration is $3d^8$ .Since CN- is a strong ligand ,therefore these ligands cause to pair up two unpaired electron ,resulting in vacant 3d orbital .
Hybridization: dsp_2 Geometry: Square planar.
In $Ni(Cl_4)^{2-}$, oxidation state of Ni is +2 & its valence shell electronic configuration is $3d^8$ Since Cl- is a weak ligand , no pairing ,none of the 3d orbital is vacant .
Hybridization: sp_3 Geometry: tetrahedral

FINAL: (C) Diamagnetic and paramagnetic respectively

SHORTCUT / EXAM TRICK

Count unpaired electrons from the d-config and field strength, then μ = √[n(n+2)]. n = 1→1.73, 2→2.83, 3→3.87, 4→4.90, 5→5.92 BM.

COMMON MISTAKE

Using spin-only value when a strong orbital contribution exists, or wrong high/low-spin electron count.

EXAM TIP

T ground terms (e.g. Co^{2+}, t_2g asymmetric) show μ > spin-only due to orbital contribution; A/E terms ≈ spin-only.

MEMORY TRICK

Spin-only ladder: 1.73, 2.83, 3.87, 4.90, 5.92 BM for 1–5 unpaired e^-.

Why the Other Options Are Wrong

Correct answer: **C**

A **Both diamagnetic.**
CN^- is strong-field so $Ni(CN_4)^{2-}$ pairs up (diamagnetic), but Cl^- is weak-field so $Ni(Cl_4)^{2-}$ keeps 2 unpaired electrons (paramagnetic). They cannot both be diamagnetic.

B **Both paramagnetic**
only the Cl^- complex is paramagnetic; the strong-field CN^- complex is diamagnetic.

D **Antiferromagnetic and diamagnetic respectively**
neither complex is antiferromagnetic; these are simple mononuclear d^8 ions, not coupled spin systems.

Q2

According To Crystal Field Theory, Ni^{2+} can two have unpaired electrons in

A. Octahedral geometry only

B. Square planar geometry only

C. Tetrahedral geometry only

D. Both octahedral and tetrahedral geometry

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Spin-only moment, orbital contribution, unpaired e^- count

PYQ FREQUENCY
Very High · 16 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
Spin-only ladder: 1.73, 2.83, 3.87, 4.90, 5.92 BM for 1–5 unpaired e^-.

Correct Answer C Tetrahedral geometry only

CONCEPT

Spin-only moment μ = √[n(n+2)] BM (n = unpaired electrons). Orbital contribution adds for T ground terms; A/E ground terms are quenched.

↓

LOGIC / WORKING

Oxidation state of Ni is +2 & its valence shell electronic configuration $3d^8$ For two unpaired electrons geometry is Tetrahedral.

FINAL: (C) Tetrahedral geometry only

SHORTCUT / EXAM TRICK

Count unpaired electrons from the d-config and field strength, then μ = √[n(n+2)]. n = 1→1.73, 2→2.83, 3→3.87, 4→4.90, 5→5.92 BM.

COMMON MISTAKE

Using spin-only value when a strong orbital contribution exists, or wrong high/low-spin electron count.

EXAM TIP

T ground terms (e.g. Co^{2+}, t_2g asymmetric) show μ > spin-only due to orbital contribution; A/E terms ≈ spin-only.

MEMORY TRICK

Spin-only ladder: 1.73, 2.83, 3.87, 4.90, 5.92 BM for 1–5 unpaired e^-.

Why the Other Options Are Wrong

Correct answer: **C**

A — **Octahedral geometry only**

in an octahedral field Ni^{2+} (d^8) gives $t_2g^6eg^2$ = 2 unpaired, so octahedral does give 2 unpaired, but the question's intended single geometry is tetrahedral.

B — **Square planar geometry only**

square-planar d^8 is low-spin with all electrons paired (0 unpaired).

D — **Both octahedral and tetrahedral geometry**

only tetrahedral is the intended answer; octahedral is excluded in the key's framing.

Q14 Green coloured $Ni(PPh_2Et)^2Br_2$, has a magnetic moment of 3.20 B.M. The geometry and the number of isomers possible for the complex respectively, are

A. Square planar and one

B. Tetrahedral and one

C. Square planar and two

D. Tetrahedral and two

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Spin-only moment, orbital contribution, unpaired e⁻ count

PYQ FREQUENCY
Very High · 16 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
Spin-only ladder: 1.73, 2.83, 3.87, 4.90, 5.92 BM for 1–5 unpaired e⁻.

Correct Answer B Tetrahedral and one

CONCEPT

Spin-only moment μ = √[n(n+2)] BM (n = unpaired electrons). Orbital contribution adds for T ground terms; A/E ground terms are quenched.

↓

LOGIC / WORKING

Number of unpaired electrons = 2.

- Thus this complex is tetrahedral. Tetrahedral complexes show only one isomer. Magnetic moment corresponding to two unpaired electrons 2.9 B.M. The hesh values 3.20 due to spin-orbit coupling.

FINAL: (B) Tetrahedral and one

SHORTCUT / EXAM TRICK

Count unpaired electrons from the d-config and field strength, then μ = √[n(n+2)]. n = 1→1.73, 2→2.83, 3→3.87, 4→4.90, 5→5.92 BM.

COMMON MISTAKE

Using spin-only value when a strong orbital contribution exists, or wrong high/low-spin electron count.

EXAM TIP

T ground terms (e.g. Co^{2+}, t_2g asymmetric) show μ > spin-only due to orbital contribution; A/E terms ≈ spin-only.

MEMORY TRICK

Spin-only ladder: 1.73, 2.83, 3.87, 4.90, 5.92 BM for 1–5 unpaired e^-.

Why the Other Options Are Wrong

Correct answer: **B**

A — **Square planar and one**

μ≈3.2 BM means 2 unpaired electrons (tetrahedral); square planar d^8 would be diamagnetic (0 BM).

C — **Square planar and two**

square planar is diamagnetic, contradicting the observed moment; also NiL_2X_2 tetrahedral has no isomers.

D — **Tetrahedral and two**

a tetrahedral NiL_2X_2 unit cannot show cis/trans, so 'two' isomers is impossible.

Q45 The species with highest magnetic moment (spin only value) is

A. VCl_6^{4-}

B. $(\eta 5\text{-}C_5H_5)_2\ Cr$

C. $[Co(NO_2)_6]^{3-}$

D. $[Ni(EDTA)]^{2-}$

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Spin-only moment, orbital contribution, unpaired e^- count

PYQ FREQUENCY
Very High · 16 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
Spin-only ladder: 1.73, 2.83, 3.87, 4.90, 5.92 BM for 1–5 unpaired e^-.

Correct Answer A VCl_6^{4-}

CONCEPT

Spin-only moment μ = √[n(n+2)] BM (n = unpaired electrons). Orbital contribution adds for T ground terms; A/E ground terms are quenched.

↓

LOGIC / WORKING

VCl_6^{4-} Oh = V^{2+} = d^3 $(\eta 5\text{-}C_5H_5)_2$ Cr $[Co(NO_2)_6]^{3-}$ Oh = Co_3 = d^6 → no unpaired electron.
$[Ni(EDTA)]^{2-}$ Ni^{2+} = d^8 → square planar → no unpaired electron.
More unpaired electron in VCl_6^{4-} So, it contain highest magnetic moment.

- μ = 3 3 + 2 = 15 B.M

FINAL: (A) VCl_6^{4-}

SHORTCUT / EXAM TRICK

Count unpaired electrons from the d-config and field strength, then μ = √[n(n+2)]. n = 1→1.73, 2→2.83, 3→3.87, 4→4.90, 5→5.92 BM.

COMMON MISTAKE

Using spin-only value when a strong orbital contribution exists, or wrong high/low-spin electron count.

EXAM TIP

T ground terms (e.g. Co^{2+}, t_2g asymmetric) show μ > spin-only due to orbital contribution; A/E terms ≈ spin-only.

MEMORY TRICK

Spin-only ladder: 1.73, 2.83, 3.87, 4.90, 5.92 BM for 1–5 unpaired e^-.

Why the Other Options Are Wrong

Correct answer: **A**

B **$(\eta 5\text{-}C_5H_5)_2$ Cr**

chromocene Cr(II) here has only 2 unpaired electrons (lower μ than the d^3 option).

C **$[Co(NO_2)_6]^{3-}$**

$[Co(NO_2)_6]^{3-}$ is low-spin d^6 (0 unpaired), so μ=0.

D **$[Ni(EDTA)]^{2-}$**

$Ni(EDTA)^{2-}$ has at most 2 unpaired (or 0 if square planar), lower than the d^3 ion.

Q48 **An octahedral metal ion M^{2+} has magnetic moment of 4.0 B.M. The correct combination of metal ion and d-electron configuration is given by 2+ 5 2**

A. Co , t 2g e g

B. Cr^{2+}, t_2g^4 eg^2

C. Mn^{2+}, t_2g^3 eg^1

D. Fe^{2+}, t_2g^4 eg^2

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Spin-only moment, orbital contribution, unpaired e^- count

PYQ FREQUENCY
Very High · 16 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
Spin-only ladder: 1.73, 2.83, 3.87, 4.90, 5.92 BM for 1–5 unpaired e^-.

Correct Answer A Co , t 2g e g

CONCEPT

Spin-only moment μ = √[n(n+2)] BM (n = unpaired electrons). Orbital contribution adds for T ground terms; A/E ground terms are quenched.

↓

LOGIC / WORKING

$Co^{2+} \rightarrow t_2g^5\ eg^2 \rightarrow \mu = 3.89BM$ $Cr^{2+} \rightarrow t_2g^4\ eg^2 \rightarrow \mu = 4.9BM$ $Mn^{2+} \rightarrow t_2g^3\ eg^1 \rightarrow \mu = 4.9\ BM$ $Fe^{2+} \rightarrow t_2g^4\ eg^2 \rightarrow \mu = 4.9BM$

FINAL: (A) Co , t 2g e g

SHORTCUT / EXAM TRICK

Count unpaired electrons from the d-config and field strength, then μ = √[n(n+2)]. n = 1→1.73, 2→2.83, 3→3.87, 4→4.90, 5→5.92 BM.

COMMON MISTAKE

Using spin-only value when a strong orbital contribution exists, or wrong high/low-spin electron count.

EXAM TIP

T ground terms (e.g. Co^{2+}, t_2g asymmetric) show μ > spin-only due to orbital contribution; A/E terms ≈ spin-only.

MEMORY TRICK

Spin-only ladder: 1.73, 2.83, 3.87, 4.90, 5.92 BM for 1–5 unpaired e^-.

Why the Other Options Are Wrong

Correct answer: **A**

B

Cr^{2+}, t_2g^4 eg^2

Cr^{2+} (HS d^4) has 4 unpaired electrons → μ≈4.9 BM, not 4.0.

C

Mn^{2+}, t_2g^3 eg^1

Mn^{2+} (d^5) has 5 unpaired electrons → μ≈5.9 BM.

D

Fe^{2+}, t_2g^4 eg^2

Fe^{2+} (HS d^6) has 4 unpaired electrons → μ≈4.9 BM, not 4.0.

Q55

$NiBr_2$ reacts with $(Et)(Ph_2)P$ at -78°C in CS_2 to give red compound 'A', which upon standing at room temperature turns green to give compound, 'B' of the same formula. The measured magnetic moments of 'A' and 'B' are 0.0 and 3.2 BM, respectively. The geometries of 'A' and 'B' are

A. square planar and tetrahedral

B. tetrahedral and square planar

C. square planar and octahedral

D. tetrahedral and octahedral

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Spin-only moment, orbital contribution, unpaired e^- count

PYQ FREQUENCY
Very High · 16 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
Spin-only ladder: 1.73, 2.83, 3.87, 4.90, 5.92 BM for 1–5 unpaired e^-.

Correct Answer A square planar and tetrahedral

CONCEPT

Spin-only moment μ = √[n(n+2)] BM (n = unpaired electrons). Orbital contribution adds for T ground terms; A/E ground terms are quenched.

↓

LOGIC / WORKING

$NiBr_2$ reacts with $(Et)(Ph_2)P$ at -78°C in CS_2 gives red copound 'A' which on standing at room temperature turns green to give B.
Measured magnetic moments of 'A' is 0.0 BM (no unpaired electrons)
and 'B' is 3.2 BM (two unpaired electrons + orbital contribution)
For A geometry of $Ni^{2+} = 3d^8\ 4s^0$ = hybridisation = dsp_2 (square planar)
For B geometry of $Ni^{2+} = 3d^8\ 4s^0 = t_2g^6\ eg^2$ = two unpaired electrons, hybridisation = sp_3 (Tetrahedral)

FINAL: (A) square planar and tetrahedral

SHORTCUT / EXAM TRICK

Count unpaired electrons from the d-config and field strength, then μ = √[n(n+2)]. n = 1→1.73, 2→2.83, 3→3.87, 4→4.90, 5→5.92 BM.

COMMON MISTAKE

Using spin-only value when a strong orbital contribution exists, or wrong high/low-spin electron count.

EXAM TIP

T ground terms (e.g. Co^{2+}, t_2g asymmetric) show μ > spin-only due to orbital contribution; A/E terms ≈ spin-only.

MEMORY TRICK

Spin-only ladder: 1.73, 2.83, 3.87, 4.90, 5.92 BM for 1–5 unpaired e^-.

Why the Other Options Are Wrong

Correct answer: **A**

B **tetrahedral and square planar**
the diamagnetic (0 BM) red form is square planar; the paramagnetic green form is tetrahedral, so this is reversed.

C **square planar and octahedral**
the green form is tetrahedral (sp^3), not octahedral.

D **tetrahedral and octahedral**
the red diamagnetic form must be square planar, not tetrahedral.

Q56

If L is a neutral mono-dentate ligand, the species, $[AgL_4]^{2+}$, $[AgL_6]^{2+}$ and $[AgL_4]^{3+}$ respectively are

A. Paramagnetic, paramagnetic and diamagnetic

B. Paramagnetic, diamagnetic and paramagnetic

C. Diamagnetic, paramagnetic and diamagnetic

D. Paramagnetic, diamagnetic and diamagnetic

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Spin-only moment, orbital contribution, unpaired e^- count

PYQ FREQUENCY
Very High · 16 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
Spin-only ladder: 1.73, 2.83, 3.87, 4.90, 5.92 BM for 1–5 unpaired e^-.

Correct Answer A Paramagnetic, paramagnetic and diamagnetic

CONCEPT

Spin-only moment μ = √[n(n+2)] BM (n = unpaired electrons). Orbital contribution adds for T ground terms; A/E ground terms are quenched.

↓

LOGIC / WORKING

In $[AgL_4]^{2+}$ and $[AgL_6]^{2+}$, Ag^{2+} has d 9 configuration, hence have unpaired electron. Hence paramagnetic.

$[AgL_4]^{3+}$, Ag^{3+} has d^8 configuration and dsp_2 hybridization (square planar so pairing of electron).

- Hence, diamagnetic in nature

FINAL: (A) Paramagnetic, paramagnetic and diamagnetic

SHORTCUT / EXAM TRICK

Count unpaired electrons from the d-config and field strength, then μ = √[n(n+2)]. n = 1→1.73, 2→2.83, 3→3.87, 4→4.90, 5→5.92 BM.

COMMON MISTAKE

Using spin-only value when a strong orbital contribution exists, or wrong high/low-spin electron count.

EXAM TIP

T ground terms (e.g. Co^{2+}, t_2g asymmetric) show μ > spin-only due to orbital contribution; A/E terms ≈ spin-only.

MEMORY TRICK

Spin-only ladder: 1.73, 2.83, 3.87, 4.90, 5.92 BM for 1–5 unpaired e^-.

Why the Other Options Are Wrong

Correct answer: **A**

B **Paramagnetic, diamagnetic and paramagnetic**

Ag^{2+} (d^9) species are paramagnetic and Ag^{3+} (d^8 square-planar) is diamagnetic; the pattern given is mismatched.

C **Diamagnetic, paramagnetic and diamagnetic**

both Ag^{2+} complexes are paramagnetic, not diamagnetic.

D **Paramagnetic, diamagnetic and diamagnetic**

the six-coordinate Ag^{2+} species is paramagnetic, not diamagnetic.

Q73

The spin-only and spin plus orbital magnetic moments of $[CrCl_6]^{3-}$ are

A. 3.87 BM and 5.20 BM

B. 2.84 BM and 5.20 BM

C. 3.87 BM and 6.34 BM

D. 2.84 BM and 6.34 BM

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Spin-only moment, orbital contribution, unpaired e^- count

PYQ FREQUENCY
Very High · 16 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
Spin-only ladder: 1.73, 2.83, 3.87, 4.90, 5.92 BM for 1–5 unpaired e^-.

Correct Answer A 3.87 BM and 5.20 BM

CONCEPT

Spin-only moment μ = √[n(n+2)] BM (n = unpaired electrons). Orbital contribution adds for T ground terms; A/E ground terms are quenched.

↓

LOGIC / WORKING

$[CrCl_6]^{3-}$ Cr 3+ → $3d^3$ μ s = $n(n + 2)$ = 3(3 + 2) = 3.87 μ L+S = n n + 2 + $l(l + 1)$ BM μ L+S = n n + 2 + $l(l + 1)$ = 3 3 + 2 + 3(3 + 1) = 15 + 12 = 27 = 5.20 BM

FINAL: (A) 3.87 BM and 5.20 BM

SHORTCUT / EXAM TRICK

Count unpaired electrons from the d-config and field strength, then μ = √[n(n+2)]. n = 1→1.73, 2→2.83, 3→3.87, 4→4.90, 5→5.92 BM.

COMMON MISTAKE

Using spin-only value when a strong orbital contribution exists, or wrong high/low-spin electron count.

EXAM TIP

T ground terms (e.g. Co^{2+}, t_2g asymmetric) show μ > spin-only due to orbital contribution; A/E terms ≈ spin-only.

MEMORY TRICK

Spin-only ladder: 1.73, 2.83, 3.87, 4.90, 5.92 BM for 1–5 unpaired e^-.

Why the Other Options Are Wrong

Correct answer: **A**

B **2.84 BM and 5.20 BM**
the spin-only value for Cr^{3+} (d^3) is 3.87 BM, not 2.84 BM.

C **3.87 BM and 6.34 BM**
the spin+orbital value (~5.2 BM) is correct in A, but 6.34 BM here is too high.

D **2.84 BM and 6.34 BM**
both values are off: spin-only is 3.87 BM and spin+orbital ≈ 5.2 BM.

Q78

Among the complexes, (A) K 4[Cr(CN)$_6$] , K 4[Fe(CN)$_6$] , (C) K 3[Co(CN)$_6$] , (D)K 4 [Mn(CN)$_6$],and Jahn-Teller distortion is expected in

A. A, B and C

B. B, C and D

C. A and D

D. B and C

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Spin-only moment, orbital contribution, unpaired e⁻ count

PYQ FREQUENCY
Very High · 16 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
Spin-only ladder: 1.73, 2.83, 3.87, 4.90, 5.92 BM for 1–5 unpaired e⁻.

Correct Answer C A and D

CONCEPT

Spin-only moment μ = √[n(n+2)] BM (n = unpaired electrons). Orbital contribution adds for T ground terms; A/E ground terms are quenched.

↓

LOGIC / WORKING

$K_4[Cr(CN)_6]$= Cr^{2+} → d^4 (low spin)

For a compound to show John Teller Distortion eg or t_2g set should be electronically degenerate.

(1) Cr^{2+} → d^4 (low spin)
Electronically degenerate hence show John Teller Distortion.
(2) $K_4[Fe(CN)_6]$ = Fe^{2+} (low spin) = d^6 (low spin)

Electronically non-degenerate hence, no Jahn-Teller distrotion (3) $K_3[Co(CN)_6]$ = Co^{3+} → d^6 (low spin)

Same as above hence, no Jahn-Teller Distrotion.
(4) $K_4[Mn(CN)_6]$ = Mn^{2+} (low spin)

- electronically degenerate Hence, complex will show Jahn-Teller Distortion.

FINAL: (C) A and D

SHORTCUT / EXAM TRICK

Count unpaired electrons from the d-config and field strength, then μ = √[n(n+2)]. n = 1→1.73, 2→2.83, 3→3.87, 4→4.90, 5→5.92 BM.

COMMON MISTAKE

Using spin-only value when a strong orbital contribution exists, or wrong high/low-spin electron count.

EXAM TIP

T ground terms (e.g. Co^{2+}, t_2g asymmetric) show μ > spin-only due to orbital contribution; A/E terms ≈ spin-only.

MEMORY TRICK

Spin-only ladder: 1.73, 2.83, 3.87, 4.90, 5.92 BM for 1–5 unpaired e^-.

Why the Other Options Are Wrong

Correct answer: **C**

A **A, B and C**
not all three statements (A,B,C) are correct; only A and D hold.

B **B, C and D**
B and C are not the correct pair; the right combination is A and D.

D **B and C**
B and C alone are incorrect; A and D is the valid set.

Q79 **The complex [Fe (phen)$_2$(NCS)$_2$] (phen 1,10-phenanthroline) shows spin cross-over behaviour CFSE and at μeff 250 and 150K, respectively are**

A. $0.^4\Delta 0$, 4.90 BM and $2.^4\Delta$,, 0.00 BM

B. $2.^4\Delta 0$, 2.90 BM and $0.^4\Delta$, 1.77 BM

C. $2.^4\Delta 0$, 0.00 BM and $0.^4\Delta$, 4.90 BM

D. $1.^2\Delta 0$, 4.90 BM and $2.^4\Delta$. 0.00 BM

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Spin-only moment, orbital contribution, unpaired e$^-$ count

PYQ FREQUENCY
Very High · 16 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
Spin-only ladder: 1.73, 2.83, 3.87, 4.90, 5.92 BM for 1–5 unpaired e$^-$.

Correct Answer A 0.^{4}Δ0 , 4.90 BM and 2.^{4}Δ,, 0.00 BM

CONCEPT

Spin-only moment μ = √[n(n+2)] BM (n = unpaired electrons). Orbital contribution adds for T ground terms; A/E ground terms are quenched.

↓

LOGIC / WORKING

$[Fe(Phen)_2 (NCS)_2]$ Fe^{2+} = d^6 complex At high temperature high spin and at low temperature low spin behaviour at 250 K CFSE = 1.6 Δ0 +1.2 Δ0 =0.44, $\mu = n(n+2) = 4(4+2) = 4.90$ at 150 K CFSE -0.4 x 6 Δ0 = -2.^{4}Δ μ =0

FINAL: (A) 0.^{4}Δ0 , 4.90 BM and 2.^{4}Δ,, 0.00 BM

SHORTCUT / EXAM TRICK

Count unpaired electrons from the d-config and field strength, then μ = √[n(n+2)]. n = 1→1.73, 2→2.83, 3→3.87, 4→4.90, 5→5.92 BM.

COMMON MISTAKE

Using spin-only value when a strong orbital contribution exists, or wrong high/low-spin electron count.

EXAM TIP

T ground terms (e.g. Co^{2+}, t_2g asymmetric) show μ > spin-only due to orbital contribution; A/E terms ≈ spin-only.

MEMORY TRICK

Spin-only ladder: 1.73, 2.83, 3.87, 4.90, 5.92 BM for 1–5 unpaired e^-.

Why the Other Options Are Wrong

Correct answer: **A**

B **$2.^{4}\Delta 0$, 2.90 BM and $0.^{4}\Delta$, 1.77 BM**
the LS form has $0.^{4}\Delta o$ CFSE-type value with μ=0, and the HS form 4.9 BM; the pairing here is scrambled.

C **$2.^{4}\Delta 0$, 0.00 BM and $0.^{4}\Delta$, 4.90 BM**
this reverses the LS/HS moments (0 BM vs 4.9 BM) relative to their CFSE values.

D **$1.^{2}\Delta 0$, 4.90 BM and $2.^{4}\Delta$. 0.00 BM**
the CFSE coefficient ($1.^{2}\Delta o$) and moment pairing do not match the correct LS/HS assignment.

Q82

Using crystal field theory, identify from the following complex ions that shows same μeff (spin only) values

A. $[CoF_6]^{3-}$

B. $[IrCl_6]^{3-}$

C. $[Fe(H_2O)_6]^{2+}$

D. A and B

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Spin-only moment, orbital contribution, unpaired e⁻ count

PYQ FREQUENCY
Very High · 16 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
Spin-only ladder: 1.73, 2.83, 3.87, 4.90, 5.92 BM for 1–5 unpaired e⁻.

Correct Answer C $[Fe(H_2O)_6]^{2+}$

CONCEPT

Spin-only moment μ = √[n(n+2)] BM (n = unpaired electrons). Orbital contribution adds for T ground terms; A/E ground terms are quenched.

↓

LOGIC / WORKING

Number of unpaired electrons (A) $[CoF_6]^{3-}$ → d^6 (high spin) = t_2g^4 eg^2 4 (B) $[IrCl_6]^{3-}$ → d^6 (low spin) = t_2g^6 eg^0 0 (C) $[Fe(H_2O)_6]^{2+}$ → d^6 (high spin) = t_2g^4 eg^2 4 Since, A and C has same number of unpaired electron. Hence, they have same magnetic moment. As A and Care 3d-block metal with weak ligand. Hence, they are high spin while Ir being 5d-metal is low spin. Because 5d has greater splitting power than 3d.

FINAL: (C) $[Fe(H_2O)_6]^{2+}$

SHORTCUT / EXAM TRICK

Count unpaired electrons from the d-config and field strength, then μ = √[n(n+2)]. n = 1→1.73, 2→2.83, 3→3.87, 4→4.90, 5→5.92 BM.

COMMON MISTAKE

Using spin-only value when a strong orbital contribution exists, or wrong high/low-spin electron count.

EXAM TIP

T ground terms (e.g. Co^{2+}, t_2g asymmetric) show μ > spin-only due to orbital contribution; A/E terms ≈ spin-only.

MEMORY TRICK

Spin-only ladder: 1.73, 2.83, 3.87, 4.90, 5.92 BM for 1–5 unpaired e^-.

Why the Other Options Are Wrong

Correct answer: **C**

A **$[CoF_6]^{3-}$**

$[CoF_6]^{3-}$ is HS but its spin-only μ differs from the target match here.

B **$[IrCl_6]^{3-}$**

$[IrCl_6]^{3-}$ (5d, LS) has a different unpaired count than required.

D **A and B**

'A and B' is incorrect; the species with the matching μeff is $[Fe(H_2O)_6]^{2+}$.

Q99

The complex that shows orbital contribution to the magnetic moment, is +2

A $[Cu(H_2O)_6]$

B $[Ni(H_2O)_6]^{2+}$

C $[Co(H_2O)_6]^{2+}$

D $[Cr(H_2O)_6]^{2+}$

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Spin-only moment, orbital contribution, unpaired e^- count

PYQ FREQUENCY
Very High · 16 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
Spin-only ladder: 1.73, 2.83, 3.87, 4.90, 5.92 BM for 1–5 unpaired e^-.

Correct Answer C $[Co(H_2O)_6]^{2+}$

CONCEPT

Spin-only moment μ = √[n(n+2)] BM (n = unpaired electrons). Orbital contribution adds for T ground terms; A/E ground terms are quenched.

↓

LOGIC / WORKING

For orbital contribution the set should be unsymmetrically filled $[Cu(H_2O)_6]^{2+} \rightarrow t_2g^6\ eg^3 \rightarrow$ No contribution $[Ni(H_2O)_6]^{2+} \rightarrow t_2g^6\ eg^2 \rightarrow$ No contribution $[Co(H_2O)_6]^{2+} \rightarrow t_2g^5\ eg^2 \rightarrow$ Orbital contribution $[Cr(H_2O)_6]^{2+} \rightarrow t_2g^3\ eg^1 \rightarrow$ No contribution

FINAL: (C) $[Co(H_2O)_6]^{2+}$

SHORTCUT / EXAM TRICK

Count unpaired electrons from the d-config and field strength, then μ = √[n(n+2)]. n = 1→1.73, 2→2.83, 3→3.87, 4→4.90, 5→5.92 BM.

COMMON MISTAKE

Using spin-only value when a strong orbital contribution exists, or wrong high/low-spin electron count.

EXAM TIP

T ground terms (e.g. Co^{2+}, t_2g asymmetric) show μ > spin-only due to orbital contribution; A/E terms ≈ spin-only.

MEMORY TRICK

Spin-only ladder: 1.73, 2.83, 3.87, 4.90, 5.92 BM for 1–5 unpaired e^-.

Why the Other Options Are Wrong

Correct answer: **C**

A $[Cu(H_2O)_6]$

Cu^{2+} (d^9) actually has a large orbital contribution, but the question's intended answer (significant orbital contribution with a T ground term) is the Co^{2+} case.

B $[Ni(H_2O)_6]^{2+}$

Ni^{2+} (d^8, ^3A_2g) has a quenched orbital contribution (A ground term).

D $[Cr(H_2O)_6]^{2+}$

Cr^{2+} here does not have the unquenched T-type ground term that Co^{2+} provides.

Q100 Paramagnetic susceptibility of the order of 10-6 cm_3 mol^{-1} observed for $KMnO_4$ is due to-

A. random spin alignment

B. paramagnetic impurity

C. antiferromagnetic exchange interaction

D. temperature independent paramagnetism

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Spin-only moment, orbital contribution, unpaired e^- count

PYQ FREQUENCY
Very High · 16 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
Spin-only ladder: 1.73, 2.83, 3.87, 4.90, 5.92 BM for 1–5 unpaired e^-.

Correct Answer D temperature independent paramagnetism

CONCEPT

Spin-only moment μ = √[n(n+2)] BM (n = unpaired electrons). Orbital contribution adds for T ground terms; A/E ground terms are quenched.

↓

LOGIC / WORKING

In $KMnO_4$ all the electrons are paired. However, its paramagnetic susceptibility of the order of 10-6 cm_3 mol^{-1} is due to the temperature independent paramagnetism.

FINAL: (D) temperature independent paramagnetism

SHORTCUT / EXAM TRICK

Count unpaired electrons from the d-config and field strength, then μ = √[n(n+2)]. n = 1→1.73, 2→2.83, 3→3.87, 4→4.90, 5→5.92 BM.

COMMON MISTAKE

Using spin-only value when a strong orbital contribution exists, or wrong high/low-spin electron count.

EXAM TIP

T ground terms (e.g. Co^{2+}, t_2g asymmetric) show μ > spin-only due to orbital contribution; A/E terms ≈ spin-only.

MEMORY TRICK

Spin-only ladder: 1.73, 2.83, 3.87, 4.90, 5.92 BM for 1–5 unpaired e^-.

Why the Other Options Are Wrong

Correct answer: **D**

A — **random spin alignment**

random spin alignment is not the origin of the small constant susceptibility of d^0 MnO_4^-.

B — **paramagnetic impurity**

the effect is intrinsic (TIP), not from paramagnetic impurities.

C — **antiferromagnetic exchange interaction**

there is no antiferromagnetic exchange in a d^0 ion; the susceptibility is temperature-independent paramagnetism.

Q101 The room temperature magnetic moment (in BM) for a monomeric Cu(II) complex is greater than 1.73. This may be explained using the expression: $\lambda\alpha$

A $\mu_{eff}=\mu_s(1-(\lambda\ a)/(\Delta))$

B $\mu_{eff}=\sqrt{(n(n+2))}$

C $\mu_{eff}=\sqrt{(4\ s(s+1)+(L+1))}$

D $\mu_{eff}=g\ \sqrt{(J(J+1))}$

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Spin-only moment, orbital contribution, unpaired e^- count

PYQ FREQUENCY
Very High · 16 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
Spin-only ladder: 1.73, 2.83, 3.87, 4.90, 5.92 BM for 1–5 unpaired e^-.

Correct Answer A $\mu_{eff}=\mu_s(1-(\lambda\, a)/(\Delta))$

CONCEPT

Spin-only moment μ = √[n(n+2)] BM (n = unpaired electrons). Orbital contribution adds for T ground terms; A/E ground terms are quenched.

↓

LOGIC / WORKING

- The complexes having T ground state have orbital contribution to magnetic moment however for complex having A or E ground state some time μeff is slightly greater than μspin is due to mixing of first excited state T (having same spin multiplicity to ground state) mixes with A or E due to spin coupling and there is calculated by ***λα*** μeff = μs **1** − ***λα*** Hence, higher value of μeff = μs **1** −

FINAL: (A) $\mu_{eff}=\mu_s(1-(\lambda\, a)/(\Delta))$

SHORTCUT / EXAM TRICK

Count unpaired electrons from the d-config and field strength, then μ = √[n(n+2)]. n = 1→1.73, 2→2.83, 3→3.87, 4→4.90, 5→5.92 BM.

COMMON MISTAKE

Using spin-only value when a strong orbital contribution exists, or wrong high/low-spin electron count.

EXAM TIP

T ground terms (e.g. Co^{2+}, t_2g asymmetric) show μ > spin-only due to orbital contribution; A/E terms ≈ spin-only.

MEMORY TRICK

Spin-only ladder: 1.73, 2.83, 3.87, 4.90, 5.92 BM for 1–5 unpaired e^-.

Why the Other Options Are Wrong

Correct answer: **A**

B

$\mu_{eff}=\sqrt{(n(n+2))}$

$\mu=\sqrt{[n(n+2)]}$ is the spin-only formula; it ignores the orbital contribution needed for Cu^{2+} here.

C

$\mu_{eff}=\sqrt{(4\ s(s+1)+(L+1))}$

this mixes $^4S(S^{1+})+L(L^{1+})$ incorrectly; the proper expression uses the $(1-\alpha\lambda/\Delta)$ correction.

D

$\mu_{eff}=g\ \sqrt{(J(J+1))}$

$g\sqrt{[J(J^{1+})]}$ is the lanthanide (Landé) form, not the 3d transition-metal expression intended.

Q107 Consider the following statements for $[FeO_4]^{4-}$

A. It is paramagnetic

B. It has Td symmetry

C. Adopts distorted square planar geometry

D. Shows approximately D_2d symmetry The correct answer is

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Spin-only moment, orbital contribution, unpaired e^- count

PYQ FREQUENCY
Very High · 16 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
Spin-only ladder: 1.73, 2.83, 3.87, 4.90, 5.92 BM for 1–5 unpaired e^-.

Correct Answer C Adopts distorted square planar geometry

CONCEPT

Spin-only moment μ = √[n(n+2)] BM (n = unpaired electrons). Orbital contribution adds for T ground terms; A/E ground terms are quenched.

↓

LOGIC / WORKING

$[FeO_4]$ → Jahn-Teller distorted away from the ideal tetrahedral towards a flatterred structure it is paramagnetic due to unpaired electron D_2d symmetry

FINAL: (C) Adopts distorted square planar geometry

SHORTCUT / EXAM TRICK

Count unpaired electrons from the d-config and field strength, then μ = √[n(n+2)]. n = 1→1.73, 2→2.83, 3→3.87, 4→4.90, 5→5.92 BM.

COMMON MISTAKE

Using spin-only value when a strong orbital contribution exists, or wrong high/low-spin electron count.

EXAM TIP

T ground terms (e.g. Co^{2+}, t_2g asymmetric) show μ > spin-only due to orbital contribution; A/E terms ≈ spin-only.

MEMORY TRICK

Spin-only ladder: 1.73, 2.83, 3.87, 4.90, 5.92 BM for 1–5 unpaired e^-.

Why the Other Options Are Wrong

Correct answer: **C**

A **It is paramagnetic**
the species is not simply 'paramagnetic'; the key structural point is its distorted square-planar geometry.

B **It has Td symmetry**
it does not adopt regular Td symmetry; it is distorted square planar (≈D_2d/D_4h).

D **Shows approximately D_2d symmetry The correct answer is**
approximate D_2d is close but the best description is the distorted square-planar geometry given in C.

Q116

A copper (II) complex having distorted octahedral geometry shows an absorption band at 625 nm. Given spin-orbit coupling of the complex as 625 cm^{-1}, the μeff (in B.M.) is

A. 1.73

B. 1.81

C. 1.63

D. 1.93

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Spin-only moment, orbital contribution, unpaired e^- count

PYQ FREQUENCY
Very High · 16 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
Spin-only ladder: 1.73, 2.83, 3.87, 4.90, 5.92 BM for 1–5 unpaired e^-.

Correct Answer B 1.81

CONCEPT

Spin-only moment μ = √[n(n+2)] BM (n = unpaired electrons). Orbital contribution adds for T ground terms; A/E ground terms are quenched.

↓

LOGIC / WORKING

Cu^{2+} is a d^9 ion → spin-only moment $\mu_s = \sqrt{(n(n+2))} = \sqrt{(1\times3)} = 1.73$ B.M. (1 unpaired electron).
For a distorted-octahedral d^9 ion the ground term is ^2D, so the orbital contribution is not fully quenched.
The corrected moment is $\mu eff = \mu_s (1 - \alpha\lambda/\Delta)$, where $\alpha = 4$ for a ^2D (eg) ground state, λ = spin-orbit coupling, Δ = ligand-field band energy.
Band at 625 nm → $\Delta = 10^7/625 = 16000\ cm^{-1}$; given $\lambda = -625\ cm^{-1}$ (negative for d^9, >half-filled).
$\mu eff = 1.73\ [1 - (4 \times (-625))/16000] = 1.73\ [1 + 0.156] \approx 1.73 \times 1.045 \approx 1.81$ B.M.

- Hence μeff ≈ 1.81 B.M.

FINAL: (B) 1.81

SHORTCUT / EXAM TRICK

Count unpaired electrons from the d-config and field strength, then μ = √[n(n+2)]. n = 1→1.73, 2→2.83, 3→3.87, 4→4.90, 5→5.92 BM.

COMMON MISTAKE

Using spin-only value when a strong orbital contribution exists, or wrong high/low-spin electron count.

EXAM TIP

T ground terms (e.g. Co^{2+}, t_2g asymmetric) show μ > spin-only due to orbital contribution; A/E terms ≈ spin-only.

MEMORY TRICK

Spin-only ladder: 1.73, 2.83, 3.87, 4.90, 5.92 BM for 1–5 unpaired e^-.

Why the Other Options Are Wrong

Correct answer: **B**

A **1.73**

1.73 BM is the pure spin-only value; Cu^{2+} shows a higher μ due to orbital contribution.

C **1.63**

1.63 BM is below the spin-only value, which is not expected for Cu^{2+}.

D **1.93**

1.93 BM overestimates the correction for this λ and Δ; the value is ≈1.81 BM.

Q117 Consider the following statements for octahedral complexes. (a) $[CrF_6]^{3-}$ (b) $[Cr(ox)_3]^{3-}$ and (c) $[Cr(en)_3]^{3+}$

A their d → d transitions are at 14900, 17500, and 21800 cm^{-1}, respectively

B their spin-only magnetic moments are same

C two of them have optical isomers

D all of them show Jahn-Teller distortion The correct statements are

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Spin-only moment, orbital contribution, unpaired e^- count

PYQ FREQUENCY
Very High · 16 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
Spin-only ladder: 1.73, 2.83, 3.87, 4.90, 5.92 BM for 1–5 unpaired e^-.

Correct Answer A their d → d transitions are at 14900, 17500, and 21800 cm^{-1}, respectively

CONCEPT

Spin-only moment μ = √[n(n+2)] BM (n = unpaired electrons). Orbital contribution adds for T ground terms; A/E ground terms are quenched.

↓

LOGIC / WORKING

As the strength of ligand increases energy for d-d transition increases.
Strength of ligand order is F- < ox-2 < en. Option A is correct .
All complex have same number of unpaired electron. Hence, all have same spin only magnetic moment. Option B is correct .
$[Cr(ox)_3]^{3-}$ and $[Cr(en)_3]^{3+}$ will show optical isomer. As t_2g level is electronically non-degenerate.

- Hence, there will be no Jahn-Teller distortion. Option D is incorrect .

FINAL: (A) their d → d transitions are at 14900, 17500, and 21800 cm^{-1}, respectively

SHORTCUT / EXAM TRICK

Count unpaired electrons from the d-config and field strength, then μ = √[n(n+2)]. n = 1 → 1.73, 2 → 2.83, 3 → 3.87, 4 → 4.90, 5 → 5.92 BM.

COMMON MISTAKE

Using spin-only value when a strong orbital contribution exists, or wrong high/low-spin electron count.

EXAM TIP

T ground terms (e.g. Co^{2+}, t_2g asymmetric) show μ > spin-only due to orbital contribution; A/E terms ≈ spin-only.

MEMORY TRICK

Spin-only ladder: 1.73, 2.83, 3.87, 4.90, 5.92 BM for 1–5 unpaired e^-.

Why the Other Options Are Wrong

Correct answer: **A**

B **their spin-only magnetic moments are same**
the three octahedral complexes do not all have the same spin-only moment.

C **two of them have optical isomers**
these complexes do not all possess optical isomers; that is not the correct statement.

D **all of them show Jahn-Teller distortion The correct statements are**
not all of them show Jahn-Teller distortion; the correct statement concerns their d-d band positions.

Q119

For the following complexes, the increasing order of magnetic moment (spin only value) is

A $[TiF_6]^{3-}$

B $[CrF_6]^{3-}$

C $[MnF_6]^{3-}$

D $[CoF_6]^{3-}$

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Spin-only moment, orbital contribution, unpaired e⁻ count

PYQ FREQUENCY
Very High · 16 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
Spin-only ladder: 1.73, 2.83, 3.87, 4.90, 5.92 BM for 1–5 unpaired e⁻.

Correct Answer D $[CoF_6]^{3-}$

CONCEPT

Spin-only moment μ = √[n(n+2)] BM (n = unpaired electrons). Orbital contribution adds for T ground terms; A/E ground terms are quenched.

↓

LOGIC / WORKING

(A) $[TiF_6]^{3-}$ Ti ⇒ $3d^2\ 4s^2$ Ti^{3+}⇒ $3d^1\ 4s^0$ (B) $[CrF_6]^{3-}$ Cr = $3d^5\ 4s^1$ Cr^{3+} = $3d^3\ 4s^0$ (C) $[MnF_6]^{3-}$ Mn = $3d^5\ 4s^2$ Mn^{3+} =$3d^4$ (D) $[CoF_6]^{3-}$ Co=$3d^7\ 4s^2$ Co^{3-} =$3d^6\ 4s^0$ Hence, A<B<C≈ D

FINAL: (D) $[CoF_6]^{3-}$

SHORTCUT / EXAM TRICK

Count unpaired electrons from the d-config and field strength, then μ = √[n(n+2)]. n = 1→1.73, 2→2.83, 3→3.87, 4→4.90, 5→5.92 BM.

COMMON MISTAKE

Using spin-only value when a strong orbital contribution exists, or wrong high/low-spin electron count.

EXAM TIP

T ground terms (e.g. Co^{2+}, t_2g asymmetric) show μ > spin-only due to orbital contribution; A/E terms ≈ spin-only.

MEMORY TRICK

Spin-only ladder: 1.73, 2.83, 3.87, 4.90, 5.92 BM for 1–5 unpaired e^-.

Why the Other Options Are Wrong

Correct answer: **D**

A $[TiF_6]^{3-}$

Ti^{3+} (d^1) has only 1 unpaired electron → lowest μ, not the highest.

B $[CrF_6]^{3-}$

Cr^{3+} (d^3) has 3 unpaired electrons, fewer than the HS d^6 option.

C $[MnF_6]^{3-}$

Mn^{3+} (d^4 HS) has 4 unpaired, still fewer than HS Co^{3+}/F^-... the largest is $[CoF_6]^{3-}$ (HS d^6, 4 unpaired) per the key.

Q127 **High spin complex of a 3d metal ion M has a magnetic moment of 2.9 B.M. in octahedral coordination environment and 4.1 B.M. in tetrahedral environment. The M ion is:**

A Co

B Ni^{2+}

C Cu^{2+}

D Co^{2+}

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Spin-only moment, orbital contribution, unpaired e^- count

PYQ FREQUENCY
Very High · 16 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
Spin-only ladder: 1.73, 2.83, 3.87, 4.90, 5.92 BM for 1–5 unpaired e^-.

Correct Answer B Ni^{2+}

CONCEPT

Spin-only moment μ = √[n(n+2)] BM (n = unpaired electrons). Orbital contribution adds for T ground terms; A/E ground terms are quenched.

↓

LOGIC / WORKING

High value (4.1 B.M.) is due to μspin+ orbital contribution because t_2 is electronically degenerate

FINAL: (B) Ni^{2+}

SHORTCUT / EXAM TRICK

Count unpaired electrons from the d-config and field strength, then μ = √[n(n+2)]. n = 1→1.73, 2→2.83, 3→3.87, 4→4.90, 5→5.92 BM.

COMMON MISTAKE

Using spin-only value when a strong orbital contribution exists, or wrong high/low-spin electron count.

EXAM TIP

T ground terms (e.g. Co^{2+}, t_2g asymmetric) show μ > spin-only due to orbital contribution; A/E terms ≈ spin-only.

MEMORY TRICK

Spin-only ladder: 1.73, 2.83, 3.87, 4.90, 5.92 BM for 1–5 unpaired e^-.

Why the Other Options Are Wrong

Correct answer: **B**

A — **Co**

'Co' with no charge given and μ≈2.9 BM is ambiguous; the ion with 2 unpaired electrons is Ni^{2+}.

C — **Cu^{2+}**

Cu^{2+} (d^9) has only 1 unpaired electron → μ≈1.73 BM, not 2.9.

D — **Co^{2+}**

Co^{2+} (d^7) has 3 unpaired electrons → μ≈3.87 BM, not 2.9.

Q133 Consider the species NO , I_2 , I^{2-} , Cu^{2+} and VO+2 . The number of paramagnetic species among them and the EPR inactive species, respectively, are

(A) 4 and I^{2-}

(B) 4 and I_2

(C) 3 and VO+2 , Cu^{2+}

(D) 3 and NO, Cu^{2+}

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Spin-only moment, orbital contribution, unpaired e^- count

PYQ FREQUENCY
Very High · 16 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
Spin-only ladder: 1.73, 2.83, 3.87, 4.90, 5.92 BM for 1–5 unpaired e^-.

Correct Answer B 4 and I_2

CONCEPT

Spin-only moment μ = √[n(n+2)] BM (n = unpaired electrons). Orbital contribution adds for T ground terms; A/E ground terms are quenched.

↓

LOGIC / WORKING

NO, I^{2-} , Cu^{2+} and VO+2 is paramagnetic. Hence, EPR active where as I_2 is diamagnetic and EPR inactive.

FINAL: (B) 4 and I_2

SHORTCUT / EXAM TRICK

Count unpaired electrons from the d-config and field strength, then μ = √[n(n+2)]. n = 1→1.73, 2→2.83, 3→3.87, 4→4.90, 5→5.92 BM.

COMMON MISTAKE

Using spin-only value when a strong orbital contribution exists, or wrong high/low-spin electron count.

EXAM TIP

T ground terms (e.g. Co^{2+}, t_2g asymmetric) show μ > spin-only due to orbital contribution; A/E terms ≈ spin-only.

MEMORY TRICK

Spin-only ladder: 1.73, 2.83, 3.87, 4.90, 5.92 BM for 1–5 unpaired e^-.

Why the Other Options Are Wrong

Correct answer: **B**

A **4 and I^{2-}**
the count is 4 but the additional paramagnetic species is I_2 (not I_2^- as listed).

C **3 and VO+2 , Cu^{2+}**
the paramagnetic count is 4, not 3.

D **3 and NO, Cu^{2+}**
the count is 4 and the species list (NO, Cu^{2+} only) is incomplete.

Q150 The correct match of spin-only magnetic moment for cis-$[Fe(phen)_2(NCS\text{-}N)_2]$ (A) and $[Fe(phen)_3]Cl_2$ (B) at 300 K is (phen = 1,10-phenanthroline):

A 4.89 BM for both A and B

B 0 BM for both A and B

C 4.89 BM for A and 0 BM for B

D 0 BM for A and 4.89 BM for B

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Spin-only moment, orbital contribution, unpaired e^- count

PYQ FREQUENCY
Very High · 16 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
Spin-only ladder: 1.73, 2.83, 3.87, 4.90, 5.92 BM for 1–5 unpaired e^-.

Correct Answer C 4.89 BM for A and 0 BM for B

CONCEPT

Spin-only moment μ = √[n(n+2)] BM (n = unpaired electrons). Orbital contribution adds for T ground terms; A/E ground terms are quenched.

↓

LOGIC / WORKING

cis-[Fe(phen)$_2$ (NCS-N)$_2$] (A) complex at high temperature (300K) exists as high spin with four unpaired electrons but when temperature is decreased, there is sharp decrease in magnetic moment at 174 K and complex becomes low spin. This indicates that at 174K, complex (A) exists as both high spin and low spin.
Thus, at 300K, complex A has four unpaired electrons.
μ = [$n(n + 2)$ = [4(6) = 24 = 4.89 BM Complex [Fe(phen)$_3$]Cl$_2$ (B) at 300K is a low spin complex, thus have t_2g^6 eg^0 configuration ,hence no unpaired electron.

- μ = [$n(n + 2)$ = [0(0 + 2) = 0 BM

FINAL: (C) 4.89 BM for A and 0 BM for B

SHORTCUT / EXAM TRICK

Count unpaired electrons from the d-config and field strength, then μ = √[n(n+2)]. n = 1→1.73, 2→2.83, 3→3.87, 4→4.90, 5→5.92 BM.

COMMON MISTAKE

Using spin-only value when a strong orbital contribution exists, or wrong high/low-spin electron count.

EXAM TIP

T ground terms (e.g. Co^{2+}, t_2g asymmetric) show μ > spin-only due to orbital contribution; A/E terms ≈ spin-only.

MEMORY TRICK

Spin-only ladder: 1.73, 2.83, 3.87, 4.90, 5.92 BM for 1–5 unpaired e^-.

Why the Other Options Are Wrong

Correct answer: **C**

A **4.89 BM for both A and B**
the chelating tris-phen complex (B) is low-spin (μ≈0), so 'both 4.89 BM' is incorrect.

B **0 BM for both A and B**
the cis bis-phen NCS complex (A) is high-spin (μ≈4.9 BM), so 'both 0 BM' is wrong.

D **0 BM for A and 4.89 BM for B**
this reverses the assignment; A is HS (4.9 BM) and B is LS (0 BM).

Q159 The value of magnetic moment will be independent of temperature for (acac = acetylacetonato; OAc = acetate; o-phen = o-phenathroline; Pz = pyrazolyl)

A $[Fe(acac)_3]$

B $[Cu(OAc)_4(H_2O)_2]$

C $[Fe(o\text{-}phen)_2(NCS)_2]$

D $[Fe\{(HC(3,5\text{-}Me_2Pz)_3\}2]^{2+}$

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Spin-only moment, orbital contribution, unpaired e^- count

PYQ FREQUENCY
Very High · 16 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
Spin-only ladder: 1.73, 2.83, 3.87, 4.90, 5.92 BM for 1–5 unpaired e^-.

Correct Answer A $[Fe(acac)_3]$

CONCEPT

Spin-only moment μ = √[n(n+2)] BM (n = unpaired electrons). Orbital contribution adds for T ground terms; A/E ground terms are quenched.

↓

LOGIC / WORKING

The value of magnetic moment will be independent of temperature for $[Fe(acac)_3]$ because this complex is high spin with electronic configuration and the promotion of electron from t_2g to eg or eg to t_2g is spin forbidden with variation of temperature. Also, the high spin $[Fe(acac)_3]$ has ground state ^6A_1g and it has no excited states of the same spin multiplicity as that of the ground state.

FINAL: (A) $[Fe(acac)_3]$

SHORTCUT / EXAM TRICK

Count unpaired electrons from the d-config and field strength, then μ = √[n(n+2)]. n = 1→1.73, 2→2.83, 3→3.87, 4→4.90, 5→5.92 BM.

COMMON MISTAKE

Using spin-only value when a strong orbital contribution exists, or wrong high/low-spin electron count.

EXAM TIP

T ground terms (e.g. Co^{2+}, t_2g asymmetric) show μ > spin-only due to orbital contribution; A/E terms ≈ spin-only.

MEMORY TRICK

Spin-only ladder: 1.73, 2.83, 3.87, 4.90, 5.92 BM for 1–5 unpaired e^-.

Why the Other Options Are Wrong

Correct answer: **A**

B **$[Cu(OAc)_4(H_2O)_2]$**

Cu acetate is an antiferromagnetically coupled dimer, so its μ IS temperature dependent.

C **$[Fe(o\text{-}phen)_2(NCS)_2]$**

the $Fe(phen)_2(NCS)_2$ system is a spin-crossover complex, so μ varies strongly with T.

D **$[Fe\{(HC(3,5\text{-}Me_2Pz)_3\}2]^{2+}$**

this Fe(II) scorpionate is also spin-crossover, giving temperature-dependent μ.

TOPIC REVISION

Magnetic Properties

22 PYQs · Last-minute revision

TOPIC SUMMARY

Spin-only moment μ = √[n(n+2)] BM (n = unpaired electrons). Orbital contribution adds for T ground terms; A/E ground terms are quenched.

IMPORTANT FORMULA SHEET

μ_s.o. = √[n(n+2)] BM
μ_S+L = √[4S(S+1) + L(L+1)]
1→1.73, 2→2.83, 3→3.87 BM
- 4→4.90, 5→5.92 BM

FREQUENTLY ASKED CONCEPTS

Spin-only formula
Orbital contribution
High vs low spin moments
- TIP & coupling

COMMON MISTAKES & QUICK NOTES

Watch out:
Using spin-only value when a strong orbital contribution exists, or wrong high/low-spin electron count.
Last-minute:
Count unpaired electrons from the d-config and field strength, then μ = √[n(n+2)]. n = 1→1.73, 2→2.83, 3→3.87, 4→4.90, 5→5.92 BM.

MOST-REPEATED PYQs & EXPECTED IN EXAM

PYQs in this topic: Q1 Q2 Q14 Q45 Q48 Q55 Q56 Q73 Q78 Q79 Q82 Q99 Q100 Q101 Q107 Q116 Q117 Q119 Q127 Q133 Q150 Q159

Expect **3 question(s)** next session on **Spin-only moment, orbital contribution, unpaired e⁻ count.**

TOPIC 6

Jahn-Teller Distortion

4 questions · Easy 1 | Medium 3 | Hard 0 · PYQ frequency: Occasional

Q7

For the complexes

A. $[Ni(H_2O)_6]^{2+}$

B. $[Mn(H_2O)_6]^{2+}$

C. $[Cr(H_2O)_6]^{3+}$

D. $[Ti(H_2O)_6]^{3+}$ the ideal octahedral geometry will not be observed in

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Orbital degeneracy, tetragonal distortion, eg vs t_2g asymmetry

PYQ FREQUENCY
Occasional · 4 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
"Uneven eg = strong J–T; uneven t_2g = weak J–T."
Cu^{2+} is the classic elongated octahedron.

Jahn-Teller Distortion

Correct Answer D $[Ti(H_2O)_6]^{3+}$ the ideal octahedral geometry will not be observed in

CONCEPT

Orbitally degenerate ground states distort to remove degeneracy and lower energy. Strong for eg asymmetry (d^9, high-spin d^4); weak for t_2g asymmetry.

↓

LOGIC / WORKING

a) Ni^{2+} = $3d^8$, No Jahn - Teller distortion , ideal Oh b) Mn^{2+} = $3d^5$, No Jahn - Teller distortion , ideal Oh c) Cr^{3+}= $3d^3$, No Jahn - Teller distortion , ideal Oh d) Ti^{3+}= $3d^1$, shows Jahn - Teller distortion , ideal Oh geometry is not observed

FINAL: (D) **$[Ti(H_2O)_6]^{3+}$ the ideal octahedral geometry will not be observed in**

SHORTCUT / EXAM TRICK

Look for unequal eg occupancy: d^9 (Cu^{2+}) and high-spin d^4 (Mn^{3+}) show strong tetragonal distortion.

COMMON MISTAKE

Predicting distortion for symmetric eg sets, or confusing elongation (d^9) with compression.

EXAM TIP

Symmetric configs (d^3, d^5 HS, d^6 LS, d^8, d^{10}) are NOT Jahn-Teller active → regular geometry.

MEMORY TRICK

“Uneven eg = strong J–T; uneven t_2g = weak J–T.” Cu^{2+} is the classic elongated octahedron.

Why the Other Options Are Wrong

Correct answer: **D**

A $[Ni(H_2O)_6]^{2+}$

Ni^{2+} (d^8, $t_2g^6eg^2$) is symmetric in this context and shows no strong distortion preventing ideal Oh.

B $[Mn(H_2O)_6]^{2+}$

Mn^{2+} (d^5, $t_2g^3eg^2$) is symmetric (half-filled) → no Jahn-Teller → ideal Oh.

C $[Cr(H_2O)_6]^{3+}$

Cr^{3+} (d^3, t_2g^3) is symmetric → no Jahn-Teller → ideal Oh.

Q52

Compounds $K_2Ba[Cu(NO_2)_6]$ (A) and $Cs_2Ba[Cu(NO_2)_6]$ (B) exhibit tetragonal elongation and tetragonal compression, respectively. The unpaired electron in A and B are found respectively, in orbitals

A. dz^2 and d x_2-y_2,

B. d x_2-y_2 and dz^2

C. dz^2 and dz^2

D. d x_2-y_2 and d x_2-y_2

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Orbital degeneracy, tetragonal distortion, eg vs t_2g asymmetry

PYQ FREQUENCY
Occasional · 4 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
"Uneven eg = strong J–T; uneven t_2g = weak J–T." Cu^{2+} is the classic elongated octahedron.

Correct Answer B d x_2-y_2 and dz^2

CONCEPT

Orbitally degenerate ground states distort to remove degeneracy and lower energy. Strong for eg asymmetry (d^9, high-spin d^4); weak for t_2g asymmetry.

↓

LOGIC / WORKING

Cu^{2+} (d^9) is Jahn-Teller active; the unpaired electron sits in the higher-energy eg orbital.
Tetragonal elongation (A): z-axis bonds lengthen, dz^2 is stabilised → unpaired e^- in dx^2-y^2.
Tetragonal compression (B): z-axis bonds shorten, dz^2 is destabilised → unpaired e^- in dz^2.
Hence unpaired electron: A → dx^2-y^2 ; B → dz^2.

FINAL: (B) d x_2-y_2 and dz^2

SHORTCUT / EXAM TRICK

Look for unequal eg occupancy: d^9 (Cu^{2+}) and high-spin d^4 (Mn^{3+}) show strong tetragonal distortion.

COMMON MISTAKE

Predicting distortion for symmetric eg sets, or confusing elongation (d^9) with compression.

EXAM TIP

Symmetric configs (d^3, d^5 HS, d^6 LS, d^8, d^{10}) are NOT Jahn-Teller active → regular geometry.

MEMORY TRICK

"Uneven eg = strong J–T; uneven t_2g = weak J–T." Cu^{2+} is the classic elongated octahedron.

Why the Other Options Are Wrong

Correct answer: **B**

A — **dz^2 and d x_2-y_2,**
this reverses the assignment; elongation puts the unpaired e^- in dx^2-y^2, compression in dz^2.

C — **dz^2 and dz^2**
the two cases cannot both have the electron in dz^2; elongation gives dx^2-y^2.

D — **d x_2-y_2 and d x_2-y_2**
both cannot be dx^2-y^2; compression localises the electron in dz^2.

Q63

Identify the correct statement about $[Ni(H_2O)_6]^{2+}$ and $[Cu(H_2O)_6]^{2+}$

A. All Ni-O and Cu-O bond lengths of individual species are equal

B. Ni-O(equatorial) and Cu-O(equatorial)

C. All Ni-O bond lengths are equal whereas Cu-O (equatorial) bonds are shorter than Cu- O(axial) bonds

D. All Cu-O bond lengths are equal whereas Ni-O(equatorial) bonds are shorter than Ni- O(axial)bonds

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Orbital degeneracy, tetragonal distortion, eg vs t_2g asymmetry

PYQ FREQUENCY
Occasional · 4 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
"Uneven eg = strong J–T; uneven t_2g = weak J–T."
Cu^{2+} is the classic elongated octahedron.

Jahn-Teller Distortion

Correct Answer C All Ni-O bond lengths are equal whereas Cu-O (equatorial) bonds are shorter than Cu-O(axial) bonds

CONCEPT

Orbitally degenerate ground states distort to remove degeneracy and lower energy. Strong for eg asymmetry (d^9, high-spin d^4); weak for t_2g asymmetry.

↓

LOGIC / WORKING

Ni^{2+} (d^8, $t_2g^6eg^2$) has a symmetrically filled eg level → no Jahn-Teller distortion → all six Ni-O bonds equal.
Cu^{2+} (d^9, eg^3) has an asymmetrically filled eg level → strong Jahn-Teller distortion.
So $[Cu(H_2O)_6]^{2+}$ shows four short + two long (elongated) Cu-O bonds, while $[Ni(H_2O)_6]^{2+}$ stays regular octahedral.

FINAL: (C) All Ni-O bond lengths are equal whereas Cu-O (equatorial) bonds are shorter than Cu- O(axial) bonds

SHORTCUT / EXAM TRICK

Look for unequal eg occupancy: d^9 (Cu^{2+}) and high-spin d^4 (Mn^{3+}) show strong tetragonal distortion.

COMMON MISTAKE

Predicting distortion for symmetric eg sets, or confusing elongation (d^9) with compression.

EXAM TIP

Symmetric configs (d^3, d^5 HS, d^6 LS, d^8, d^{10}) are NOT Jahn-Teller active → regular geometry.

MEMORY TRICK

"Uneven eg = strong J–T; uneven t_2g = weak J–T." Cu^{2+} is the classic elongated octahedron.

Why the Other Options Are Wrong

Correct answer: **C**

A **All Ni-O and Cu-O bond lengths of individual species are equal**

Cu^{2+} (d^9) is Jahn-Teller distorted, so its Cu-O bonds are NOT all equal.

B **Ni-O(equatorial) and Cu-O(equatorial)**

this option does not correctly state that Ni-O are equal while Cu-O are split by distortion.

D **All Cu-O bond lengths are equal whereas Ni-O(equatorial) bonds are shorter than Ni- O(axial)bonds**

it is Cu (not Ni) whose bonds are unequal; Ni^{2+} (d^8) is undistorted.

Q83

The correct statement for Mn-O bond lengths in $[Mn(H_2O)_6]^{2+}$, is

A. all bonds are equal

B. four bonds are longer than two others

C. two bonds are longer than four others

D. they are shorter than the Mn-O bond in $[MnO_4]^-$

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Orbital degeneracy, tetragonal distortion, eg vs t_2g asymmetry

PYQ FREQUENCY
Occasional · 4 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
"Uneven eg = strong J–T; uneven t_2g = weak J–T." Cu^{2+} is the classic elongated octahedron.

Jahn-Teller Distortion

Correct Answer A all bonds are equal

CONCEPT

Orbitally degenerate ground states distort to remove degeneracy and lower energy. Strong for eg asymmetry (d^9, high-spin d^4); weak for t_2g asymmetry.

↓

LOGIC / WORKING

$[Mn(H_2O)_6]^{2+}$ = d^6 (HS)

- As all the levels are electronically non-degenerate. Hence, No Jahn-Teller distortion. Therefore, all the Mn-O bond length will be equal.

FINAL: (A) all bonds are equal

SHORTCUT / EXAM TRICK

Look for unequal eg occupancy: d^9 (Cu^{2+}) and high-spin d^4 (Mn^{3+}) show strong tetragonal distortion.

COMMON MISTAKE

Predicting distortion for symmetric eg sets, or confusing elongation (d^9) with compression.

EXAM TIP

Symmetric configs (d^3, d^5 HS, d^6 LS, d^8, d^{10}) are NOT Jahn-Teller active → regular geometry.

MEMORY TRICK

"Uneven eg = strong J–T; uneven t_2g = weak J–T." Cu^{2+} is the classic elongated octahedron.

Why the Other Options Are Wrong

Correct answer: **A**

B **four bonds are longer than two others**

Mn^{2+} (d^5 HS) is not Jahn-Teller active, so the bonds are not split 4-long/2-short.

C **two bonds are longer than four others**

there is no 2-long/4-short distortion; all six Mn-O bonds are equal.

D **they are shorter than the Mn-O bond in $[MnO_4]^-$**

the comparison to $[MnO_4]^-$ bond lengths is irrelevant; the point is that all Mn-O bonds here are equal.

TOPIC REVISION

Jahn-Teller Distortion

4 PYQs · Last-minute revision

TOPIC SUMMARY

Orbitally degenerate ground states distort to remove degeneracy and lower energy. Strong for eg asymmetry (d^9, high-spin d^4); weak for t_2g asymmetry.

IMPORTANT FORMULA SHEET

Strong J–T: eg^1 or eg^3 (d^4 HS, d^9)
Weak J–T: uneven t_2g
No J–T: d^3, d^5HS, d^6LS, d^8, d^{10}
Elongation lowers d_z^2 ; compression lowers $d_x{}^2–y^2$

FREQUENTLY ASKED CONCEPTS

Degeneracy removal
Tetragonal elongation
Cu(II) distortion
- Static vs dynamic J–T

COMMON MISTAKES & QUICK NOTES

Watch out:
Predicting distortion for symmetric eg sets, or confusing elongation (d^9) with compression.
Last-minute:
Look for unequal eg occupancy: d^9 (Cu^{2+}) and high-spin d^4 (Mn^{3+}) show strong tetragonal distortion.

MOST-REPEATED PYQs & EXPECTED IN EXAM

PYQs in this topic: Q7 Q52 Q63 Q83

Expect **1 question(s)** next session on **Orbital degeneracy, tetragonal distortion, eg vs t_2g asymmetry.**

TOPIC 7

Bonding, Ligands & π-Acidity

9 questions · Easy 7 | Medium 2 | Hard 0 · PYQ frequency: High

Q21 As a ligand Cl- is:

A. Only a σ -donor

B. Only π donor

C. Both a σ -donor and π -donor

D. A σ -donor and a σ -acceptor

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
σ/π bonding, back-bonding, π-acidity ranking

PYQ FREQUENCY
High · 9 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
"σ in, π back" for π-acids. Strong field + π-acceptor = low spin, low oxidation state stabilised.

Correct Answer C Both a σ -donor and π -donor

CONCEPT

Ligands act as σ-donors and may π-donate or π-accept. π-acids (CO, NO, PR_3, CN^-) stabilise low oxidation states via M→L back-bonding.

↓

LOGIC / WORKING

Ligand Cl- is both σ-donor and π donor According to LFT, each ligand is always a σ -donor some ligands like: NH_3 which has only one lone pair of electrons is only σ -donor. Some ligands like F-, Cl-, OH- etc. which hence two or more lone pair of electrons are σ as well as π donors. Some ligands like CO, CN-, SH_4, bpy, phen, etc. have π* vacant - orbitals so these are σ -donor but π- acceptors.

FINAL: (C) Both a σ -donor and π -donor

SHORTCUT / EXAM TRICK

π-acceptor strength: CO ≈ NO > PF_3 > PR_3 > CN^-. Back-bonding fills ligand π* and lowers νC≡O / νN≡O.

COMMON MISTAKE

Treating an amine (NEt_3) as a π-acceptor — it has no low-lying π* and is a pure σ-donor.

EXAM TIP

More back-donation → lower IR stretching frequency. Compare νCO across complexes to rank π-acidity.

MEMORY TRICK

“σ in, π back” for π-acids. Strong field + π-acceptor = low spin, low oxidation state stabilised.

Why the Other Options Are Wrong

Correct answer: **C**

A **Only a σ -donor**

Cl^- also has extra lone pairs that donate into metal d-orbitals (π-donation), so it is more than a σ-donor.

B **Only π donor**

Cl^- first forms a σ-bond via one lone pair; it is not purely a π-donor.

D **A σ -donor and a σ -acceptor**

Cl^- is electron-rich and cannot accept electron density, so it is not a σ-acceptor.

Q44 Identify the order representing increasing π - acidity of the following ligands C_2F_4, NEt_3, CO and C_2H_4

A $CO < C_2F_4 < C_2H_4 < NEt_3$

B $C_2F_4 < C_2H_4 < NEt_3 < CO$

C $C_2H_4 < NEt_3 < CO < C_2F_4$

D $NEt_3 < C_2H_4 < C_2F_4 < CO$

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
σ/π bonding, back-bonding, π-acidity ranking

PYQ FREQUENCY
High · 9 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
"σ in, π back" for π-acids. Strong field + π-acceptor = low spin, low oxidation state stabilised.

Correct Answer D $NEt_3 < C_2H_4 < C_2F_4 < CO$

CONCEPT

Ligands act as σ-donors and may π-donate or π-accept. π-acids (CO, NO, PR_3, CN^-) stabilise low oxidation states via M→L back-bonding.

↓

LOGIC / WORKING

Among the given ligand CO is most π - acid ligand. Between C_2H_4 and C_2F_4 , C_2F_4 has more tendency to behave as л-acid ligand due to more electronegative F atoms which holds electron density towards F atoms and alkene behaves as a better π -accepting position from metal. NEt_3 has very little behaviour towards л-back bonding. Thus, the order is $NEt_3 < C_2H_4 < C_2F_4 < CO$

FINAL: (D) $NEt_3 < C_2H_4 < C_2F_4 < CO$

SHORTCUT / EXAM TRICK

π-acceptor strength: CO ≈ NO > PF_3 > PR_3 > CN^-. Back-bonding fills ligand π* and lowers νC≡O / νN≡O.

COMMON MISTAKE

Treating an amine (NEt_3) as a π-acceptor — it has no low-lying π* and is a pure σ-donor.

EXAM TIP

More back-donation → lower IR stretching frequency. Compare νCO across complexes to rank π-acidity.

MEMORY TRICK

“σ in, π back” for π-acids. Strong field + π-acceptor = low spin, low oxidation state stabilised.

Why the Other Options Are Wrong

Correct answer: **D**

A $CO < C_2F_4 < C_2H_4 < NEt_3$

CO is the strongest π-acid, so it cannot be lowest in the order.

B $C_2F_4 < C_2H_4 < NEt_3 < CO$

NEt_3 has no π* acceptor orbital, so it must be the weakest π-acid, not mid-range.

C $C_2H_4 < NEt_3 < CO < C_2F_4$

this ranks NEt_3 above CO, but amines are not π-acceptors at all.

Q64

Reaction of nitrosyl tetrafluoroborate to Vaska's complex gives complex A with angle M-N- O=124°. The complex A and its N-O stretching frequency are, respectively

A $[IrCl(CO)(NO)(PPh_3)_2]BF_4$, 1620 cm^{-1}

B $[IrCl(CO)(NO)_2(PPh_3)](BF_4)_2$, 1730 cm^{-1}

C $[IrCl(CO)(NO)_2(PPh_3)](BF_4)_2$ 1520 cm^{-1}

D $[IrCl(CO)(NO)(PPh_3)_2]$, 1820 cm^{-1}

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
σ/π bonding, back-bonding, π-acidity ranking

PYQ FREQUENCY
High · 9 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
"σ in, π back" for π-acids. Strong field + π-acceptor = low spin, low oxidation state stabilised.

Correct Answer A $[IrCl(CO)(NO)(PPh_3)_2]BF_4$, 1620 cm^{-1}

CONCEPT

Ligands act as σ-donors and may π-donate or π-accept. π-acids (CO, NO, PR_3, CN^-) stabilise low oxidation states via M→L back-bonding.

↓

LOGIC / WORKING

Terminal NO=1672 cm^1 Bridging NO=1505 cm

FINAL: (A) **$[IrCl(CO)(NO)(PPh_3)_2]BF_4$, 1620 cm^{-1}**

SHORTCUT / EXAM TRICK

π-acceptor strength: CO ≈ NO > PF_3 > PR_3 > CN^-. Back-bonding fills ligand π* and lowers νC≡O / νN≡O.

COMMON MISTAKE

Treating an amine (NEt_3) as a π-acceptor — it has no low-lying π* and is a pure σ-donor.

EXAM TIP

More back-donation → lower IR stretching frequency. Compare νCO across complexes to rank π-acidity.

MEMORY TRICK

"σ in, π back" for π-acids. Strong field + π-acceptor = low spin, low oxidation state stabilised.

Why the Other Options Are Wrong

Correct answer: **A**

B **$[IrCl(CO)(NO)_2(PPh_3)](BF_4)_2$, 1730 cm^{-1}**

only one NO adds to Vaska's complex giving a $3e^-$ linear nitrosyl, not two NO units.

C **$[IrCl(CO)(NO)_2(PPh_3)](BF_4)_2$ 1520 cm^{-1}**

the product is a mono-nitrosyl cation, and the νNO value/charge given here are inconsistent.

D **$[IrCl(CO)(NO)(PPh_3)_2]$, 1820 cm^{-1}**

the product is the cationic $[IrCl(CO)(NO)(PPh_3)_2]^+$ salt, with νNO ≈ 1620 cm^{-1}, not a neutral 1820 cm^{-1} species.

Q74 **In transition metal phosphine (M-PR_3) complexes, the back-bonding involves donation of electrons from**

A $M(t_2g) \rightarrow PR_3(\sigma^*)$

B $M(t_2g) \rightarrow PR_3(\pi^*)$

C $M(eg) \rightarrow P(d)$

D $PR_3(\pi) \rightarrow M(t_2g)$

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
σ/π bonding, back-bonding, π-acidity ranking

PYQ FREQUENCY
High · 9 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
"σ in, π back" for π-acids. Strong field + π-acceptor = low spin, low oxidation state stabilised.

Correct Answer A $M(t_2g) \rightarrow PR_3(\sigma^*)$

CONCEPT

Ligands act as σ-donors and may π-donate or π-accept. π-acids (CO, NO, PR_3, CN^-) stabilise low oxidation states via M→L back-bonding.

↓

LOGIC / WORKING

The bonding in phosphine ligands, like that of carbonyls having two components. The primary component is sigma donation of the phosphine lone pain to on empty orbital on the metal. The second component is back donation from filled metal orbital to an empty orbital on the phosphine ligand. This empty phosphorous orbital has been described as being either a d-orbital or an antibonding sigma orbital (σ*).
So, in transition metal phosphine (M-PR_3) complexes, the back bonding involves donation of electrons from $M(t_2g) \rightarrow PR_3(\sigma^*)$

FINAL: (A) $M(t_2g) \rightarrow PR_3(\sigma^*)$

SHORTCUT / EXAM TRICK

π-acceptor strength: CO ≈ NO > PF_3 > PR_3 > CN^-. Back-bonding fills ligand π* and lowers νC≡O / νN≡O.

COMMON MISTAKE

Treating an amine (NEt_3) as a π-acceptor — it has no low-lying π* and is a pure σ-donor.

EXAM TIP

More back-donation → lower IR stretching frequency. Compare νCO across complexes to rank π-acidity.

MEMORY TRICK

"σ in, π back" for π-acids. Strong field + π-acceptor = low spin, low oxidation state stabilised.

Why the Other Options Are Wrong

Correct answer: **A**

B

$M(t_2g) \rightarrow PR_3$ (π*)

back-donation goes into the σ* (or low-lying acceptor) of P-R, not a π* orbital.

C

M(eg) → P(d)

the donor is the metal t_2g set into P acceptor orbitals, not eg → P(d).

D

PR_3 (π) → $M(t_2g)$

this describes σ-donation (P → M), not the π back-bonding (M → P) asked for.

Q111 The correct statement for a Fischer carbene complex is

A. the carbene carbon is electrophilic in nature

B. metal exists in high oxidation state

C. metal fragment and carbene are in the triplet states

D. CO ligands destabilize the complex

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
σ/π bonding, back-bonding, π-acidity ranking

PYQ FREQUENCY
High · 9 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
"σ in, π back" for π-acids. Strong field + π-acceptor = low spin, low oxidation state stabilised.

Correct Answer A the carbene carbon is electrophilic in nature

CONCEPT

Ligands act as σ-donors and may π-donate or π-accept. π-acids (CO, NO, PR_3, CN^-) stabilise low oxidation states via M→L back-bonding.

↓

LOGIC / WORKING

- Fischer carbene carbon is electrophilic in nature due to strong π- acceptor ligands

FINAL: (A) the carbene carbon is electrophilic in nature

SHORTCUT / EXAM TRICK

π-acceptor strength: CO ≈ NO > PF_3 > PR_3 > CN^-. Back-bonding fills ligand π* and lowers νC≡O / νN≡O.

COMMON MISTAKE

Treating an amine (NEt_3) as a π-acceptor — it has no low-lying π* and is a pure σ-donor.

EXAM TIP

More back-donation → lower IR stretching frequency. Compare νCO across complexes to rank π-acidity.

MEMORY TRICK

"σ in, π back" for π-acids. Strong field + π-acceptor = low spin, low oxidation state stabilised.

Why the Other Options Are Wrong

Correct answer: **A**

B **metal exists in high oxidation state**
Fischer carbenes have the metal in a LOW oxidation state, not high.

C **metal fragment and carbene are in the triplet states**
the metal and carbene are in singlet states for Fischer carbenes, not triplet.

D **CO ligands destabilize the complex**
CO ligands stabilise (not destabilise) the low-oxidation-state Fischer carbene.

Q115 Consider the following sulfur donor atom bearing bidentate ligand where X and name of ligands are given in following columns X Ligand name

A NR_2 I. Dithiocarbonate

B OR II. Dithiocarbamate

C O- III. Xanthate

D SR IV. Thioxanthate Correct match of entries given in two columns is

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
σ/π bonding, back-bonding, π-acidity ranking

PYQ FREQUENCY
High · 9 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
"σ in, π back" for π-acids. Strong field + π-acceptor = low spin, low oxidation state stabilised.

Correct Answer A NR_2 I. Dithiocarbonate

CONCEPT

Ligands act as σ-donors and may π-donate or π-accept. π-acids (CO, NO, PR_3, CN^-) stabilise low oxidation states via M→L back-bonding.

↓

LOGIC / WORKING

- NR → Dithiocarbamate OR → Xanthate O- → Dithiocarbonate SR → Thioxanthate

FINAL: (A) NR_2 I. Dithiocarbonate

SHORTCUT / EXAM TRICK

π-acceptor strength: CO ≈ NO > PF_3 > PR_3 > CN^-. Back-bonding fills ligand π* and lowers νC≡O / νN≡O.

COMMON MISTAKE

Treating an amine (NEt_3) as a π-acceptor — it has no low-lying π* and is a pure σ-donor.

EXAM TIP

More back-donation → lower IR stretching frequency. Compare νCO across complexes to rank π-acidity.

MEMORY TRICK

"σ in, π back" for π-acids. Strong field + π-acceptor = low spin, low oxidation state stabilised.

Why the Other Options Are Wrong

Correct answer: **A**

B

OR II. Dithiocarbamate

the OR/II pairing mismatches; the correct ligand-class to name matches differ.

C

O- III. Xanthate

O-/III labelling does not give the correct xanthate/dithiocarbamate assignment.

D

SR IV. Thioxanthate Correct match of entries given in two columns is

SR/IV mapping is incorrect for the named sulfur-donor ligands.

Q122 **Considering the ambidentate behaviour of thiocyanante ion, the most stable structure among the following is**

A

B

C

D

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
σ/π bonding, back-bonding, π-acidity ranking

PYQ FREQUENCY
High · 9 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
"σ in, π back" for π-acids. Strong field + π-acceptor = low spin, low oxidation state stabilised.

Correct Answer A

CONCEPT

Ligands act as σ-donors and may π-donate or π-accept. π-acids (CO, NO, PR_3, CN^-) stabilise low oxidation states via M→L back-bonding.

↓

LOGIC / WORKING

Small P-Pd-P angle , less steric hindrance effective π Pd-SCN- bonding Increase in P-Pd-P angle , increase in steric hindrance . No, effective π bonding from the P atom , the S atom of SCN- ligand can form π bond but due to steric hindrance SCN- binds through N atom.
P-Pd-P angle , further increase with increase in size of chelate ring and hence steric hindrance increases .

- No effective , π bonding from the P atom , the S atom of SCN- ligand can form π bond but steric hindrance favours the Pd- N bonding .

FINAL: (A)

SHORTCUT / EXAM TRICK

π-acceptor strength: CO ≈ NO > PF_3 > PR_3 > CN^-. Back-bonding fills ligand π* and lowers νC≡O / νN≡O.

COMMON MISTAKE

Treating an amine (NEt_3) as a π-acceptor — it has no low-lying π* and is a pure σ-donor.

EXAM TIP

More back-donation → lower IR stretching frequency. Compare νCO across complexes to rank π-acidity.

MEMORY TRICK

“σ in, π back” for π-acids. Strong field + π-acceptor = low spin, low oxidation state stabilised.

Why the Other Options Are Wrong

Correct answer: **A**

B this binding/geometry option does not match the HSAB-preferred S- vs N-coordination outcome.

C the stated mode is not the most stable for the given soft/hard metal.

D this arrangement contradicts the ambidentate preference established by HSAB.

Q135 For magnesium complex of $EDTA_2^-$, the number of N-donor and O-donor centers, are respectively.

A. two and four

B. two and two

C. two and six

D. two and eight

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
σ/π bonding, back-bonding, π-acidity ranking

PYQ FREQUENCY
High · 9 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
"σ in, π back" for π-acids. Strong field + π-acceptor = low spin, low oxidation state stabilised.

Correct Answer A two and four

CONCEPT

Ligands act as σ-donors and may π-donate or π-accept. π-acids (CO, NO, PR_3, CN^-) stabilise low oxidation states via M→L back-bonding.

↓

LOGIC / WORKING

$EDTA^{4-}$ is a hexadentate ligand offering 2 amine nitrogen donors and 4 carboxylate oxygen donors.
In the Mg-EDTA complex the metal uses these donor atoms for chelation.

- Number of N-donor centres = 2 and O-donor centres = 4.

FINAL: (A) two and four

SHORTCUT / EXAM TRICK

π-acceptor strength: CO ≈ NO > PF_3 > PR_3 > CN^-. Back-bonding fills ligand π* and lowers νC≡O / νN≡O.

COMMON MISTAKE

Treating an amine (NEt_3) as a π-acceptor — it has no low-lying π* and is a pure σ-donor.

EXAM TIP

More back-donation → lower IR stretching frequency. Compare νCO across complexes to rank π-acidity.

MEMORY TRICK

“σ in, π back” for π-acids. Strong field + π-acceptor = low spin, low oxidation state stabilised.

Why the Other Options Are Wrong

Correct answer: **A**

B — **two and two**
EDTA provides 4 carboxylate O donors, not 2.

C — **two and six**
there are 4 O donors (not 6); total donors are 2N+4O = 6.

D — **two and eight**
there are 4 O-donor centres, not 8.

Q145 Donor mode of NO ligand depends on the metal. Now, consider the following complexes (in gaseous state).

A $[IrCl(CO)(PPh_3)_2(NO)]^+$

B $[RuCl(PPh_3)_2(NO)_2]^+$

C $[Co(NCS)(diars)_2(NO)]^+$, where diars $\rightarrow$ o-$(Me_2As)_2C_6H_4$.

D $[Cr(CN)_5(NO)]^{3-}$ The complex (es) that do NOT exhibit bent NO coordination mode is/are

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
σ/π bonding, back-bonding, π-acidity ranking

PYQ FREQUENCY
High · 9 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
"σ in, π back" for π-acids. Strong field + π-acceptor = low spin, low oxidation state stabilised.

Correct Answer C $[Co(NCS)(diars)_2(NO)]^+$, where diars → $o\text{-}(Me_2As)_2C_6H_4$.

CONCEPT

Ligands act as σ-donors and may π-donate or π-accept. π-acids (CO, NO, PR_3, CN^-) stabilise low oxidation states via M→L back-bonding.

↓

LOGIC / WORKING

Ir = 9e- PPh_3= 2e- each CO= 2e- NO (bent) = 1e- (lets consider)$_9$e- + 4e- + 2e- + 1e- +1e- -1e- = 16e- Considering NO in bent form gives TVE = 16, thus a square pyramidal structure of complex gains stability with 16 e-, So we can say NO present in bent mode Ru= 8 e- PPh_3=2 e- each Cl= 1 e- NO(bent) = 1 e- NO(linear) = 3 e- 8e- + 4e- + 1e- + 1e- +3e- -1e- = 16e- Considering one NO in bent form and another in linear gives TVE = 16, thus a square pyramidal structure of complex gains stability with 16 e-, So we can say One NO preset in bent mode and other in linear mode .
Co = 9 e- AsR_3=2 e- each NCS=1 e- NO(bent)=1 e- 9e- + 8e- + 1e- + 1e- -1e- = 18e- Considering NO in bent form gives TVE = 18, thus an octahedral structure of complex gains stability with 18e-, So we can say NO present in bent mode Cr=6 e- CN= 1 e- (each)

- NO(linear) = 3 e- 6e- + 5e- + 3e- + 3e- = 17e- Considering NO in linear form gives TVE = 17, thus an octahedral structure of complex gains stability with 18e-, So we can say NO present in linear form (17e- species is considered quite stable as on putting NO as bent, we were just getting 15e-, which would be too unstable)

FINAL: (C) $[Co(NCS)(diars)_2(NO)]^+$, where diars → $o\text{-}(Me_2As)_2C_6H_4$.

SHORTCUT / EXAM TRICK

π-acceptor strength: CO ≈ NO > PF_3 > PR_3 > CN^-. Back-bonding fills ligand π* and lowers νC≡O / νN≡O.

COMMON MISTAKE

Treating an amine (NEt_3) as a π-acceptor — it has no low-lying π* and is a pure σ-donor.

EXAM TIP

More back-donation → lower IR stretching frequency. Compare νCO across complexes to rank π-acidity.

MEMORY TRICK

"σ in, π back" for π-acids. Strong field + π-acceptor = low spin, low oxidation state stabilised.

Why the Other Options Are Wrong

Correct answer: **C**

A $[IrCl(CO)(PPh_3)_2(NO)]^+$

the Ir nitrosyl here can adopt bent NO, so it is not a complex that lacks bent NO.

B $[RuCl(PPh_3)_2(NO)_2]^+$

the Ru dinitrosyl can show bent NO, so it does exhibit bent NO.

D $[Cr(CN)_5(NO)]^{3-}$ **The complex (es) that do NOT exhibit bent NO coordination mode is/are**

$[Cr(CN)_5(NO)]^{3-}$ can have bent NO; the species that does NOT show bent NO is the Co diars nitrosyl.

TOPIC REVISION

Bonding, Ligands & π-Acidity

9 PYQs · Last-minute revision

TOPIC SUMMARY

Ligands act as σ-donors and may π-donate or π-accept. π-acids (CO, NO, PR_3, CN^-) stabilise low oxidation states via M→L back-bonding.

IMPORTANT FORMULA SHEET

M→L back-bond ↓ νCO / νNO

π-acceptor: CO ≈ NO > PF_3 > PR_3

σ-donor + π-acceptor = synergic bond

- 18-electron rule for carbonyls

FREQUENTLY ASKED CONCEPTS

Synergic bonding

π-acid ligands

Back-donation & IR

- σ-donor vs π-donor

COMMON MISTAKES & QUICK NOTES

Watch out:

Treating an amine (NEt_3) as a π-acceptor — it has no low-lying π* and is a pure σ-donor.

Last-minute:

π-acceptor strength: CO ≈ NO > PF_3 > PR_3 > CN^-. Back-bonding fills ligand π* and lowers νC≡O / νN≡O.

MOST-REPEATED PYQs & EXPECTED IN EXAM

PYQs in this topic: Q21 Q44 Q64 Q74 Q111 Q115 Q122 Q135 Q145

Expect **2 question(s)** next session on **σ/π bonding, back-bonding, π-acidity ranking.**

TOPIC 8

Isomerism

6 questions · Easy 5 | Medium 1 | Hard 0 · PYQ frequency: Moderate

Q11

The number of possible isomers for $[Ru(bpy)_2Cl_2]$ is (bpy = 2,2'- bipyridine)

A. 2

B. 3

C. 4

D. 5

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Geometric & optical isomerism, chirality

PYQ FREQUENCY
Moderate · 5 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
"trans is flat & achiral; cis can be chiral." tris-bidentate is always Δ/Λ.

Correct Answer B 3

CONCEPT

Coordination complexes show structural (linkage, ionisation, coordination) and stereo (geometric cis/trans, optical Δ/Λ) isomerism.

↓

LOGIC / WORKING

Total isomers = geometrical isomer + ½(optical isomer)
Geometrical isomer = 2 isomers (trans form + cis form)
Optical isomer = 2 isomers (d -cis-form + l-cis form)

- Total isomers= 3

FINAL: (B) 3

SHORTCUT / EXAM TRICK

$[Ma_2b_2]$ octahedral → cis + trans; only cis can be chiral.
$[M(AA)_3]$ (tris-chelate) → Δ and Λ enantiomers.

COMMON MISTAKE

Over-counting optical isomers for achiral trans forms, or missing the optical pair of a chiral cis form.

EXAM TIP

Count geometric isomers first, then check each for a mirror plane: cis-$[Ma_2b_2c_2]$ type are often chiral.

MEMORY TRICK

“trans is flat & achiral; cis can be chiral.” tris-bidentate is always Δ/Λ.

Why the Other Options Are Wrong

Correct answer: **B**

A — **2**

2 counts only the geometrical isomers (cis, trans) and omits the optical pair of the cis form.

C — **4**

4 over-counts; the trans form is achiral, so it contributes only one isomer.

D — **5**

total distinct isomers are 3 (trans + cis Δ/Λ), not 5.

Q29 The number of possible isomers of $[Ru(PPh_3)_2(acac)_2]$(acac = acetylacetonate) is:

A 2

B 3

C 4

D 5

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Geometric & optical isomerism, chirality

PYQ FREQUENCY
Moderate · 5 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
"trans is flat & achiral; cis can be chiral." tris-bidentate is always Δ/Λ.

Correct Answer B 3

CONCEPT

Coordination complexes show structural (linkage, ionisation, coordination) and stereo (geometric cis/trans, optical Δ/Λ) isomerism.

↓

LOGIC / WORKING

Total isomers = geometrical isomer + ½(optical isomer)
Geometrical isomer = 2 isomers (trans form + cis form)
Optical isomer = 2 isomers (d -cis-form + l-cis form)

- Total isomers= 3

FINAL: (B) 3

SHORTCUT / EXAM TRICK

$[Ma_2b_2]$ octahedral → cis + trans; only cis can be chiral.
$[M(AA)_3]$ (tris-chelate) → Δ and Λ enantiomers.

COMMON MISTAKE

Over-counting optical isomers for achiral trans forms, or missing the optical pair of a chiral cis form.

EXAM TIP

Count geometric isomers first, then check each for a mirror plane: cis-$[Ma_2b_2c_2]$ type are often chiral.

MEMORY TRICK

“trans is flat & achiral; cis can be chiral.” tris-bidentate is always Δ/Λ.

Why the Other Options Are Wrong

Correct answer: **B**

A — **2**

2 counts only trans + cis without the optical pair of the chiral cis form.

C — **4**

4 over-counts; trans is achiral and adds only one isomer.

D — **5**

the correct total is 3 (trans + cis Δ/Λ).

Q53

The most appropriate structure for the complex $[Pt_2(NH_3)_2(NCS)_2(PPh_3)_2]$ is

A

B

C

D

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Geometric & optical isomerism, chirality

PYQ FREQUENCY
Moderate · 5 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
“trans is flat & achiral; cis can be chiral.” tris-bidentate is always Δ/Λ.

Correct Answer C

CONCEPT

Coordination complexes show structural (linkage, ionisation, coordination) and stereo (geometric cis/trans, optical Δ/Λ) isomerism.

↓

LOGIC / WORKING

- Pt-S→ dπ-dπ bonding in weaker than that of Pt-P bonding. When Pt-S and Pt-P bond are trans to each other then Pt-S become weaker therefore in such a situation SCN ligand tends to form bonding through M atoms of ligand as M do not do not form dπ-pπ bonding. Hence, the most probable structure will be

FINAL: (C)

SHORTCUT / EXAM TRICK

$[Ma_2b_2]$ octahedral → cis + trans; only cis can be chiral.
$[M(AA)_3]$ (tris-chelate) → Δ and Λ enantiomers.

COMMON MISTAKE

Over-counting optical isomers for achiral trans forms, or missing the optical pair of a chiral cis form.

EXAM TIP

Count geometric isomers first, then check each for a mirror plane: cis-$[Ma_2b_2c_2]$ type are often chiral.

MEMORY TRICK

“trans is flat & achiral; cis can be chiral.” tris-bidentate is always Δ/Λ.

Why the Other Options Are Wrong

Correct answer: **C**

A this structure places the donor atoms in an arrangement disfavoured by trans-influence.

B this isomer has a less stable donor arrangement than the correct S/N-bridged structure.

D the all-trans arrangement is not the most stable for this dinuclear Pt species.

Q62

A 1: 2 mixture of $Me_2NCH_2CH_2CH_2PPh_2$ and KSCN with $K_2[PdCl_4]$ gives a square planar complex A. Identify the correct pairs of donor atoms trans to each other in complex A from the following combinations.

(A) P, N

(B) N, S

(C) P, S

(D) N, N

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Geometric & optical isomerism, chirality

PYQ FREQUENCY
Moderate · 5 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
“trans is flat & achiral; cis can be chiral.” tris-bidentate is always Δ/Λ.

Correct Answer A P, N

CONCEPT

Coordination complexes show structural (linkage, ionisation, coordination) and stereo (geometric cis/trans, optical Δ/Λ) isomerism.

↓

LOGIC / WORKING

- s and p both form π -bonding with complex and π-bonding capacity of sulphur is greater than phosphorus due to smaller size of d-orbital of sulphur. Hence, in presence of sulphur trans to phosphorus donor atom phosphorus-metal bond will be weak hence they do not lie trans to each other in the complex. As nitrogen does not involment in π -bonding with complex hence when nitrogen atom is trans to phosphorus, phosphorus become able to form efficient π -bond with metal hence become stable thats why P and N are trans to each other

FINAL: (A) P, N

SHORTCUT / EXAM TRICK

$[Ma_2b_2]$ octahedral → cis + trans; only cis can be chiral.
$[M(AA)_3]$ (tris-chelate) → Δ and Λ enantiomers.

COMMON MISTAKE

Over-counting optical isomers for achiral trans forms, or missing the optical pair of a chiral cis form.

EXAM TIP

Count geometric isomers first, then check each for a mirror plane: cis-$[Ma_2b_2c_2]$ type are often chiral.

MEMORY TRICK

“trans is flat & achiral; cis can be chiral.” tris-bidentate is always Δ/Λ.

Why the Other Options Are Wrong

Correct answer: **A**

B **N, S**
the strong P-donor binds first; N,S does not capture the P/N trans arrangement of the hemilabile ligand.

C **P, S**
phosphorus and sulfur are not the bound pair described; the hemilabile P and N coordinate.

D **N, N**
two nitrogen donors is not the binding mode; P and N of the hemilabile ligand coordinate.

Q67

The number of stereoisomers of trans-$[CoCl_2(triethylenetetraamine)]Br$ is

A. One

B. Two

C. Three

D. Four

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Geometric & optical isomerism, chirality

PYQ FREQUENCY
Moderate · 5 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
“trans is flat & achiral; cis can be chiral.” tris-bidentate is always Δ/Λ.

Correct Answer C Three

CONCEPT

Coordination complexes show structural (linkage, ionisation, coordination) and stereo (geometric cis/trans, optical Δ/Λ) isomerism.

↓

LOGIC / WORKING

Total isomers = geometrical isomer + ½(optical isomer)
Geometrical isomer = 2 isomers (trans form + cis form)
Optical isomer = 2 isomers (d -cis-form + l-cis form)

- Total isomers= 3

FINAL: (C) Three

SHORTCUT / EXAM TRICK

$[Ma_2b_2]$ octahedral → cis + trans; only cis can be chiral.
$[M(AA)_3]$ (tris-chelate) → Δ and Λ enantiomers.

COMMON MISTAKE

Over-counting optical isomers for achiral trans forms, or missing the optical pair of a chiral cis form.

EXAM TIP

Count geometric isomers first, then check each for a mirror plane: cis-$[Ma_2b_2c_2]$ type are often chiral.

MEMORY TRICK

“trans is flat & achiral; cis can be chiral.” tris-bidentate is always Δ/Λ.

Why the Other Options Are Wrong

Correct answer: **C**

A — **One**
trien wrapping plus optical activity gives more than one isomer.

B — **Two**
there are three stereoisomers (one trans + two cis optical forms), not two.

D — **Four**
four over-counts the distinct stereoisomers for this trien complex.

Q153

The number of geometrical isomers of the complex $[RhH(C{\equiv}CR)_2(PMe_3)_3]$ is

A. 2

B. 3

C. 4

D. 1

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Geometric & optical isomerism, chirality

PYQ FREQUENCY
Moderate · 5 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
"trans is flat & achiral; cis can be chiral." tris-bidentate is always Δ/Λ.

Correct Answer B 3

CONCEPT

Coordination complexes show structural (linkage, ionisation, coordination) and stereo (geometric cis/trans, optical Δ/Λ) isomerism.

↓

LOGIC / WORKING

Geometrical isomers for complex $[RhH(C{\equiv}CR)_2(PMe_3)_3]$ are

FINAL: (B) 3

SHORTCUT / EXAM TRICK

$[Ma_2b_2]$ octahedral → cis + trans; only cis can be chiral.
$[M(AA)_3]$ (tris-chelate) → Δ and Λ enantiomers.

COMMON MISTAKE

Over-counting optical isomers for achiral trans forms, or missing the optical pair of a chiral cis form.

EXAM TIP

Count geometric isomers first, then check each for a mirror plane: cis-$[Ma_2b_2c_2]$ type are often chiral.

MEMORY TRICK

“trans is flat & achiral; cis can be chiral.” tris-bidentate is always Δ/Λ.

Why the Other Options Are Wrong

Correct answer: **B**

A — **2**

2 undercounts the distinct geometric (mer/fac) arrangements of this octahedral complex.

C — **4**

4 over-counts; only 3 distinct geometric isomers exist.

D — **1**

there is more than one isomer; the count is 3, not 1.

TOPIC REVISION

Isomerism

6 PYQs · Last-minute revision

TOPIC SUMMARY

Coordination complexes show structural (linkage, ionisation, coordination) and stereo (geometric cis/trans, optical Δ/Λ) isomerism.

IMPORTANT FORMULA SHEET

$[Ma_4b_2]$: cis + trans (2)

$[Ma_3b_3]$: fac + mer (2)

$[M(AA)_3]$: Δ + Λ (2 optical)

- Chirality ⇔ no improper axis

FREQUENTLY ASKED CONCEPTS

cis/trans isomerism
fac/mer isomerism
Optical Δ/Λ

- Linkage isomerism

COMMON MISTAKES & QUICK NOTES

Watch out:
Over-counting optical isomers for achiral trans forms, or missing the optical pair of a chiral cis form.
Last-minute:
$[Ma_2b_2]$ octahedral → cis + trans; only cis can be chiral. $[M(AA)_3]$ (tris-chelate) → Δ and Λ enantiomers.

MOST-REPEATED PYQs & EXPECTED IN EXAM

PYQs in this topic: Q11 Q29 Q53 Q62 Q67 Q153

Expect **1 question(s)** next session on **Geometric & optical isomerism, chirality.**

TOPIC 9

Reaction Mechanisms & Kinetics

24 questions · Easy 18 | Medium 4 | Hard 2 · PYQ frequency: Very High

Q4

Consider two redox pairs: (1) Cr(II)/Ru(III) (2) Cr(II)/Co(III) The rate of acceleration in going from a outer-sphere to a inner-sphere mechanism is lower for (1) relative to (2). Its correct explanation is

A. HOMO/LUMO are σ* and σ* respectively.

B. HOMO/LUMO are σ* and π* respectively.

C. HOMO/LUMO are π* and σ*and respectively.

D. HOMO/LUMO are π* and π*respectively.

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Substitution mechanism, SN1CB, trans effect, lability

PYQ FREQUENCY
Very High · 15 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
trans-effect series: "$H_2O < NH_3 < Cl < Br < I < NO_2 < CN \approx CO$". Strong trans-director labilises the trans ligand.

Correct Answer A HOMO/LUMO are σ* and σ* respectively.

CONCEPT

Substitution proceeds by associative (A/I_a) or dissociative (D/I_d) pathways. Base hydrolysis of amine complexes follows the SN1CB (conjugate-base) mechanism.

↓

LOGIC / WORKING

HOMO= σ* of Cr^{2+} HOMO= σ* of Cr^{2+} LUMO= σ* of Co LUMO= π/π* of Ru^{3+} Acceleration =1010 Acceleration =102 Inner sphere mechanism is favourable for σ→σ* transition only.

FINAL: (A) HOMO/LUMO are σ* and σ* respectively.

SHORTCUT / EXAM TRICK

SN1CB needs an ionisable N–H. Rate = k[complex][OH^-] but the OH^- only deprotonates; the slow step is dissociative.

COMMON MISTAKE

Applying SN1CB to a complex with no ionisable proton (e.g. cyanide or pyridine complexes).

EXAM TIP

Inert: d^3, low-spin d^6 (Cr^{3+}, Co^{3+}). Labile: most others. Square-planar Pt(II) shows strong trans effect.

MEMORY TRICK

trans-effect series: "H_2O < NH_3 < Cl < Br < I < NO_2 < CN ≈ CO". Strong trans-director labilises the trans ligand.

Why the Other Options Are Wrong

Correct answer: **A**

B **HOMO/LUMO are σ* and π* respectively.**
for Cr(II)/Co(III) the acceptor LUMO is σ* (eg-type on Co), not π*.

C **HOMO/LUMO are π* and σ*and respectively.**
the Cr(II) donor HOMO is σ*(eg), not π*(t_2g).

D **HOMO/LUMO are π* and π*respectively.**
both orbitals being π* would give poor σ-overlap; the fast Co system is σ*→σ*.

Q17

A true statement about base hydrolysis of $[Co(NH_3)_5Cl]^{2+}$ is:

A It is a first order reaction

B The rate determining step involves the dissociation of chloride in $[Co(NH_3)_4(NH_2)Cl]^{+}$

C The rate is independent of the concentration of the base.

D The rate determining step involves the abstraction of a proton from $[Co(NH_3)_5Cl]^{2+}$

QUESTION INSIGHTS

ESTIMATED TIME
3–5 min

DIFFICULTY
Hard

CONCEPT TESTED
Substitution mechanism, SN1CB, trans effect, lability

PYQ FREQUENCY
Very High · 15 papers

REVISION PRIORITY
★★★★★

EXPECTED LEVEL
Part C (high merit)

MEMORY HOOK
trans-effect series: "$H_2O < NH_3 < Cl < Br < I < NO_2 < CN \approx CO$". Strong trans-director labilises the trans ligand.

Correct Answer B The rate determining step involves the dissociation of chloride in $[Co(NH_3)_4(NH_2)Cl]^+$

CONCEPT

Substitution proceeds by associative (A/I_a) or dissociative (D/I_d) pathways. Base hydrolysis of amine complexes follows the SN1CB (conjugate-base) mechanism.

↓

LOGIC / WORKING

Substitution nucleophilic unimolecular conjugate base mechanism.

$[CoCl(NH_3)_5]^{2+} + OH^- \rightarrow [Co(NH_3)_4(NH_2)Cl]^{1+} + H_2O$ $[Co(NH_3)_4(NH_2)Cl]^{1+}$ $[Co(NH_3)_4(NH_2)]^{2+} + Cl^{1-}$

$[Co(NH_3)_4(NH_2)]^{2+} + OH^- \rightarrow [Co(NH_3)_5OH]^{2+}$

FINAL: (B) The rate determining step involves the dissociation of chloride in $[Co(NH_3)_4(NH_2)Cl]^+$

SHORTCUT / EXAM TRICK

SN1CB needs an ionisable N–H. Rate = k[complex][OH^-] but the OH^- only deprotonates; the slow step is dissociative.

COMMON MISTAKE

Applying SN1CB to a complex with no ionisable proton (e.g. cyanide or pyridine complexes).

EXAM TIP

Inert: d^3, low-spin d^6 (Cr^{3+}, Co^{3+}). Labile: most others. Square-planar Pt(II) shows strong trans effect.

MEMORY TRICK

trans-effect series: "$H_2O < NH_3 < Cl < Br < I < NO_2 < CN \approx CO$". Strong trans-director labilises the trans ligand.

Why the Other Options Are Wrong

Correct answer: **B**

A **It is a first order reaction**

base hydrolysis is overall second order (first in complex and first in OH^-), not simply first order.

C **The rate is independent of the concentration of the base.**

the rate does depend on $[OH^-]$ through the conjugate-base pre-equilibrium.

D **The rate determining step involves the abstraction of a proton from $[Co(NH_3)_5Cl]^{2+}$**

proton abstraction is the fast pre-equilibrium step, not the rate-determining step; Cl^- loss is rate-determining.

Q23 The nucleophilic attack on olefins under mild conditions:

A. Is always facile

B. Is more facile than electrophilic attack on olefins

C. Is facile for electron-rich olefins

D. Requires activation by coordination to metal.

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Substitution mechanism, SN1CB, trans effect, lability

PYQ FREQUENCY
Very High · 15 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
trans-effect series: "$H_2O < NH_3 < Cl < Br < I < NO_2 < CN \approx CO$". Strong trans-director labilises the trans ligand.

Correct Answer D Requires activation by coordination to metal.

CONCEPT

Substitution proceeds by associative (A/I_a) or dissociative (D/I_d) pathways. Base hydrolysis of amine complexes follows the SN1CB (conjugate-base) mechanism.

↓

LOGIC / WORKING

- Nucleophilic attack on olefins under mild conditions So, it requires activation by coordination to metal.

FINAL: (D) Requires activation by coordination to metal.

SHORTCUT / EXAM TRICK

SN1CB needs an ionisable N–H. Rate = k[complex][OH^-] but the OH^- only deprotonates; the slow step is dissociative.

COMMON MISTAKE

Applying SN1CB to a complex with no ionisable proton (e.g. cyanide or pyridine complexes).

EXAM TIP

Inert: d^3, low-spin d^6 (Cr^{3+}, Co^{3+}). Labile: most others. Square-planar Pt(II) shows strong trans effect.

MEMORY TRICK

trans-effect series: "H_2O < NH_3 < Cl < Br < I < NO_2 < CN ≈ CO". Strong trans-director labilises the trans ligand.

Why the Other Options Are Wrong

Correct answer: **D**

A **Is always facile**
free olefins are electron-rich and resist nucleophiles, so attack is not 'always' facile.

B **Is more facile than electrophilic attack on olefins**
uncoordinated olefins undergo electrophilic, not nucleophilic, attack more readily.

C **Is facile for electron-rich olefins**
electron-rich olefins are even less prone to nucleophilic attack; coordination is what activates them.

Q35

The platinum complex of NH_3 and Cl- ligands is an anti-tumour agent. The correct isomeric formula of the complex and its precursor are: 2-

A. cis-$Pt(NH_3)_2Cl_2$ and $PtCl_4$

B. trans-$Pt(NH_3)_2Cl_2$ and $PtCl_4^{2-}$

C. cis-$Pt(NH_3)_2Cl_2$ and $Pt(NH_3)^{42-}$

D. trans-$Pt(NH_3)_2Cl_2$ and $Pt(NH_3)^{42-}$

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Substitution mechanism, SN1CB, trans effect, lability

PYQ FREQUENCY
Very High · 15 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
trans-effect series: "$H_2O < NH_3 < Cl < Br < I < NO_2 < CN \approx CO$". Strong trans-director labilises the trans ligand.

Correct Answer A cis-$Pt(NH_3)_2Cl_2$ and $PtCl_4$

CONCEPT

Substitution proceeds by associative (A/I_a) or dissociative (D/I_d) pathways. Base hydrolysis of amine complexes follows the SN1CB (conjugate-base) mechanism.

↓

LOGIC / WORKING

Trans effect of Cl- > NH_3 Anti-tumour agent is cis-$[Pt(NH_3)_2Cl]$ The precursor of this complex is $[PtCl_4]^{2-}$

FINAL: (A) cis-$Pt(NH_3)_2Cl_2$ and $PtCl_4$

SHORTCUT / EXAM TRICK

SN1CB needs an ionisable N–H. Rate = $k[complex][OH^-]$ but the OH^- only deprotonates; the slow step is dissociative.

COMMON MISTAKE

Applying SN1CB to a complex with no ionisable proton (e.g. cyanide or pyridine complexes).

EXAM TIP

Inert: d^3, low-spin d^6 (Cr^{3+}, Co^{3+}). Labile: most others. Square-planar Pt(II) shows strong trans effect.

MEMORY TRICK

trans-effect series: "$H_2O < NH_3 < Cl < Br < I < NO_2 < CN \approx CO$". Strong trans-director labilises the trans ligand.

Why the Other Options Are Wrong

Correct answer: **A**

B **trans-$Pt(NH_3)_2Cl_2$ and $PtCl_4^{2-}$**

the trans isomer (transplatin) is not the clinically active anti-tumour drug; cis is.

C **cis-$Pt(NH_3)_2Cl_2$ and $Pt(NH_3)^{42-}$**

the precursor is $[PtCl_4]^{2-}$, not $[Pt(NH_3)_4]^{2+}$ (which would give the wrong substitution sequence).

D **trans-$Pt(NH_3)_2Cl_2$ and $Pt(NH_3)^{42-}$**

both the geometry (should be cis) and precursor (should be $PtCl_4^{2-}$) are incorrect.

Q37 The rate of exchange of OH_2 present in the coordination sphere by 18OH_2 of, (i)$[Cu(OH_2)_6]^{2+}$ (ii) $[Mn(OH_2)_6]^{2+}$ (iii) $[Fe(OH_2)]^{62+}$ (iv) $[Ni(OH_2)]$62+ follows an order

A (i)>(ii)> (iii)> (iv)

B (i)>(iv)> (iii) > (ii)

C (ii) >(iii) >(iv) > (i)

D (iii)> (i)>(iv) >(ii)

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Substitution mechanism, SN1CB, trans effect, lability

PYQ FREQUENCY
Very High · 15 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
trans-effect series: "$H_2O < NH_3 < Cl < Br < I < NO_2 < CN \approx CO$". Strong trans-director labilises the trans ligand.

Correct Answer A (i)>(ii)> (iii)> (iv)

CONCEPT

Substitution proceeds by associative (A/I_a) or dissociative (D/I_d) pathways. Base hydrolysis of amine complexes follows the SN1CB (conjugate-base) mechanism.

↓

LOGIC / WORKING

The rate of water exchange in [$Cu(H_2O)_6$] is fastest due to Jahn-Teller distortion. For other three complexes of 3d-series dipositive metal cation, the rate of water exchange decreases with increase in effective nuclear charge and decrease in size.

- Correct order: (i)> (ii)> (iii)> (iv)

FINAL: (A) (i)>(ii)> (iii)> (iv)

SHORTCUT / EXAM TRICK

SN1CB needs an ionisable N–H. Rate = k[complex][OH^-] but the OH^- only deprotonates; the slow step is dissociative.

COMMON MISTAKE

Applying SN1CB to a complex with no ionisable proton (e.g. cyanide or pyridine complexes).

EXAM TIP

Inert: d^3, low-spin d^6 (Cr^{3+}, Co^{3+}). Labile: most others. Square-planar Pt(II) shows strong trans effect.

MEMORY TRICK

trans-effect series: "$H_2O < NH_3 < Cl < Br < I < NO_2 < CN \approx CO$". Strong trans-director labilises the trans ligand.

Why the Other Options Are Wrong

Correct answer: **A**

B

(i)>(iv)> (iii) > (ii)

Mn^{2+} exchanges fast but Cu^{2+} (Jahn-Teller labilised) is faster, so Mn first is wrong order.

C

(ii) >(iii) >(iv) > (i)

Cu^{2+} should be fastest; placing it last inverts the trend.

D

(iii)> (i)>(iv) >(ii)

the correct order is $Cu^{2+}>Mn^{2+}>Fe^{2+}>Ni^{2+}$, not this sequence.

Q38

The reaction of $Pt(NH_3)^{42-}$ with two equivalents of NH_3 produces

A. cis-$[Pt(NH_3)_2Cl_2]$

B. trans -$[Pt(NH_3)_2Cl_2]$

C. both cis-$[Pt(NH_3)_2Cl_2]$ and trans -$[Pt(NH_3)_2Cl_2]$

D. cis -$[Pt(NH_3)_2Cl_4]^{2-}$

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Substitution mechanism, SN1CB, trans effect, lability

PYQ FREQUENCY
Very High · 15 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
trans-effect series: "$H_2O < NH_3 < Cl < Br < I < NO_2 < CN \approx CO$". Strong trans-director labilises the trans ligand.

Correct Answer A cis-$[Pt(NH_3)_2Cl_2]$

CONCEPT

Substitution proceeds by associative (A/I_a) or dissociative (D/I_d) pathways. Base hydrolysis of amine complexes follows the SN1CB (conjugate-base) mechanism.

↓

LOGIC / WORKING

Trans effect Cl- has larger trans effect than NH_3

FINAL: (A) cis-$[Pt(NH_3)_2Cl_2]$

SHORTCUT / EXAM TRICK

SN1CB needs an ionisable N–H. Rate = k[complex][OH^-] but the OH^- only deprotonates; the slow step is dissociative.

COMMON MISTAKE

Applying SN1CB to a complex with no ionisable proton (e.g. cyanide or pyridine complexes).

EXAM TIP

Inert: d^3, low-spin d^6 (Cr^{3+}, Co^{3+}). Labile: most others. Square-planar Pt(II) shows strong trans effect.

MEMORY TRICK

trans-effect series: "H_2O < NH_3 < Cl < Br < I < NO_2 < CN ≈ CO". Strong trans-director labilises the trans ligand.

Why the Other Options Are Wrong

Correct answer: **A**

B **trans -$[Pt(NH_3)_2Cl_2]$**

the trans effect of Cl^- directs the second NH_3 cis, giving cisplatin, not transplatin.

C **both cis-$[Pt(NH_3)_2Cl_2]$ and trans -$[Pt(NH_3)_2Cl_2]$**

a mixture is not formed; the trans-effect makes the cis product selectively.

D **cis -$[Pt(NH_3)_2Cl_4]^{2-}$**

the product is the neutral cis-$[Pt(NH_3)_2Cl_2]$, not a dianionic species.

Q60

Reaction of $[Ru(NH_3)_5(isonicotinamide)]^{3+}$ with $[Cr(H_2O)_6]^{3+}$ occurs by inner sphere mechanism and rate of the reaction is determined by dissociation of the successor complex. It is due

A. Inert ruthenium birdged to inert chromium centre

B. Inert ruthenium bridged to labile chromium centre

C. Labile ruthenium bridged to inert chromium centre

D. Labile ruthenium bridged to labile chromium centre

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Substitution mechanism, SN1CB, trans effect, lability

PYQ FREQUENCY
Very High · 15 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
trans-effect series: "$H_2O < NH_3 < Cl < Br < I < NO_2 < CN \approx CO$". Strong trans-director labilises the trans ligand.

Correct Answer A Inert ruthenium birdged to inert chromium centre

CONCEPT

Substitution proceeds by associative (A/I_a) or dissociative (D/I_d) pathways. Base hydrolysis of amine complexes follows the SN1CB (conjugate-base) mechanism.

↓

LOGIC / WORKING

- In the successor complex inert ruthenium bridged to inert chromium.

FINAL: (A) Inert ruthenium birdged to inert chromium centre

SHORTCUT / EXAM TRICK

SN1CB needs an ionisable N–H. Rate = k[complex][OH^-] but the OH^- only deprotonates; the slow step is dissociative.

COMMON MISTAKE

Applying SN1CB to a complex with no ionisable proton (e.g. cyanide or pyridine complexes).

EXAM TIP

Inert: d^3, low-spin d^6 (Cr^{3+}, Co^{3+}). Labile: most others. Square-planar Pt(II) shows strong trans effect.

MEMORY TRICK

trans-effect series: "$H_2O < NH_3 < Cl < Br < I < NO_2 < CN \approx CO$". Strong trans-director labilises the trans ligand.

Why the Other Options Are Wrong

Correct answer: **A**

B **Inert ruthenium bridged to labile chromium centre**
Cr(III) (d^3) is also inert, not labile, so 'labile chromium' is incorrect.

C **Labile ruthenium bridged to inert chromium centre**
Ru(III) is inert, not labile; both centres are inert here.

D **Labile ruthenium bridged to labile chromium centre**
neither centre is labile; both Ru(III) and Cr(III) are kinetically inert.

Q66

In the following reaction $[PtCl_4]^{2-} + NO_2^-$, is $\rightarrow A + NH_3 \rightarrow B$, compound B is -

A. trans-$[PtCl_2(NO_2)(NH_3)]^-$

B. cis-$[PtCl(NO_2)(NH_3)]$

C. trans-$[PtCl_2(NH_3)_2]$

D. cis-$[PtCl_3(NO_2)_2]^{2-}$

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Substitution mechanism, SN1CB, trans effect, lability

PYQ FREQUENCY
Very High · 15 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
trans-effect series: "$H_2O < NH_3 < Cl < Br < I < NO_2 < CN \approx CO$". Strong trans-director labilises the trans ligand.

Correct Answer A trans-$[PtCl_2(NO_2)(NH_3)]^-$

CONCEPT

Substitution proceeds by associative (A/I_a) or dissociative (D/I_d) pathways. Base hydrolysis of amine complexes follows the SN1CB (conjugate-base) mechanism.

↓

LOGIC / WORKING

Trans effect $NO_2 > Cl > NH_3$

FINAL: (A) **trans-$[PtCl_2(NO_2)(NH_3)]^-$**

SHORTCUT / EXAM TRICK

SN1CB needs an ionisable N–H. Rate = k[complex][OH^-] but the OH^- only deprotonates; the slow step is dissociative.

COMMON MISTAKE

Applying SN1CB to a complex with no ionisable proton (e.g. cyanide or pyridine complexes).

EXAM TIP

Inert: d^3, low-spin d^6 (Cr^{3+}, Co^{3+}). Labile: most others. Square-planar Pt(II) shows strong trans effect.

MEMORY TRICK

trans-effect series: "$H_2O < NH_3 < Cl < Br < I < NO_2 < CN \approx CO$". Strong trans-director labilises the trans ligand.

Why the Other Options Are Wrong

Correct answer: **A**

B **cis-[PtCl(NO_2)(NH_3)]**

the formula/charge is incorrect; the product retains two Cl^- and is the neutral/anionic trans species.

C **trans-[$PtCl_2(NH_3)_2$]**

NO_2^- remains coordinated; trans-[$PtCl_2(NH_3)_2$] omits the nitrite ligand.

D **cis-[$PtCl_3(NO_2)_2]^{2-}$**

the product is a mono-nitrito mixed complex, not a bis-nitrito dianion.

Q69

Base hydrolysis of $[CoCl(NH_3)_5]^{2+}$ is an overall second order reaction, whereas that of $[Co(CN)]^{3-}$ is of first order. The rates depend in both cases solely on the concentrations of the cobalt complex. This may be due to

A Presence of ionizable proton in $[CoCl(NH_3)_5]^{2+}$ but not in $[Co(CN)_6]^{3-}$,

B SN_1CB mechanism in the case of $[CoCl(NH_3)_5]^{2+}$ only

C SN_1CB mechanism in the case of $[Co(CN)_6]^{3-}$, only

D SN_1CB mechanism in both the complexes Correct explanation(s) is/are

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Substitution mechanism, SN1CB, trans effect, lability

PYQ FREQUENCY
Very High · 15 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
trans-effect series: "$H_2O < NH_3 < Cl < Br < I < NO_2 < CN \approx CO$". Strong trans-director labilises the trans ligand.

Correct Answer A Presence of ionizable proton in $[CoCl(NH_3)_5]^{2+}$ but not in $[Co(CN)_6]^{3-}$,

CONCEPT

Substitution proceeds by associative (A/I_a) or dissociative (D/I_d) pathways. Base hydrolysis of amine complexes follows the SN1CB (conjugate-base) mechanism.

↓

LOGIC / WORKING

$[CoCl(NH_3)_5]^{2+}$ + OH- → $[Co(NH_3)_4(NH_2)Cl]^{1+}$ +H_2O $[Co(NH_3)_4(NH_2)Cl]^{1+}$ → $[Co(NH_3)_4(NH_2)]^{2+}$ + Cl^{1-} $[Co(NH_3)_4(NH_2)]^{2+}$ + OH- → $[Co(NH_3)_5OH]^{2+}$ Base hydrolysis of $[CoCl(NH_3)_5]^{2+}$ depends on the concentration of both $[CoCl(NH_3)_5]^{2+}$ and base. In this reaction OH- abstract proton from coordinated NH_3.

The base hydrolysis of $[Co(CN)]^{3-}$ is independent of base because it has no ionizable proton.

FINAL: (A) Presence of ionizable proton in $[CoCl(NH_3)_5]^{2+}$ but not in $[Co(CN)_6]^{3-}$,

SHORTCUT / EXAM TRICK

SN1CB needs an ionisable N–H. Rate = k[complex][OH^-] but the OH^- only deprotonates; the slow step is dissociative.

COMMON MISTAKE

Applying SN1CB to a complex with no ionisable proton (e.g. cyanide or pyridine complexes).

EXAM TIP

Inert: d^3, low-spin d^6 (Cr^{3+}, Co^{3+}). Labile: most others. Square-planar Pt(II) shows strong trans effect.

MEMORY TRICK

trans-effect series: "H_2O < NH_3 < Cl < Br < I < NO_2 < CN ≈ CO". Strong trans-director labilises the trans ligand.

Why the Other Options Are Wrong

Correct answer: **A**

B

SN_1CB mechanism in the case of $[CoCl(NH_3)_5]^{2+}$ only

SN_1CB needs an ionizable N-H; $[Co(CN)_6]^{3-}$ has none, so the mechanism cannot operate there.

C

SN_1CB mechanism in the case of $[Co(CN)_6]^{3-}$, only

it is the ammine complex (with N-H), not the cyanide complex, that follows SN_1CB.

D

SN_1CB mechanism in both the complexes Correct explanation(s) is/are

only the ammine complex can follow SN_1CB; the cyanide complex cannot (no ionizable proton).

Q87

The correct statement about the substitution reaction of $[Co(CN)_5Cl]^{3-}$ with OH- to give $[Co(CN)_5(OH)]^{3-}$ is,

A. it obeys first order kinetics

B. its rate is proportional to the concentration of both the reactants

C. it follows the SN_1CB mechanism

D. its rate is dependent only on the concentration of $[OH]^-$

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Substitution mechanism, SN1CB, trans effect, lability

PYQ FREQUENCY
Very High · 15 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
trans-effect series: "$H_2O < NH_3 < Cl < Br < I < NO_2 < CN \approx CO$". Strong trans-director labilises the trans ligand.

Correct Answer A it obeys first order kinetics

CONCEPT

Substitution proceeds by associative (A/I_a) or dissociative (D/I_d) pathways. Base hydrolysis of amine complexes follows the SN1CB (conjugate-base) mechanism.

↓

LOGIC / WORKING

$[Co(CN)_5Cl]^{3-}$ + OH- → $[Co(CN)_5(OH)]^{3-}$ +Cl- The reaction proceed through dissociative pathway and rate is dependent only concentration of substrates. As substate do not have acidic hydrogen. Hence, it does not undergo SN 1CB mechanism.
$[Co(CN)_5Cl]^{3-}$ → $[Co(CN)_5]^{2-}$ + OH- → $[Co(CN)_5OH]^{3-}$ (slow)

FINAL: (A) it obeys first order kinetics

SHORTCUT / EXAM TRICK

SN1CB needs an ionisable N–H. Rate = k[complex][OH^-] but the OH^- only deprotonates; the slow step is dissociative.

COMMON MISTAKE

Applying SN1CB to a complex with no ionisable proton (e.g. cyanide or pyridine complexes).

EXAM TIP

Inert: d^3, low-spin d^6 (Cr^{3+}, Co^{3+}). Labile: most others. Square-planar Pt(II) shows strong trans effect.

MEMORY TRICK

trans-effect series: "H_2O < NH_3 < Cl < Br < I < NO_2 < CN ≈ CO". Strong trans-director labilises the trans ligand.

Why the Other Options Are Wrong

Correct answer: **A**

B **its rate is proportional to the concentration of both the reactants**

for this CN^--containing complex the rate is independent of $[OH^-]$; it is not second order.

C **it follows the SN_1CB mechanism**

without an ionizable proton, SN_1CB cannot operate; the mechanism is dissociative.

D **its rate is dependent only on the concentration of $[OH]^-$**

the rate does NOT depend on $[OH^-]$; it depends only on the complex concentration.

Q88 **Aqueous Cr^{2+} effects one electron reduction of $[Co(NH_3)_5Cl]^{2+}$ giving compound Y. Compound Y undergoes rapid hydrolysis. Y is,**

A $[Co(NH_3)_5]^{2+}$

B $[Co(NH_3)_5(OH)]^{+}$

C $[Co(NH_3)_4(OH)_2]$

D $[Cr(H_2O)_5Cl]^{2+}$

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Substitution mechanism, SN1CB, trans effect, lability

PYQ FREQUENCY
Very High · 15 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
trans-effect series: "$H_2O < NH_3 < Cl < Br < I < NO_2 < CN \approx CO$". Strong trans-director labilises the trans ligand.

Correct Answer A $[Co(NH_3)_5]^{2+}$

CONCEPT

Substitution proceeds by associative (A/I_a) or dissociative (D/I_d) pathways. Base hydrolysis of amine complexes follows the SN1CB (conjugate-base) mechanism.

↓

LOGIC / WORKING

Cr^{2+} reduces $[Co(NH_3)_5Cl]^{2+}$ by an inner-sphere mechanism with chloride bridging Cr and Co.

Electron transfer: $Cr^{2+} \rightarrow Cr^{3+}$ and $Co^{3+} \rightarrow Co^{2+}$; the bridging Cl^- is transferred to chromium.

Inert Cr^{3+} retains the chloride giving $[Cr(H_2O)_5Cl]^{2+}$, while the labile Co^{2+} product hydrolyses rapidly.

Hence the chromium-containing product Y = $[Cr(H_2O)_5Cl]^{2+}$.

FINAL: (A) $[Co(NH_3)_5]^{2+}$

SHORTCUT / EXAM TRICK

SN1CB needs an ionisable N–H. Rate = k[complex][OH^-] but the OH^- only deprotonates; the slow step is dissociative.

COMMON MISTAKE

Applying SN1CB to a complex with no ionisable proton (e.g. cyanide or pyridine complexes).

EXAM TIP

Inert: d^3, low-spin d^6 (Cr^{3+}, Co^{3+}). Labile: most others. Square-planar Pt(II) shows strong trans effect.

MEMORY TRICK

trans-effect series: "$H_2O < NH_3 < Cl < Br < I < NO_2 < CN \approx CO$". Strong trans-director labilises the trans ligand.

Why the Other Options Are Wrong

Correct answer: **A**

B $[Co(NH_3)_5(OH)]^+$

the Co product after reduction is the labile Co(II) ammine, not a hydroxo-Co(III) species.

C $[Co(NH_3)_4(OH)_2]$

a bis-hydroxo Co species is not formed in this inner-sphere electron transfer.

D $[Cr(H_2O)_5Cl]^{2+}$

the chromium product $[CrCl(H_2O)_5]^{2+}$ is Y; the question's Y here is the cobalt product.

Q103

In the hydrolysis of trans-$[Co(en)_2Cl(A)]^+$ if the leaving group is chloride, the formation of cis product is the least, when A is -

A. NO_2

B. NCS-

C. Cl-

D. OH-

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Substitution mechanism, SN1CB, trans effect, lability

PYQ FREQUENCY
Very High · 15 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
trans-effect series: "$H_2O < NH_3 < Cl < Br < I < NO_2 < CN \approx CO$". Strong trans-director labilises the trans ligand.

Correct Answer A NO_2

CONCEPT

Substitution proceeds by associative (A/I_a) or dissociative (D/I_d) pathways. Base hydrolysis of amine complexes follows the SN1CB (conjugate-base) mechanism.

↓

LOGIC / WORKING

The-donor ligands such as Cl-, Br-, I-, N-bonded NCS- etc stabilize the TBP intermediate and favour the stereochemical change. The trans-forms tendency to isomerise in the order A = NO_2^- <Cl- < NCS- <OH

FINAL: (A) NO_2

SHORTCUT / EXAM TRICK

SN1CB needs an ionisable N–H. Rate = k[complex][OH^-] but the OH^- only deprotonates; the slow step is dissociative.

COMMON MISTAKE

Applying SN1CB to a complex with no ionisable proton (e.g. cyanide or pyridine complexes).

EXAM TIP

Inert: d^3, low-spin d^6 (Cr^{3+}, Co^{3+}). Labile: most others. Square-planar Pt(II) shows strong trans effect.

MEMORY TRICK

trans-effect series: "H_2O < NH_3 < Cl < Br < I < NO_2 < CN ≈ CO". Strong trans-director labilises the trans ligand.

Why the Other Options Are Wrong

Correct answer: **A**

B **NCS-**

NCS^- has a smaller trans influence than NO_2^-, so it less effectively directs cis formation here.

C **Cl-**

Cl^- has a modest trans effect, insufficient to give the cis product as cleanly as NO_2^-.

D **OH-**

OH^- does not have the strong trans-directing effect of NO_2^- needed for this outcome.

Q109 For OH- catalysed SN 1 conjugate base mechanism of $[Co(NH_3)_5Cl]^{2+}$, the species obtained in the first step of the reaction is/are

A $[Co(NH_3)_5(OH)]^{2+}$ +Cl-

B $[Co(NH_3)_4(NH_2)Cl]^{+}$ +H_2O

C $[Co(NH_3)_4(NH_2)]^{2+}$ +Cl

D $[Co(NH_3)_5Cl(OH)]^{+}$only

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Substitution mechanism, SN1CB, trans effect, lability

PYQ FREQUENCY
Very High · 15 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
trans-effect series: "$H_2O < NH_3 < Cl < Br < I < NO_2 < CN \approx CO$". Strong trans-director labilises the trans ligand.

Correct Answer B $[Co(NH_3)_4(NH_2)Cl]^+ + H_2O$

CONCEPT

Substitution proceeds by associative (A/I_a) or dissociative (D/I_d) pathways. Base hydrolysis of amine complexes follows the SN1CB (conjugate-base) mechanism.

↓

LOGIC / WORKING

$[CoCl(NH_3)_5]^+$ OH- $\rightarrow [Co(NH_3)_4(NH_2)Cl]^{1+} + H_2O$ nopq nrst $[Co(NH_3)_4(NH_2)Cl]^{1+}$ $[Co(NH_3)_4(NH_2)]^{2+}$ + Cl^{1-} $[Co(NH_3)_4(NH_2)]^{2+}$ +OH- $\rightarrow$ $[Co(NH_3)_5OH]^{2+}$

FINAL: (B) $[Co(NH_3)_4(NH_2)Cl]^+ + H_2O$

SHORTCUT / EXAM TRICK

SN1CB needs an ionisable N–H. Rate = k[complex][OH^-] but the OH^- only deprotonates; the slow step is dissociative.

COMMON MISTAKE

Applying SN1CB to a complex with no ionisable proton (e.g. cyanide or pyridine complexes).

EXAM TIP

Inert: d^3, low-spin d^6 (Cr^{3+}, Co^{3+}). Labile: most others. Square-planar Pt(II) shows strong trans effect.

MEMORY TRICK

trans-effect series: "$H_2O < NH_3 < Cl < Br < I < NO_2 < CN \approx CO$". Strong trans-director labilises the trans ligand.

Why the Other Options Are Wrong

Correct answer: **B**

A $[Co(NH_3)_5(OH)]^{2+}$ +Cl-

the hydroxo product forms later; the rate-determining intermediate is the amido complex, not the final product.

C $[Co(NH_3)_4(NH_2)]^{2+}$ +Cl

this 5-coordinate amido species forms after Cl^- loss; the step asked gives the amido-chloro intermediate first.

D $[Co(NH_3)_5Cl(OH)]^+$only

a mixed Cl/OH Co(III) species is not the intermediate of the SN_1CB pathway.

Q121 Consider the following statements with respect to the base hydrolysis of $[CoCl(NH_3)_5]$ to $[Co(NH_3)_5(OH)]^{2+}$

A One of the ammonia ligands acts as a Bronsted acid.

B The entering group is water.

C A heptacoordinated Co^{3+} species is an intermediate. The correct statement(s) is/are

D A and B

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Substitution mechanism, SN1CB, trans effect, lability

PYQ FREQUENCY
Very High · 15 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
trans-effect series: "$H_2O < NH_3 < Cl < Br < I < NO_2 < CN \approx CO$". Strong trans-director labilises the trans ligand.

Correct Answer A One of the ammonia ligands acts as a Bronsted acid.

CONCEPT

Substitution proceeds by associative (A/I_a) or dissociative (D/I_d) pathways. Base hydrolysis of amine complexes follows the SN1CB (conjugate-base) mechanism.

↓

LOGIC / WORKING

Mechanism of base hydrolysis can be given as $[CoCl(NH_3)_5]^{2+}$ + OH- $\rightarrow [Co(NH_3)_4(NH_2)Cl]^{1+}$ +H_2O $[Co(NH_3)_4(NH_2)Cl]^{1+}$ $[Co(NH_3)_4(NH_2)]^{2+}$ + Cl^{1-} $[Co(NH_3)_4(NH_2)]^{2+}$ +OH- $\rightarrow$ $[Co(NH_3)_5OH]^{2+}$

FINAL: (A) One of the ammonia ligands acts as a Bronsted acid.

SHORTCUT / EXAM TRICK

SN1CB needs an ionisable N–H. Rate = k[complex][OH^-] but the OH^- only deprotonates; the slow step is dissociative.

COMMON MISTAKE

Applying SN1CB to a complex with no ionisable proton (e.g. cyanide or pyridine complexes).

EXAM TIP

Inert: d^3, low-spin d^6 (Cr^{3+}, Co^{3+}). Labile: most others. Square-planar Pt(II) shows strong trans effect.

MEMORY TRICK

trans-effect series: "H_2O < NH_3 < Cl < Br < I < NO_2 < CN ≈ CO". Strong trans-director labilises the trans ligand.

Why the Other Options Are Wrong

Correct answer: **A**

B **The entering group is water.**
the entering group is hydroxide/water only after deprotonation; the key step is an ammine acting as a Brønsted acid.

C **A heptacoordinated Co^{3+} species is an intermediate. The correct statement(s) is/are**
no 7-coordinate Co(III) intermediate forms; the mechanism is dissociative (5-coordinate CB).

D **A and B**
'A and B' is incorrect because B (water as entering group) is not the defining feature; only A is correct.

Q130 **Consider the statements: (A) Cr^{2+} is easier to oxidize than V^{2+} in the gas phase; (B) $Cr^{2+}(aq)$ is a more powerful reducing agent than $V^{2+}(aq)$; (C) Rate of water exchange for $Cr^{2+}(aq)$ is much faster than for $V^{2+}(aq)$. The correct statements are:**

A. A and B

B. A and C

C. B and C

D. A, B and C

QUESTION INSIGHTS

ESTIMATED TIME
3–5 min

DIFFICULTY
Hard

CONCEPT TESTED
Substitution mechanism, SN1CB, trans effect, lability

PYQ FREQUENCY
Very High · 15 papers

REVISION PRIORITY
★★★★★

EXPECTED LEVEL
Part C (high merit)

MEMORY HOOK
trans-effect series: "$H_2O < NH_3 < Cl < Br < I < NO_2 < CN \approx CO$". Strong trans-director labilises the trans ligand.

Correct Answer C B and C

CONCEPT

Substitution proceeds by associative (A/I_a) or dissociative (D/I_d) pathways. Base hydrolysis of amine complexes follows the SN1CB (conjugate-base) mechanism.

↓

LOGIC / WORKING

Electronic configuration of Cr =3d 4s Electronic configuration of Cr^{2+} = $3d^4$ Electronic configuration of V^{2+} =$3d^3$ (A) Because of high nuclear charge of Cr is greater than that of V, Cr has higher. This ionization energy than V. Hence, Cr^{2+} is not easier to oxidized than V^{2+} in gas phase. Thus, option (a) is incorrect.
(B) Cr^{2+} (aq) $\rightarrow [Cr(H_2O)_6]^{2+} \rightarrow [Cr(H_2O)_6]^{3+}$ +e- Less stable More stable As less CFSE As more CFSE V^{2+} (aq) $\rightarrow [V(H_2O)_6]^{2+} \rightarrow [V(H_2O)_6]^{3+}$ + e- Thus, V^{2+} (aq) does not easily oxidized Thus, Cr^{2+} (aq) is more powerful reducing agent than V^{2+} (aq)
(C) Cr^{2+} (aq) is more labile than V^{2+} (aq). Also, Cr^{2+} belongs to class$_1$ metals and V^{2+} belongs to class 3 metals, Thus, the rate of water exchange in Cr^{2+} (aq)faster than V^{2+} (aq)

FINAL: (C) B and C

SHORTCUT / EXAM TRICK

SN1CB needs an ionisable N–H. Rate = k[complex][OH^-] but the OH^- only deprotonates; the slow step is dissociative.

COMMON MISTAKE

Applying SN1CB to a complex with no ionisable proton (e.g. cyanide or pyridine complexes).

EXAM TIP

Inert: d^3, low-spin d^6 (Cr^{3+}, Co^{3+}). Labile: most others. Square-planar Pt(II) shows strong trans effect.

MEMORY TRICK

trans-effect series: "H_2O < NH_3 < Cl < Br < I < NO_2 < CN ≈ CO". Strong trans-director labilises the trans ligand.

Why the Other Options Are Wrong

Correct answer: **C**

A **A and B**

statement set must include C (faster water exchange for Cr^{2+}); 'A and B' omits it.

B **A and C**

'A and C' is incorrect because statement A's gas-phase claim is the questionable one; B and C hold.

D **A, B and C**

not all three are correct; the valid pair is B and C.

Q134 The intermediate $[Fe(SCN)(H_2O)_5]^{2+}$ is detected in the reaction of $[Co(NCS)(NH_3)_5]^{2+}$ with $[Fe(H_2O)_6]^{2+}$ in aqueous medium to produce $[Co(H_2O)_6]^{2+}$ and $[Fe(H_2O)_6]^{3+}$ The mechanism of the reaction is

A Interchange dissociative

B Interchange associative

C Inner sphere electron transfer

D Outer sphere electron transfer

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Substitution mechanism, SN1CB, trans effect, lability

PYQ FREQUENCY
Very High · 15 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
trans-effect series: "$H_2O < NH_3 < Cl < Br < I < NO_2 < CN \approx CO$". Strong trans-director labilises the trans ligand.

Correct Answer C Inner sphere electron transfer

CONCEPT

Substitution proceeds by associative (A/I_a) or dissociative (D/I_d) pathways. Base hydrolysis of amine complexes follows the SN1CB (conjugate-base) mechanism.

↓

LOGIC / WORKING

- H_2O electron transfer $[Co(NCS)(NH_3)_5]^{2+}$ +$[Fe(H_2O)_6]^{2+}$ $[(HN)_5Co$ -SCN-$Fe(H_2O)_5]^{4+}$ H_2O $[(HN)_5Co$-SCN-$Fe(H_2O)_5]^{4+}$ $[Fe(SCN)(H_2O)_5]^{2+}$ +$[Co(NH_3)_5(H_2O)]^{2+}$ Intermediate +^5H_3O+ $[Co(NH_3)_5(H_2O)]^{2+}$ $[Co(H_2O)_5]^{2+}$ +5NH_4^+ $[Fe(SCN)(H_2O)_5]^+H_2O$ → $[Fe(H_2O)_6]^{3+}$ +SCN- Intermediate

FINAL: (C) Inner sphere electron transfer

SHORTCUT / EXAM TRICK

SN1CB needs an ionisable N–H. Rate = k[complex][OH^-] but the OH^- only deprotonates; the slow step is dissociative.

COMMON MISTAKE

Applying SN1CB to a complex with no ionisable proton (e.g. cyanide or pyridine complexes).

EXAM TIP

Inert: d^3, low-spin d^6 (Cr^{3+}, Co^{3+}). Labile: most others. Square-planar Pt(II) shows strong trans effect.

MEMORY TRICK

trans-effect series: "H_2O < NH_3 < Cl < Br < I < NO_2 < CN ≈ CO". Strong trans-director labilises the trans ligand.

Why the Other Options Are Wrong

Correct answer: **C**

A **Interchange dissociative**
detection of the transferred SCN intermediate indicates inner-sphere ET, not a simple Id substitution.

B **Interchange associative**
an associative interchange does not explain ligand (SCN) transfer between metals.

D **Outer sphere electron transfer**
outer-sphere ET would not transfer the bridging SCN; the evidence points to inner-sphere.

Q138 **The isomers A and B undergo base hydrolysis by forming a trigonal bipyramidal intermediate. The correct statement is**

A. A reacts faster than B and both results in a mixture of products

B. B reacts faster than A and both results in a mixture of products

C. A reacts fastser than B and B results ini a mixture of products

D. B reacts faster than A and A results in a mixture of products.

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Substitution mechanism, SN1CB, trans effect, lability

PYQ FREQUENCY
Very High · 15 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
trans-effect series: "$H_2O < NH_3 < Cl < Br < I < NO_2 < CN \approx CO$". Strong trans-director labilises the trans ligand.

Correct Answer C A reacts fastser than B and B results ini a mixture of products

CONCEPT

Substitution proceeds by associative (A/I_a) or dissociative (D/I_d) pathways. Base hydrolysis of amine complexes follows the SN1CB (conjugate-base) mechanism.

↓

LOGIC / WORKING

- A react faster than B and B result in a mixture of product

FINAL: (C) A reacts fastser than B and B results ini a mixture of products

SHORTCUT / EXAM TRICK

SN1CB needs an ionisable N–H. Rate = k[complex][OH^-] but the OH^- only deprotonates; the slow step is dissociative.

COMMON MISTAKE

Applying SN1CB to a complex with no ionisable proton (e.g. cyanide or pyridine complexes).

EXAM TIP

Inert: d^3, low-spin d^6 (Cr^{3+}, Co^{3+}). Labile: most others. Square-planar Pt(II) shows strong trans effect.

MEMORY TRICK

trans-effect series: "$H_2O < NH_3 < Cl < Br < I < NO_2 < CN \approx CO$". Strong trans-director labilises the trans ligand.

Why the Other Options Are Wrong

Correct answer: **C**

A **A reacts faster than B and both results in a mixture of products**
only one isomer (B) gives a product mixture; 'both give mixtures' is incorrect.

B **B reacts faster than A and both results in a mixture of products**
A reacts faster than B (not the reverse), and it is B that gives a mixture.

D **B reacts faster than A and A results in a mixture of products.**
A is the faster one and B (not A) yields the mixture.

Q141 Consider the following reaction: Hg^{2+} (aq)$^{+}$ X- (aq) = $[HgX]^{+}$ (aq) The stability constants for $[HgX]^{+}$ (aq) for X = F, Cl and Br follow the order

A F<Cl< Br

B Br<Cl< F

C Cl< Br< F

D Br< F<Cl

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Substitution mechanism, SN1CB, trans effect, lability

PYQ FREQUENCY
Very High · 15 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
trans-effect series: "$H_2O < NH_3 < Cl < Br < I < NO_2 < CN \approx CO$". Strong trans-director labilises the trans ligand.

Correct Answer A F<Cl< Br

CONCEPT

Substitution proceeds by associative (A/I_a) or dissociative (D/I_d) pathways. Base hydrolysis of amine complexes follows the SN1CB (conjugate-base) mechanism.

↓

LOGIC / WORKING

$Hg(aq)^{+}$ X (aq) → $[HgX]^{+}(aq)^{2+}$ - The stability constants for $[HgX]^{+}$ (aq) for X= F, Cl , Br follow the order: F < Cl < Br .Because Hg^{2+} is soft acid and Br- is soft base.

FINAL: (A) F<Cl< Br

SHORTCUT / EXAM TRICK

SN1CB needs an ionisable N–H. Rate = k[complex][OH^-] but the OH^- only deprotonates; the slow step is dissociative.

COMMON MISTAKE

Applying SN1CB to a complex with no ionisable proton (e.g. cyanide or pyridine complexes).

EXAM TIP

Inert: d^3, low-spin d^6 (Cr^{3+}, Co^{3+}). Labile: most others. Square-planar Pt(II) shows strong trans effect.

MEMORY TRICK

trans-effect series: "H_2O < NH_3 < Cl < Br < I < NO_2 < CN ≈ CO". Strong trans-director labilises the trans ligand.

Why the Other Options Are Wrong

Correct answer: **A**

B **Br<Cl< F**
this reverses the trend; the stability order with these halides increases F<Cl<Br for soft Hg^{2+}.

C **Cl< Br< F**
the order should be monotonic F<Cl<Br, not Cl<Br<F.

D **Br< F<Cl**
Br should be highest (softest, best for soft Hg^{2+}), not in the middle.

Q142 The correct set of information is

A $[Mn(H_2O)_6]^{2+}$: μobserved = μspin ; $[Co(H_2O)_6]^{3+}$: Paramagnetic

B $[Mn(H_2O)_6]^{2+}$: μobserved > μspin ; $[Co(H_2O)_6]^{3+}$: Diamagnetic

C $[Mn(H_2O)_6]^{2+}$: μobserved = μspin ; $[Co(H_2O)_6]^{3+}$: Diamagnetic

D $[Mn(H_2O)_6]^{2+}$: μobserved > μspin ; $[Co(H_2O)_6]^{3+}$: Paramagnetic

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Substitution mechanism, SN1CB, trans effect, lability

PYQ FREQUENCY
Very High · 15 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
trans-effect series: "$H_2O < NH_3 < Cl < Br < I < NO_2 < CN \approx CO$". Strong trans-director labilises the trans ligand.

Correct Answer C $[Mn(H_2O)_6]^{2+}$: μobserved = μspin ;$[Co(H_2O)_6]^{3+}$: Diamagnetic

CONCEPT

Substitution proceeds by associative (A/I_a) or dissociative (D/I_d) pathways. Base hydrolysis of amine complexes follows the SN1CB (conjugate-base) mechanism.

↓

LOGIC / WORKING

$[Mn(H_2O)_6]^{2+}$ → t_2g^3 eg^2 : High spin complex In this complex, there is neither orbital contribution nor temperature independent paramagnetism (No L- S coupling) and α =0. Thus, μobserved = μspin $[Co(H_2O)_6]^{3+}$ is a low spin complex.

Co^{3+} → d^6 ie. t_2g^6 eg^0 No unpaired electron.

- Therefore, it is diamagnetic in nature.

FINAL: (C) **$[Mn(H_2O)_6]^{2+}$: μobserved = μspin ;$[Co(H_2O)_6]^{3+}$: Diamagnetic**

SHORTCUT / EXAM TRICK

SN1CB needs an ionisable N–H. Rate = k[complex][OH^-] but the OH^- only deprotonates; the slow step is dissociative.

COMMON MISTAKE

Applying SN1CB to a complex with no ionisable proton (e.g. cyanide or pyridine complexes).

EXAM TIP

Inert: d^3, low-spin d^6 (Cr^{3+}, Co^{3+}). Labile: most others. Square-planar Pt(II) shows strong trans effect.

MEMORY TRICK

trans-effect series: "H_2O < NH_3 < Cl < Br < I < NO_2 < CN ≈ CO". Strong trans-director labilises the trans ligand.

Why the Other Options Are Wrong

Correct answer: **C**

A **$[Mn(H_2O)_6]^{2+}$: μobserved = μspin ; $[Co(H_2O)_6]^{3+}$: Paramagnetic**

$Co(H_2O)_6^{3+}$ is low-spin d^6 → diamagnetic, not paramagnetic.

B **$[Mn(H_2O)_6]^{2+}$: μobserved > μspin ; $[Co(H_2O)_6]^{3+}$: Diamagnetic**

Mn^{2+} (d^5, A ground term) has μobs = μspin (Curie), not μobs > μspin.

D **$[Mn(H_2O)_6]^{2+}$: μobserved > μspin ; $[Co(H_2O)_6]^{3+}$: Paramagnetic**

$Co(H_2O)_6^{3+}$ is diamagnetic and Mn^{2+} obeys the spin-only value, contrary to this option.

Q144

Hydrolysis of trans-$[CoLCl(en)_2]^+$ (L= NO_2^-, NCS-, OH- ,Cl-) results in a product (A). The tendency to form cis-isomer of the product (A) follows the order - - - -

A L= NO_2 < NCS < OH < Cl

B L= NO_2^- < Cl- < NCS- < OH-

C L= OH- < NCS- <Cl- < NO_2^-

D L= OH- <Cl- < NO_2^- < NCS-

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Substitution mechanism, SN1CB, trans effect, lability

PYQ FREQUENCY
Very High · 15 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
trans-effect series: "H_2O < NH_3 < Cl < Br < I < NO_2 < CN ≈ CO". Strong trans-director labilises the trans ligand.

Correct Answer B L= NO_2^- < Cl- < NCS- < OH-

CONCEPT

Substitution proceeds by associative (A/I_a) or dissociative (D/I_d) pathways. Base hydrolysis of amine complexes follows the SN1CB (conjugate-base) mechanism.

↓

LOGIC / WORKING

trans-$[CoLCl(en)_2]^+$ → A (on hydrolysis)

L= NO_2^-, NCS-, OH- ,Cl- The tendency to form cis-isomer of the product (A) follows the order:

L= NO_2^- < Cl- < NCS- < OH-

FINAL: (B) L= NO_2^- < Cl- < NCS- < OH-

SHORTCUT / EXAM TRICK

SN1CB needs an ionisable N–H. Rate = k[complex][OH^-] but the OH^- only deprotonates; the slow step is dissociative.

COMMON MISTAKE

Applying SN1CB to a complex with no ionisable proton (e.g. cyanide or pyridine complexes).

EXAM TIP

Inert: d^3, low-spin d^6 (Cr^{3+}, Co^{3+}). Labile: most others. Square-planar Pt(II) shows strong trans effect.

MEMORY TRICK

trans-effect series: "H_2O < NH_3 < Cl < Br < I < NO_2 < CN ≈ CO". Strong trans-director labilises the trans ligand.

Why the Other Options Are Wrong

Correct answer: **B**

A

L= NO_2 < NCS < OH < Cl

the trans-influence ordering is incorrect; NO_2^-<Cl^-<NCS^-<OH^- is the intended sequence.

C

L= OH- < NCS- <Cl- < NO_2^-

this reverses the order; NO_2^- should be weakest in this ranking, not OH^-.

D

L= OH- <Cl- < NO_2^- < NCS-

the sequence does not match the correct trans-directing order for these ligands.

Q148

The correct statement about base hydrolysis of $[Co(py)_4Cl_2]^+$ (py = pyridine) is:

A Rate expression is Rate = $k[Co(py)_4Cl_2]^+[OH^-]$

B Reaction does not depend on hydroxide ion concentration

C Reaction proceeds through SN_1CB mechanism

D Intermediate involved is $[Co(py)_4Cl_2(OH)]$

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Substitution mechanism, SN1CB, trans effect, lability

PYQ FREQUENCY
Very High · 15 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
trans-effect series: "$H_2O < NH_3 < Cl < Br < I < NO_2 < CN \approx CO$". Strong trans-director labilises the trans ligand.

Correct Answer B Reaction does not depend on hydroxide ion concentration

CONCEPT

Substitution proceeds by associative (A/I_a) or dissociative (D/I_d) pathways. Base hydrolysis of amine complexes follows the SN1CB (conjugate-base) mechanism.

↓

LOGIC / WORKING

The base hydrolysis of $[Co(py)_4Cl_2]^+$ is independent OH- of concentration because there is no protonic hydrogen in the complex.

FINAL: (B) Reaction does not depend on hydroxide ion concentration

SHORTCUT / EXAM TRICK

SN1CB needs an ionisable N–H. Rate = k[complex][OH^-] but the OH^- only deprotonates; the slow step is dissociative.

COMMON MISTAKE

Applying SN1CB to a complex with no ionisable proton (e.g. cyanide or pyridine complexes).

EXAM TIP

Inert: d^3, low-spin d^6 (Cr^{3+}, Co^{3+}). Labile: most others. Square-planar Pt(II) shows strong trans effect.

MEMORY TRICK

trans-effect series: "$H_2O < NH_3 < Cl < Br < I < NO_2 < CN \approx CO$". Strong trans-director labilises the trans ligand.

Why the Other Options Are Wrong

Correct answer: **B**

A

Rate expression is Rate = $k[Co(py)_4Cl_2]^+[OH^-]$

pyridine has no N-H, so the rate does NOT include $[OH^-]$; this rate law is wrong.

C

Reaction proceeds through SN_1CB mechanism

SN_1CB is impossible without an ionizable proton (py has none).

D

Intermediate involved is $[Co(py)_4Cl_2(OH)]$

the hydroxo-containing intermediate of SN_1CB cannot form for this proton-less complex.

Q152

For the given reaction $[*Co(L)n]^{2+} + [Co(L)n]^{3+} \rightarrow [*Co(L)n]^{3+} + [Co(L)n]^{2+}$ the correct statement with respect to the rate of electron transfer process is o-phen = o-phenanthroline ; *Co is labeled atom

A. fast electron transfer; L= NH_3; n = 6

B. slow electron transfer ; L = o-phen; n = 3

C. very slow electron transfer ; L = NH_3 ; n = 3

D. very slow electron transfer: L = o-phen; n = 3

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Substitution mechanism, SN1CB, trans effect, lability

PYQ FREQUENCY
Very High · 15 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
trans-effect series: "$H_2O < NH_3 < Cl < Br < I < NO_2 < CN \approx CO$". Strong trans-director labilises the trans ligand.

Correct Answer C very slow electron transfer ; L = NH_3 ; n = 3

CONCEPT

Substitution proceeds by associative (A/I_a) or dissociative (D/I_d) pathways. Base hydrolysis of amine complexes follows the SN1CB (conjugate-base) mechanism.

↓

LOGIC / WORKING

$[*Co(NH_3)_6]^+$ $[Co(NH_3)_6]^{3+}$ → $[*Co(NH_3)_6]^{3+}$ + $[Co(NH_3)_6]^{2+}$ High spin low spin t_2g^5 eg^2 t_2g 6 eg^0 Labile Inert Co- NH_3 Co- NH_3 Bond length = 193.6pm Bond length = 211.4pm The rate of electron transfer for the reaction is very slow (second order rate constant =10-6 L mol-1s-1) because of following reason :

• Low spin $[Co(NH_3)_6]^{3+}$ (configuration t_2g 6 eg^0) has all the metal -electrons pointing in between the ligands whereas, high spin $[*Co(NH_3)_6]^{2+}$ (configuration t_2g^5 eg^2) has two eg electrons pointing directly at the ligands. The electrons present in eg orbitals cause more repulsion with ligands than that of t_2g electrons. Thus, M-L bond lengths in both complexes are different enough and more activation energy is needed to make them the same in transition state .

Also, no simple addition or removal of an electron can convert these configuration into one another.

Thus, it is necessary to excite the oxidation states before the reaction can occur, as shown below: rW• to t_2g $*Co^{2+}$ (t_2g^5 eg^2) → (t_2g^6 eg^1) (t_2g^5 eg^1) → (t_2g^6 eg^0) $*Co^{3+}$ (electronic transition) rW• to t_2g Co^{3+} (t_2g^6 eg^0) → (t_2g^5 eg^1) (t_2g^6 eg^1) → (t_2g^5 eg^2) Co^{2+} (electronic transition)

FINAL: (C) very slow electron transfer ; L = NH_3 ; n = 3

SHORTCUT / EXAM TRICK

SN1CB needs an ionisable N–H. Rate = k[complex][OH^-] but the OH^- only deprotonates; the slow step is dissociative.

COMMON MISTAKE

Applying SN1CB to a complex with no ionisable proton (e.g. cyanide or pyridine complexes).

EXAM TIP

Inert: d^3, low-spin d^6 (Cr^{3+}, Co^{3+}). Labile: most others. Square-planar Pt(II) shows strong trans effect.

MEMORY TRICK

trans-effect series: "H_2O < NH_3 < Cl < Br < I < NO_2 < CN ≈ CO". Strong trans-director labilises the trans ligand.

Why the Other Options Are Wrong

Correct answer: **C**

A **fast electron transfer; L= NH_3; n = 6**

the Co ammine self-exchange is very SLOW (LS↔HS reorganisation), not fast.

B **slow electron transfer ; L = o-phen; n = 3**

the slow couple here is the NH_3 (n=3-type) system, not the o-phen complex.

D **very slow electron transfer: L = o-phen; n = 3**

the ligand is NH_3 (not o-phen); o-phen would actually give faster transfer.

Q157 The products A and B for the given reaction $[Co(NH_3)_5Cl]^{2+} + [Cr(OH_2)_6]^{2+} + {}^5H_3O+ \rightarrow A+B$ are respectively,

A $[Co(OH_2)_5Cl]^+$, $[Cr(OH_2)_6]^{3+}$

B $[Co(NH_3)_5(OH_2)]^{2+}$, $[Cr(OH_2)_5Cl]^{2+}$

C $[Co(OH_2)_6]^{2+}$, $[Cr(OH_2)_5Cl]^{2+}$

D $[Co(NH_3)_5Cl]^+$, $[Cr(OH_2)_6]^{3+}$

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Substitution mechanism, SN1CB, trans effect, lability

PYQ FREQUENCY
Very High · 15 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
trans-effect series: "$H_2O < NH_3 < Cl < Br < I < NO_2 < CN \approx CO$". Strong trans-director labilises the trans ligand.

Correct Answer C $[Co(OH_2)_6]^{2+}$, $[Cr(OH_2)_5Cl]^{2+}$

CONCEPT

Substitution proceeds by associative (A/I_a) or dissociative (D/I_d) pathways. Base hydrolysis of amine complexes follows the SN1CB (conjugate-base) mechanism.

↓

LOGIC / WORKING

- H_2O electron transfer $[CoIII(NH_3)_5Cl]^{2+}$ + $[CrII(OH_2)_6]^{2+}$ $[(NH_3)_5CoIII\text{-}Cl\text{-}CrII(H_2O)_5]^{4+}$ Inert Labile $[(NH_3)_5CoII\text{-}Cl\text{-}CrIII(H_2O)_5]^{4+}$ Labile Inert $[Co(NH_3)_5]^{2+}$ + $[Co(H_2O)_5Cl]^{2+}$ +^5H_3O+ $[Co(NH_3)_5]^{2+}$ +H_2O → $[Co(NH_3)_5(H_2O)]^{2+}$ $[Co(H_2O)_6]^{2+}$ +5NH_4^+

FINAL: (C) **$[Co(OH_2)_6]^{2+}$, $[Cr(OH_2)_5Cl]^{2+}$**

SHORTCUT / EXAM TRICK

SN1CB needs an ionisable N–H. Rate = k[complex][OH^-] but the OH^- only deprotonates; the slow step is dissociative.

COMMON MISTAKE

Applying SN1CB to a complex with no ionisable proton (e.g. cyanide or pyridine complexes).

EXAM TIP

Inert: d^3, low-spin d^6 (Cr^{3+}, Co^{3+}). Labile: most others. Square-planar Pt(II) shows strong trans effect.

MEMORY TRICK

trans-effect series: "H_2O < NH_3 < Cl < Br < I < NO_2 < CN ≈ CO". Strong trans-director labilises the trans ligand.

Why the Other Options Are Wrong

Correct answer: **C**

A $[Co(OH_2)_5Cl]^+$, $[Cr(OH_2)_6]^{3+}$

the cobalt product is the labile Co(II) hexaaqua ion, not a Co(III) chloro species.

B $[Co(NH_3)_5(OH_2)]^{2+}$, $[Cr(OH_2)_5Cl]^{2+}$

the products do not retain NH_3 on Co; Co becomes $[Co(H_2O)_6]^{2+}$ after reduction.

D $[Co(NH_3)_5Cl]^+$, $[Cr(OH_2)_6]^{3+}$

Co retains no Cl/NH_3; the correct products are $[Co(H_2O)_6]^{2+}$ and $[Cr(H_2O)_5Cl]^{2+}$.

Q160

In the following sequence of reactions the correct P, Q and R are respectively +

A KNO_2 , CO_2 , $[Fe(H_2O)^5S]$, HgS

B KNO_2 , N_2, $[Fe(H_2O)_5(SCN)]^{2+}$, $[Hg(SCN)_4]^{2-}$

C KNO_3 , N_2, $[Fe(H_2O)_5(CN)]^{2+}$, $[Hg(OCN)_4]^{2-}$

D NaN_3, N_2 , $[Fe(H_2O)_5(N_3)]^{2+}$, $[Hg(N_3)_4]^{2-}$

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Substitution mechanism, SN1CB, trans effect, lability

PYQ FREQUENCY
Very High · 15 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
trans-effect series: "$H_2O < NH_3 < Cl < Br < I < NO_2 < CN \approx CO$". Strong trans-director labilises the trans ligand.

Correct Answer B KNO_2 , N_2, $[Fe(H_2O)_5(SCN)]^{2+}$, $[Hg(SCN)_4]^{2-}$

CONCEPT

Substitution proceeds by associative (A/I_a) or dissociative (D/I_d) pathways. Base hydrolysis of amine complexes follows the SN1CB (conjugate-base) mechanism.

↓

LOGIC / WORKING

Solid Thiourea KNO_2 in dil . AcOH N_2 gas ↑ + SCN- + H_2O (P) ↓ dil $FeCl_3$ $[Hg(SCN)_4]^{2-}$ —FIJd $HgCl_2$ $[Fe(H_2O)_5(SCN)]^{2+}$ solution Colourless (R) Blood red (Q)

FINAL: (B) KNO_2 , N_2, $[Fe(H_2O)_5(SCN)]^{2+}$, $[Hg(SCN)_4]^{2-}$

SHORTCUT / EXAM TRICK

SN1CB needs an ionisable N–H. Rate = k[complex][OH^-] but the OH^- only deprotonates; the slow step is dissociative.

COMMON MISTAKE

Applying SN1CB to a complex with no ionisable proton (e.g. cyanide or pyridine complexes).

EXAM TIP

Inert: d^3, low-spin d^6 (Cr^{3+}, Co^{3+}). Labile: most others. Square-planar Pt(II) shows strong trans effect.

MEMORY TRICK

trans-effect series: "H_2O < NH_3 < Cl < Br < I < NO_2 < CN ≈ CO". Strong trans-director labilises the trans ligand.

Why the Other Options Are Wrong

Correct answer: **B**

A KNO_2 , CO_2 , $[Fe(H_2O)^5S]$, HgS

the gas is N_2 (not CO_2) and the iron product is the thiocyanato complex, not a sulfide.

C KNO_3 , N_2, $[Fe(H_2O)_5(CN)]^{2+}$, $[Hg(OCN)_4]^{2-}$

the reagent is KNO_2 (not KNO_3) and the products are SCN/$[Hg(SCN)_4]^{2-}$, not cyanide/cyanate.

D NaN_3, N_2 , $[Fe(H_2O)_5(N_3)]^{2+}$, $[Hg(N_3)_4]^{2-}$

azide chemistry (NaN_3) is not involved; the sequence uses nitrite and thiocyanate.

TOPIC REVISION

Reaction Mechanisms & Kinetics

24 PYQs · Last-minute revision

TOPIC SUMMARY

Substitution proceeds by associative (A/I_a) or dissociative (D/I_d) pathways. Base hydrolysis of amine complexes follows the SN1CB (conjugate-base) mechanism.

IMPORTANT FORMULA SHEET

SN1CB rate = k[complex][OH^-]
Inert: d^3, LS d^6
trans-effect: CN ≈ CO > NO_2 > I > Br > Cl

- I_a (assoc.) vs I_d (dissoc.)

FREQUENTLY ASKED CONCEPTS

Associative vs dissociative
SN1CB mechanism
trans effect/influence

- Lability vs inertness

COMMON MISTAKES & QUICK NOTES

Watch out:
Applying SN1CB to a complex with no ionisable proton (e.g. cyanide or pyridine complexes).
Last-minute:
SN1CB needs an ionisable N–H. Rate = k[complex][OH^-] but the OH^- only deprotonates; the slow step is dissociative.

MOST-REPEATED PYQs & EXPECTED IN EXAM

PYQs in this topic: Q4 Q17 Q23 Q35 Q37 Q38 Q60 Q66 Q69 Q87 Q88 Q103 Q109 Q121 Q130 Q134 Q138 Q141 Q142 Q144 Q148 Q152 Q157 Q160

Expect **3 question(s)** next session on **Substitution mechanism, SN1CB, trans effect, lability.**

TOPIC 10

Electron Transfer Reactions

6 questions · Easy 2 | Medium 3 | Hard 1 · PYQ frequency: Moderate

Q19

For the following outer sphere electron transfer reactions. $+2\ +3\ +3\ +2\ [Co(NH_3)_6]^{+}\ [Co^*(NH_3)_6] \rightarrow [Co(NH_3)_6]^{+}\ [Co^*(NH_3)_6]\ [Ru(NH_3)_6]^{2+} + [Ru^*(NH_3)_6]^{3+} \rightarrow [Ru(NH_3)_6]^{3+} + [Ru^*(NH_3)_6]^{2+}$ the rate constants are 10 $M^{-1}s^{-1}$ and $8.2x_{10}$ $M^{-1}s^{-1}$ respectively. This difference in the rate constants is due to

A A change from high spin to low spin in Co* and high spin to low spin in Ru.

B A change from high spin to low spin in Co* and low spin to high spin Ru*.

C A change from low spin to high spin in Co* and the low spin state remains unchanged in Ru.

D A change from low spin to high spin in Co* and high spin to low spin in Ru*.

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Inner vs outer sphere, Marcus theory, reorganisation energy

PYQ FREQUENCY
Moderate · 6 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
“Bridge = inner-sphere; intact shells = outer-sphere.” Marcus links rate to driving force + reorganisation λ.

Correct Answer C A change from low spin to high spin in Co* and the low spin state remains unchanged in Ru.

CONCEPT

Outer-sphere transfer keeps both coordination shells intact (Marcus theory). Inner-sphere transfer proceeds through a bridging ligand that may be transferred.

↓

LOGIC / WORKING

$[Co^*(NH_3)_6]^{2+} \rightarrow$ High spin $[Co^*(NH_3)_6]^{3+} \rightarrow$ Low spin $[Ru(NH_3)_6]^{2+} \rightarrow$ Low spin ; $[Ru^*(NH_3)_6]^{3+} \rightarrow$ Low spin

FINAL: (C) A change from low spin to high spin in Co* and the low spin state remains unchanged in Ru.

SHORTCUT / EXAM TRICK

Ligand transfer between metals = inner-sphere. Self-exchange rate ↓ when a large bond-length change (reorganisation) accompanies electron transfer.

COMMON MISTAKE

Assuming outer-sphere when a bridging ligand is transferred — that is diagnostic of inner-sphere.

EXAM TIP

$Co(NH_3)_6^{3+/2+}$ self-exchange is slow (big LS↔HS reorganisation). $Ru(NH_3)_6^{3+/2+}$ is fast (little change).

MEMORY TRICK

“Bridge = inner-sphere; intact shells = outer-sphere.” Marcus links rate to driving force + reorganisation λ.

Why the Other Options Are Wrong

Correct answer: **C**

A **A change from high spin to low spin in Co* and high spin to low spin in Ru.**
Ru stays low-spin in both states; there is no spin change on Ru.

B **A change from high spin to low spin in Co* and low spin to high spin Ru*.**
Co goes low→high spin (not high→low), and Ru does not change spin.

D **A change from low spin to high spin in Co* and high spin to low spin in Ru*.**
Ru remains low-spin throughout; the 'high→low for Ru' part is incorrect.

Q28

The light pink color of $[Co(H_2O)_6]^{2+}$ and the deep blue color of $[CoCl_4]^{2-}$ are due to

A. MLCT transition in the first and d-d transition in the second

B. LMCT transition in both

C. d-d transitions in both.

D. d-d transition in the first and MLCT transition in the second.

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Inner vs outer sphere, Marcus theory, reorganisation energy

PYQ FREQUENCY
Moderate · 6 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
"Bridge = inner-sphere; intact shells = outer-sphere." Marcus links rate to driving force + reorganisation λ.

Correct Answer C d-d transitions in both.

CONCEPT

Outer-sphere transfer keeps both coordination shells intact (Marcus theory). Inner-sphere transfer proceeds through a bridging ligand that may be transferred.

↓

LOGIC / WORKING

$[Co(H_2O)_6]^{2+} \rightarrow t_2g^5\ eg^2$ In this electron transition from $t_2g^5 \rightarrow eg^2$, therefore d-d transition.

$[CoCl_4]^{2-} \rightarrow t_2g^5\ eg^2$ Electron transfer from e to t_2 , therefore d-d transition.

FINAL: (C) d-d transitions in both.

SHORTCUT / EXAM TRICK

Ligand transfer between metals = inner-sphere. Self-exchange rate ↓ when a large bond-length change (reorganisation) accompanies electron transfer.

COMMON MISTAKE

Assuming outer-sphere when a bridging ligand is transferred — that is diagnostic of inner-sphere.

EXAM TIP

$Co(NH_3)_6^{3+/2+}$ self-exchange is slow (big LS↔HS reorganisation). $Ru(NH_3)_6^{3+/2+}$ is fast (little change).

MEMORY TRICK

“Bridge = inner-sphere; intact shells = outer-sphere.” Marcus links rate to driving force + reorganisation λ.

Why the Other Options Are Wrong

Correct answer: **C**

A **MLCT transition in the first and d-d transition in the second**
neither complex shows MLCT; both colours come from d-d transitions of Co^{2+}.

B **LMCT transition in both**
these are not LMCT bands; Co^{2+} d-d transitions give the colours.

D **d-d transition in the first and MLCT transition in the second.**
the tetrahedral $CoCl_4^{2-}$ colour is d-d, not MLCT.

Q61

Consider the second order rate constants for the following outer-sphere electron transfer $[Fe(H_2O)_6]^{3+}$ / $[Fe(H_2O)_6]^{2+}$ 4.0 M^{1-} sec-1 $[Fe(phen)_3]^{3+}$ /$[Fe(phen)_3]^{3+}$ 3.0 x_{107} M^{1-} (phen= 1, 10-phenanthroline) The enhanced rate constant for the second reaction is due to the fact that

A. The 'phen' is a π-acceptor ligand that allows mixing of electron donor and acceptor orbitals that enhances the rate of electron transfer

B. The phen' is a π -donor ligand that enhances the rate of electron transfer

C. The 'phen' forms charge transfer complex with iron and facilitates the eletron transfer

D. The 'phen' forms kinetically labile complex with iron and facilitates the electron transfer.

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Inner vs outer sphere, Marcus theory, reorganisation energy

PYQ FREQUENCY
Moderate · 6 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
“Bridge = inner-sphere; intact shells = outer-sphere.” Marcus links rate to driving force + reorganisation λ.

Correct Answer A The 'phen' is a π-acceptor ligand that allows mixing of electron donor and acceptor orbitals that enhances the rate of electron transfer

CONCEPT

Outer-sphere transfer keeps both coordination shells intact (Marcus theory). Inner-sphere transfer proceeds through a bridging ligand that may be transferred.

↓

LOGIC / WORKING

(Phen) is an π-acceptor ligands hence there is mixing of donor and acceptor orbital having similar symmetry this leads to fast transfer of electron leading to enhance rate of reaction. $[Fe(phen)_3]^{3+}$ $[Fe(phen)_3]^{2+}$ 5 0 t 2g e g t 2g eg^0 π*5σ*0 π*6e_0g Electron transfer takes place from π*6 (Fe^{2+}) → π*5 (Fe^{3+})

- Correct answer is (a)

FINAL: (A) The 'phen' is a π-acceptor ligand that allows mixing of electron donor and acceptor orbitals that enhances the rate of electron transfer

SHORTCUT / EXAM TRICK

Ligand transfer between metals = inner-sphere. Self-exchange rate ↓ when a large bond-length change (reorganisation) accompanies electron transfer.

COMMON MISTAKE

Assuming outer-sphere when a bridging ligand is transferred — that is diagnostic of inner-sphere.

EXAM TIP

$Co(NH_3)_6^{3+/2+}$ self-exchange is slow (big LS↔HS reorganisation). $Ru(NH_3)_6^{3+/2+}$ is fast (little change).

MEMORY TRICK

“Bridge = inner-sphere; intact shells = outer-sphere.” Marcus links rate to driving force + reorganisation λ.

Why the Other Options Are Wrong

Correct answer: **A**

B **The phen' is a π -donor ligand that enhances the rate of electron transfer**
phen is a π-acceptor (not a π-donor); it accepts electron density into its π* system.

C **The 'phen' forms charge transfer complex with iron and facilitates the eletron transfer**
the fast rate is due to electronic delocalisation via phen π*, not formation of a separate CT complex.

D **The 'phen' forms kinetically labile complex with iron and facilitates the electron transfer.**
$Fe(phen)_3$ complexes are kinetically inert, not labile; lability is not the reason for fast ET.

Q110 In the following redox reaction with an equilibrium constant K = 2.0 x 108 $[Ru(NH_3)_6]^{2+} + [Fe(H_2O_6)]^{3+} \rightarrow [Ru(NH_3)_6]^{3+} + [Fe(H_2O)_6]^{2+}$ the self exchange rates for oxidant and reductant are 5.0 $M^{-1}s^{-1}$ and $4.0x_{103}$ $M^{-1}s^{-1}$ respectively. The approximate rate constant ($M^{-1}s^{-1}$) for the reaction is

A 3.16×10^6

B 2.0×10^6

C 6.32×10^6

D 3.16×10^6

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Inner vs outer sphere, Marcus theory, reorganisation energy

PYQ FREQUENCY
Moderate · 6 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
"Bridge = inner-sphere; intact shells = outer-sphere." Marcus links rate to driving force + reorganisation λ.

Correct Answer B 2.0 × 10⁶

CONCEPT

Outer-sphere transfer keeps both coordination shells intact (Marcus theory). Inner-sphere transfer proceeds through a bridging ligand that may be transferred.

↓

LOGIC / WORKING

- *k* 12 = *k* 11 *Kk* 22 *f* = 5×4×10x ×2×10y ×1.0 = 20×10Q = 2.0×10z

FINAL: (B) 2.0 × 10⁶

SHORTCUT / EXAM TRICK

Ligand transfer between metals = inner-sphere. Self-exchange rate ↓ when a large bond-length change (reorganisation) accompanies electron transfer.

COMMON MISTAKE

Assuming outer-sphere when a bridging ligand is transferred — that is diagnostic of inner-sphere.

EXAM TIP

$Co(NH_3)_6^{3+/2+}$ self-exchange is slow (big LS↔HS reorganisation). $Ru(NH_3)_6^{3+/2+}$ is fast (little change).

MEMORY TRICK

“Bridge = inner-sphere; intact shells = outer-sphere.” Marcus links rate to driving force + reorganisation λ.

Why the Other Options Are Wrong

Correct answer: **B**

A **3.16×10^6**

3.16×10^6 is not the stated equilibrium constant value for this couple.

C **6.32×10^6**

6.32×10^6 does not match the given K.

D **3.16×10^6**

3.16×10^6 (repeated) is not the correct K value.

Q131

Consider the statements A - D regarding equation I-III:
(1) $[Fe(CN)_6]^{3-} + [Co(CN)_5]^{3-} \rightarrow [Fe(CN)_6]^{4-} + [Co(CN)_5]^{2-}$ (II) $[Co(bipy)_3]^{2+} + [Co^*(bipy)_3]^{3+} \rightarrow [Co(bipy)_3]^{3-} + [Co^*(bipy)_3]^{2+}$ (III) $[Co(NH_3)F]^{2+} + [CrH_2O)_6]^{2+} \rightarrow [Co(NH_3)_5(H_2O)]^{2+} + [Cr(H_2O)^5F]^{2+}$

A Marcus equation is applicable to I and II.

B Marcus equation is applicable to II only.

C Equation I and II involve inner sphere electron transfer.

D Equation I and III involve inner sphere electron transfer. The correct statements are: 1. A and B 2. B and C 3. B and D 4. C and D

QUESTION INSIGHTS

ESTIMATED TIME
3–5 min

DIFFICULTY
Hard

CONCEPT TESTED
Inner vs outer sphere, Marcus theory, reorganisation energy

PYQ FREQUENCY
Moderate · 6 papers

REVISION PRIORITY
★★★★★

EXPECTED LEVEL
Part C (high merit)

MEMORY HOOK
“Bridge = inner-sphere; intact shells = outer-sphere.” Marcus links rate to driving force + reorganisation λ.

Correct Answer D Equation I and III involve inner sphere electron transfer. The correct statements are: 1. A and B 2. B and C 3. B and D 4. C and D

CONCEPT

Outer-sphere transfer keeps both coordination shells intact (Marcus theory). Inner-sphere transfer proceeds through a bridging ligand that may be transferred.

↓

LOGIC / WORKING

(I) $[Fe(CN)_6]^{3-} + [Co(CN)_5]^{3-} \rightarrow [(NC)^5Fe\text{-}CN\text{-}Co(CN)_5]^{6-}$ electron transfer $[Fe(CN)_6]^{4-} + [Co(CN)_5(OH_2)]^{2-}$ (Inner sphere mechanism)
(II) $[Co(bipy)_3]^{2+} + [Co(bipy)_3]^{3+} \rightarrow [Co(bipy)_3]^{3+} + [Co(bipy)_3]^{2+}$ (outer sphere mechanism) $\cdot H_2O$ electron transfer (III) $[Co(NH_3)F]^{2+} + [Cr(H_2O)_6]^{2+}$ $[(H_3N)_5CoIII\text{-}F\text{-}CrII(OH_2)_5]^{4+} + H_2O$ $[(H_3N)_5CoII\text{-}F\text{-}CrIII(OH_2)_5]^{4+}$ $[Co(NH_3)_5(OH)]^{2+} + [Cr(OH_2)^5F]^{2+}$ (Inner sphere mechanism)
Marcus equation is applicable only for cross-outer sphere reactions.
(B) is a self exchange reaction, its rate of electron transfer can be calculated experimentally.
No need to apply marcus equation.
(Reference basic inorganic chemistry by F.Albert Cotton, G Wilkinson and Paul L.Galls) third eddition.

- In this question only (d) statement is correct.

FINAL: (D) Equation I and III involve inner sphere electron transfer. The correct statements are: 1. A and B 2. B and C 3. B and D 4. C and D

SHORTCUT / EXAM TRICK

Ligand transfer between metals = inner-sphere. Self-exchange rate ↓ when a large bond-length change (reorganisation) accompanies electron transfer.

COMMON MISTAKE

Assuming outer-sphere when a bridging ligand is transferred — that is diagnostic of inner-sphere.

EXAM TIP

$Co(NH_3)_6^{3+/2+}$ self-exchange is slow (big LS ↔ HS reorganisation). $Ru(NH_3)_6^{3+/2+}$ is fast (little change).

MEMORY TRICK

“Bridge = inner-sphere; intact shells = outer-sphere.” Marcus links rate to driving force + reorganisation λ.

Why the Other Options Are Wrong

Correct answer: **D**

A **Marcus equation is applicable to I and II.**
Marcus (outer-sphere) applicability is not the feature distinguishing I and II as asked.

B **Marcus equation is applicable to II only.**
restricting Marcus to II only mis-assigns the mechanism types.

C **Equation I and II involve inner sphere electron transfer.**
it is equations I and III (not I and II) that involve inner-sphere transfer.

Q140 Self-exchange electron transfer is fastest in

A. $[Ru(NH_3)_6]^{2+}/+3$

B. $[Co(NH_3)_6]^{2+}/+3$

C. $[Cr(OH)_6]^{2+}/+3$

D. $[Fe(OH_2)_6]^{2+}/+3$

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Inner vs outer sphere, Marcus theory, reorganisation energy

PYQ FREQUENCY
Moderate · 6 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
“Bridge = inner-sphere; intact shells = outer-sphere.” Marcus links rate to driving force + reorganisation λ.

Correct Answer A $[Ru(NH_3)_6]^{2+}/+3$

CONCEPT

Outer-sphere transfer keeps both coordination shells intact (Marcus theory). Inner-sphere transfer proceeds through a bridging ligand that may be transferred.

↓

LOGIC / WORKING

Electron transfer reactions by self-exchange electron transfer is fast when HOMO is π* and LUMO is also π* i.e. electron transfer is from a π*of reductant to the π* of oxidant.
(a) $[Ru(NH_3)_6]^{2+} + [Ru(NH_3)_6]^{3+} \rightarrow [Ru(NH_3)_6]^{3+} + [Ru(NH_3)_6]^{2+}$ [Reaction is fast]6 0 (π*) (σ*) $(\pi^*)_5(\sigma^*)_0$ HOMO=(π*) LUMO=$(\pi^*)_5$ (b) $[Co(NH_3)_6]^{2+} + [Co(NH_3)_6]^{3+} \rightarrow [Co(NH_3)_6]^{3+} + [Co(NH_3)_6]^{2+}$ [Reaction is slow] $(\pi^*)_5(\sigma^*)_2$ $(\pi^*)_6(\sigma^*)_0$ HOMO=$(\pi^*)_5$ LUMO=$(\sigma^*)_0$ (c) $[Cr(H_2O)_6]^{+}$ $[Cr(H_2O)_6]^{3+} \rightarrow [Cr(H_2O)_6]^{3+} + [Cr(H_2O)_6]^{2+}$ [Reaction is slow] $(\pi^*)_3(\sigma^*)_1$ $(\pi^*)_3(\sigma^*)_0$ HOMO=(σ*) LUMO=$(\sigma^*)_0$ (d) $[Fe(H_2O)_6]^{2+} + [Fe(H_2O)_6]^{3+} \rightarrow [Fe(H_2O)_6]^{3+} + [Fe(H_2O)_6]^{2+}$ [Reaction is fast] $(\pi^*)_4(\sigma^*)_2$ $(\pi^*)_3(\sigma^*)_0$ HOMO=(π*) LUMO=$(\pi^*)_3$ Both reactions (a) and (d) are fast but reaction (a) is much faster than (d) because there is small change in M-L bond length in reaction (a) i.e. less activation energy is required

FINAL: (A) $[Ru(NH_3)_6]^{2+}/+3$

SHORTCUT / EXAM TRICK

Ligand transfer between metals = inner-sphere. Self-exchange rate ↓ when a large bond-length change (reorganisation) accompanies electron transfer.

COMMON MISTAKE

Assuming outer-sphere when a bridging ligand is transferred — that is diagnostic of inner-sphere.

EXAM TIP

$Co(NH_3)_6^{3+/2+}$ self-exchange is slow (big LS↔HS reorganisation). $Ru(NH_3)_6^{3+/2+}$ is fast (little change).

MEMORY TRICK

“Bridge = inner-sphere; intact shells = outer-sphere.” Marcus links rate to driving force + reorganisation λ.

Why the Other Options Are Wrong

Correct answer: **A**

B $[Co(NH_3)_6]^{2+}/+3$

the $Co(NH_3)_6$ couple undergoes a large LS↔HS change, giving SLOW self-exchange, not fast.

C $[Cr(OH)_6]^{2+}/+3$

the $Cr(OH)_6$ couple is not the fastest; aquo/hydroxo Cr reorganises significantly.

D $[Fe(OH_2)_6]^{2+}/+3$

$Fe(OH_2)_6$ has notable bond-length change between II/III, so it is slower than the Ru couple.

TOPIC REVISION

Electron Transfer Reactions

6 PYQs · Last-minute revision

TOPIC SUMMARY

Outer-sphere transfer keeps both coordination shells intact (Marcus theory). Inner-sphere transfer proceeds through a bridging ligand that may be transferred.

IMPORTANT FORMULA SHEET

Inner-sphere: bridging ligand transfer
Outer-sphere: intact shells (Marcus)
$\Delta G‡ = \lambda/4\ (1 + \Delta G°/\lambda)^2$

- Slow ET ⇐ large reorganisation

FREQUENTLY ASKED CONCEPTS

Inner-sphere mechanism
Outer-sphere (Marcus)
Self-exchange rates

- Bridging ligand

COMMON MISTAKES & QUICK NOTES

Watch out:
Assuming outer-sphere when a bridging ligand is transferred — that is diagnostic of inner-sphere.
Last-minute:
Ligand transfer between metals = inner-sphere. Self-exchange rate ↓ when a large bond-length change (reorganisation) accompanies electron transfer.

MOST-REPEATED PYQs & EXPECTED IN EXAM

PYQs in this topic: Q19 Q28 Q61 Q110 Q131 Q140

Expect **1 question(s)** next session on **Inner vs outer sphere, Marcus theory, reorganisation energy.**

TOPIC 11

Chelate Effect & Stability

2 questions · Easy 2 | Medium 0 | Hard 0 · PYQ frequency: Rare

Q85

The formation constant for the complexation of M+ (M= Li, Na, K and Cs) with cryptand, C_{222} follows the order

A. Li+ <Cs+ < Na+ < K+

B. Li+< Na+ <K+ <Cs+

C. K+ <Cs+ <Li+ < Na+

D. Cs+ <K+ <Li+ < Na+

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Chelate/macrocyclic effect, formation constants, entropy

PYQ FREQUENCY
Rare · 2 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
"Rings free more molecules → entropy wins." 5- and 6-membered chelate rings are the sweet spot.

Chelate Effect & Stability

Correct Answer A Li+ <Cs+ < Na+ < K+

CONCEPT

Chelate (ring-forming) ligands give extra thermodynamic stability, driven mainly by a favourable entropy change. 5- and 6-membered rings are most stable.

↓

LOGIC / WORKING

The stability (formation constant for complexation of cryptate complex depends upon)

- (1) size of cavity (2) size of metal cation Hence, K+ ion will form most stable complex with cryptand-222.

FINAL: (A) Li+ <Cs+ < Na+ < K+

SHORTCUT / EXAM TRICK

Chelate effect ≈ entropy effect: more particles released to solution on chelation → +ΔS → larger formation constant.

COMMON MISTAKE

Attributing the chelate effect mainly to enthalpy, or ignoring ring-size effects.

EXAM TIP

Macrocyclic ligands add a further 'macrocyclic effect'. Best cation–cavity size match gives the largest K.

MEMORY TRICK

“Rings free more molecules → entropy wins.” 5- and 6-membered chelate rings are the sweet spot.

Why the Other Options Are Wrong

Correct answer: **A**

B **Li+< Na+ <K+ <Cs+**
this monotonic order ignores cavity-size matching; K^+ (best fit) should be highest.

C **K+ <Cs+ <Li+ < Na+**
K^+ should give the largest formation constant, not sit in the middle/low.

D **Cs+ <K+ <Li+ < Na+**
the order must peak at the best-fitting cation (K^+), not Cs^+.

Q95 Chelate effect is

A. predominantly due to enthalpy change

B. predominantly due to entropy change

C. independent of ring size

D. due to equal contribution of entropy and enthalpy change

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Chelate/macrocyclic effect, formation constants, entropy

PYQ FREQUENCY
Rare · 2 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
"Rings free more molecules → entropy wins." 5- and 6-membered chelate rings are the sweet spot.

Correct Answer B predominantly due to entropy change

CONCEPT

Chelate (ring-forming) ligands give extra thermodynamic stability, driven mainly by a favourable entropy change. 5- and 6-membered rings are most stable.

↓

LOGIC / WORKING

- Chelate effect is predominately due to entropy change ΔH nearly same but entropy change is more.

FINAL: (B) predominantly due to entropy change

SHORTCUT / EXAM TRICK

Chelate effect ≈ entropy effect: more particles released to solution on chelation → +ΔS → larger formation constant.

COMMON MISTAKE

Attributing the chelate effect mainly to enthalpy, or ignoring ring-size effects.

EXAM TIP

Macrocyclic ligands add a further 'macrocyclic effect'. Best cation–cavity size match gives the largest K.

MEMORY TRICK

“Rings free more molecules → entropy wins.” 5- and 6-membered chelate rings are the sweet spot.

Why the Other Options Are Wrong

Correct answer: **B**

A — **predominantly due to enthalpy change**
the chelate effect is mainly entropic, not primarily an enthalpy effect.

C — **independent of ring size**
the effect does depend on ring size (5- and 6-membered rings are most stable).

D — **due to equal contribution of entropy and enthalpy change**
entropy dominates; it is not an equal enthalpy/entropy contribution.

TOPIC REVISION

Chelate Effect & Stability

2 PYQs · Last-minute revision

TOPIC SUMMARY

Chelate (ring-forming) ligands give extra thermodynamic stability, driven mainly by a favourable entropy change. 5- and 6-membered rings are most stable.

IMPORTANT FORMULA SHEET

$\Delta G = \Delta H - T\Delta S$ (entropy-driven)
5- & 6-membered rings most stable
log β rises with denticity
- Macrocyclic effect > chelate effect

FREQUENTLY ASKED CONCEPTS

Entropy-driven stability
Ring size
Formation constants
- Macrocyclic effect

COMMON MISTAKES & QUICK NOTES

Watch out:
Attributing the chelate effect mainly to enthalpy, or ignoring ring-size effects.
Last-minute:
Chelate effect ≈ entropy effect: more particles released to solution on chelation → +ΔS → larger formation constant.

MOST-REPEATED PYQs & EXPECTED IN EXAM

PYQs in this topic: Q85 Q95

Expect **1 question(s)** next session on **Chelate/macrocyclic effect, formation constants, entropy.**

TOPIC 12

Solid State & Spinel Structures

4 questions · Easy 2 | Medium 2 | Hard 0 · PYQ frequency: Occasional

Q32

Coordination number of "C" in Be_2C_3 whose structure is correlated with that of CaF_2 is:

A. 2

B. 4

C. 6

D. 8

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Spinel structures, site occupancy, CFSE site preference

PYQ FREQUENCY
Occasional · 3 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
"Normal = A in tet; Inverse = A in oct." Octahedral-loving ions decide the arrangement.

Correct Answer D 8

CONCEPT

Spinels AB_2O_4 have A and B cations in tetrahedral/octahedral holes of an FCC oxide lattice. Normal vs inverse occupancy is set by site preference (CFSE).

↓

LOGIC / WORKING

In Be_2C_3 , Be+ = In tetrahedral voids C_3-2 = In FCC arrangement (Lattice point at corner + at each face centre)
Therefore, coordination number of Be+ = 4 And coordination number of C_3-2 = 8

FINAL: (D) 8

SHORTCUT / EXAM TRICK

Normal spinel: A^{2+} tetrahedral, B^{3+} octahedral. Inverse: B^{3+} splits between both sites, A^{2+} octahedral.

COMMON MISTAKE

Swapping the tetrahedral/octahedral site assignment between normal and inverse spinels.

EXAM TIP

Ions with strong octahedral CFSE (e.g. Cr^{3+} d^3, Ni^{2+} d^8) drive the site preference and spinel type.

MEMORY TRICK

“Normal = A in tet; Inverse = A in oct.” Octahedral-loving ions decide the arrangement.

Why the Other Options Are Wrong

Correct answer: **D**

A — **2**
CN of 2 is far too low for the anti-fluorite-type lattice.

B — **4**
4 is the CN of the cation (Be) in the tetrahedral holes, not of C.

C — **6**
in the anti-fluorite structure the anion (C) sits in 8-coordinate cubic sites, not 6.

Q34 The correct spinel structure of Co_3O_4 is:

A. $(Co^{2+})\ t\ (2CO+3)\ o\ O_4$

B. $(Co^{2+})\ t\ (2Co+3\ Co^{3+})\ o\ O_4$

C. $(Co^{2+}\ Co^{3+})\ t\ (Co^{3+})\ o\ O_4$

D. $(2Co+3)\ t\ (Co^{2+})\ o\ O_4$

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Spinel structures, site occupancy, CFSE site preference

PYQ FREQUENCY
Occasional · 3 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
"Normal = A in tet; Inverse = A in oct." Octahedral-loving ions decide the arrangement.

Correct Answer A $(Co^{2+})\ t\ (2CO+3)\ o\ O_4$

CONCEPT

Spinels AB_2O_4 have A and B cations in tetrahedral/octahedral holes of an FCC oxide lattice. Normal vs inverse occupancy is set by site preference (CFSE).

↓

LOGIC / WORKING

Co_3O_4 is a normal spinel. In normal spinel the Co^{2+} ions occupy tetrahedral voids and Co^{3+} ions occupy octahedral voids. Therefore, spinel structure of Co_3O_4 is $(Co^{2+})\ t\ (2CO+3)\ o\ O_4$

FINAL: (A) $(Co^{2+})\ t\ (2CO+3)\ o\ O_4$

SHORTCUT / EXAM TRICK

Normal spinel: A^{2+} tetrahedral, B^{3+} octahedral. Inverse: B^{3+} splits between both sites, A^{2+} octahedral.

COMMON MISTAKE

Swapping the tetrahedral/octahedral site assignment between normal and inverse spinels.

EXAM TIP

Ions with strong octahedral CFSE (e.g. Cr^{3+} d^3, Ni^{2+} d^8) drive the site preference and spinel type.

MEMORY TRICK

“Normal = A in tet; Inverse = A in oct.” Octahedral-loving ions decide the arrangement.

Why the Other Options Are Wrong

Correct answer: **A**

B **(Co^{2+}) t $(2Co+3\ Co^{3+})$ o O_4**
this implies extra Co^{3+} in octahedral beyond the 2 available; stoichiometry is wrong.

C **$(Co^{2+}\ Co^{3+})$ t (Co^{3+}) o O_4**
that is an inverse-spinel arrangement; Co_3O_4 is a normal spinel with Co^{2+} in tetrahedral sites.

D **$(2Co+3)$ t (Co^{2+}) o O_4**
placing Co^{3+} in tetrahedral and Co^{2+} in octahedral is the inverse arrangement, not adopted here.

Q51 $MnCr_2O_4$ is likely to have a normal spinel structure because

A Mn^{2+} will have a LFSE in the octahedral site whereas the Cr will not

B Mn is +2 oxidation state and both the Cr are in +3 oxidation state.

C Mn is +3 oxidation state and I Cr is in +2 and the other is in +3 state.

D Cr^{3+} will have a LFSE in the octahedral site whereas the Mn^{2+} ion will not.

QUESTION INSIGHTS

ESTIMATED TIME
2–3 min

DIFFICULTY
Medium

CONCEPT TESTED
Spinel structures, site occupancy, CFSE site preference

PYQ FREQUENCY
Occasional · 3 papers

REVISION PRIORITY
★★★★☆

EXPECTED LEVEL
Part B / Part C

MEMORY HOOK
"Normal = A in tet; Inverse = A in oct." Octahedral-loving ions decide the arrangement.

Correct Answer D Cr^{3+} will have a LFSE in the octahedral site whereas the Mn^{2+} ion will not.

CONCEPT

Spinels AB_2O_4 have A and B cations in tetrahedral/octahedral holes of an FCC oxide lattice. Normal vs inverse occupancy is set by site preference (CFSE).

↓

LOGIC / WORKING

Mn → $3d^5$ → t_2g^3 eg^2 (high spin octahedral)

CFSE in Oh field=(-0.4×3 +0.6×2) =0 Cr^{3+} → $3d^3$ → t_2g^3 eg^0 (octahedral)

CFSE in octahedral field = $-0.4x_3\Delta0 = -(0.4x_3)\ \Delta o = -1.^2\Delta o$

FINAL: (D) Cr^{3+} will have a LFSE in the octahedral site whereas the Mn^{2+} ion will not.

SHORTCUT / EXAM TRICK

Normal spinel: A^{2+} tetrahedral, B^{3+} octahedral. Inverse: B^{3+} splits between both sites, A^{2+} octahedral.

COMMON MISTAKE

Swapping the tetrahedral/octahedral site assignment between normal and inverse spinels.

EXAM TIP

Ions with strong octahedral CFSE (e.g. Cr^{3+} d^3, Ni^{2+} d^8) drive the site preference and spinel type.

MEMORY TRICK

“Normal = A in tet; Inverse = A in oct.” Octahedral-loving ions decide the arrangement.

Why the Other Options Are Wrong

Correct answer: **D**

A **Mn^{2+} will have a LFSE in the octahedral site whereas the Cr will not**
it is Cr^{3+} (d^3) that gains octahedral LFSE, not Mn^{2+}; the statement is reversed.

B **Mn is +2 oxidation state and both the Cr are in +3 oxidation state.**
merely stating oxidation states does not explain the site preference; LFSE of Cr^{3+} is the reason.

C **Mn is +3 oxidation state and I Cr is in +2 and the other is in +3 state.**
the oxidation states are Mn^{2+} and $2\times Cr^{3+}$, not Mn^{3+} with mixed Cr.

Q149 **$FeCr_2O_4$ and $NiGa_2O_4$ have normal and inverse spinel structures, respectively. The correct statement is:**

A. Fe(II) and Ni(II) occupy octahedral sites

B. Fe(II) and Ni(II) occupy tetrahedral and octahedral sites, respectively

C. Cr(III) and Ga(III) occupy only octahedral sites

D. Cr(III) and Ga(III) occupy tetrahedral and octahedral sites, respectively

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
Spinel structures, site occupancy, CFSE site preference

PYQ FREQUENCY
Occasional · 3 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
“Normal = A in tet; Inverse = A in oct.” Octahedral-loving ions decide the arrangement.

Correct Answer B Fe(II) and Ni(II) occupy tetrahedral and octahedral sites, respectively

CONCEPT

Spinels AB_2O_4 have A and B cations in tetrahedral/octahedral holes of an FCC oxide lattice. Normal vs inverse occupancy is set by site preference (CFSE).

↓

LOGIC / WORKING

$FeCr_2O_4$ has normal spinel structure thus, Fe^{2+} occupy tetrahedral site. $NiGa_2O_4$ has inverse spinel structure thus, Ni^{2+} occupy octahedral site.

FINAL: (B) Fe(II) and Ni(II) occupy tetrahedral and octahedral sites, respectively

SHORTCUT / EXAM TRICK

Normal spinel: A^{2+} tetrahedral, B^{3+} octahedral. Inverse: B^{3+} splits between both sites, A^{2+} octahedral.

COMMON MISTAKE

Swapping the tetrahedral/octahedral site assignment between normal and inverse spinels.

EXAM TIP

Ions with strong octahedral CFSE (e.g. Cr^{3+} d^3, Ni^{2+} d^8) drive the site preference and spinel type.

MEMORY TRICK

“Normal = A in tet; Inverse = A in oct.” Octahedral-loving ions decide the arrangement.

Why the Other Options Are Wrong

Correct answer: **B**

A **Fe(II) and Ni(II) occupy octahedral sites**
in the normal spinel $FeCr_2O_4$, Fe(II) is tetrahedral, so 'both octahedral' is wrong.

C **Cr(III) and Ga(III) occupy only octahedral sites**
Ga(III) in the inverse spinel occupies both tetrahedral and octahedral sites, not only octahedral.

D **Cr(III) and Ga(III) occupy tetrahedral and octahedral sites, respectively**
the site description for Cr(III)/Ga(III) does not match the normal/inverse arrangement correctly.

TOPIC REVISION

Solid State & Spinel Structures

4 PYQs · Last-minute revision

TOPIC SUMMARY

Spinels AB_2O_4 have A and B cations in tetrahedral/octahedral holes of an FCC oxide lattice. Normal vs inverse occupancy is set by site preference (CFSE).

IMPORTANT FORMULA SHEET

Spinel: AB_2O_4 (FCC oxide)

Normal: A(tet), 2B(oct)

Inverse: B(tet), A+B(oct)

- Site choice ⇐ octahedral CFSE

FREQUENTLY ASKED CONCEPTS

FCC oxide lattice

Normal vs inverse spinel

Tet/oct holes

- CFSE site preference

COMMON MISTAKES & QUICK NOTES

Watch out:

Swapping the tetrahedral/octahedral site assignment between normal and inverse spinels.

Last-minute:

Normal spinel: A^{2+} tetrahedral, B^{3+} octahedral. Inverse: B^{3+} splits between both sites, A^{2+} octahedral.

MOST-REPEATED PYQs & EXPECTED IN EXAM

PYQs in this topic: Q32 Q34 Q51 Q149

Expect **1 question(s)** next session on **Spinel structures, site occupancy, CFSE site preference.**

TOPIC 13

Metal Clusters & M–M Bonding

1 questions · Easy 1 | Medium 0 | Hard 0 · PYQ frequency: Rare

Q27

In $[Mo_2(S_2)_6]^{2-}$, cluster the number of bridging S_{22} and coordination number of Mo respectively, are

A. 2 and 8

B. 2 and 6

C. 1 and 8

D. 1 and 6

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
M–M bonding, cluster electron count, δ bonds

PYQ FREQUENCY
Rare · 1 paper

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
"σ, π, π, δ" fill order for M–M bonds. δ bond is the weakest and lowest-energy transition.

Correct Answer A 2 and 8

CONCEPT

Metal clusters contain direct metal–metal bonds. Bond order is found from the d-electron count and σ/π/δ MO occupancy (e.g. quadruple bond in $Re_2Cl_8^{2-}$).

↓

LOGIC / WORKING

$[Mo_2(S_2)_6]^{2-}$ The structure of $[Mo_2(S_2)_6]^{2-}$ cluster is:

- So, the bridging SWW , is two and co-ordination number of Mo is 8.

FINAL: (A) 2 and 8

SHORTCUT / EXAM TRICK

$Re_2Cl_8^{2-}$ has a $\sigma^2\pi^4\delta^2$ configuration = quadruple bond. The $\delta \rightarrow \delta^*$ transition gives its low-energy visible band.

COMMON MISTAKE

Mis-counting bridging vs terminal ligands, giving the wrong coordination number or bond order.

EXAM TIP

Count cluster valence electrons (CVE) and bridging vs terminal ligands to assign coordination number and bond order.

MEMORY TRICK

“σ, π, π, δ” fill order for M–M bonds. δ bond is the weakest and lowest-energy transition.

Why the Other Options Are Wrong

Correct answer: **A**

B **2 and 6**
CN of Mo is 8 (each Mo binds 2 terminal + 2 bridging S_2 units), not 6.

C **1 and 8**
there are 2 bridging S_2^{2-} groups, not 1.

D **1 and 6**
both counts are off: bridging S_2^{2-} = 2 and CN = 8.

TOPIC REVISION

Metal Clusters & M–M Bonding

1 PYQs · Last-minute revision

TOPIC SUMMARY

Metal clusters contain direct metal–metal bonds. Bond order is found from the d-electron count and σ/π/δ MO occupancy (e.g. quadruple bond in $Re_2Cl_8^{2-}$).

IMPORTANT FORMULA SHEET

M–M fill order: σ < π < δ

$Re_2Cl_8^{2-}$: $\sigma^2\pi^4\delta^2$ (quadruple)

δ → δ* = low-energy band

- CVE counting for clusters

FREQUENTLY ASKED CONCEPTS

Metal–metal bonds

Quadruple bonding

δ bond

- Cluster electron count

COMMON MISTAKES & QUICK NOTES

Watch out:

Mis-counting bridging vs terminal ligands, giving the wrong coordination number or bond order.

Last-minute:

$Re_2Cl_8^{2-}$ has a $\sigma^2\pi^4\delta^2$ configuration = quadruple bond. The δ → δ* transition gives its low-energy visible band.

MOST-REPEATED PYQs & EXPECTED IN EXAM

PYQs in this topic: Q27

Expect **1 question(s)** next session on **M–M bonding, cluster electron count, δ bonds.**

TOPIC 14

Coordination Chemistry – General

6 questions · Easy 6 | Medium 0 | Hard 0 · PYQ frequency: Moderate

Q30

The total number of Cu-O bonds present in the crystalline copper(II) acetate monohydrate is:

A. 10

B. 6

C. 8

D. 4

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
General coordination chemistry, oxidation states, qualitative tests

PYQ FREQUENCY
Moderate · 6 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
"Oxidation state → d-count → everything else."
Anchor every prediction to the d-electron count.

Correct Answer A 10

CONCEPT

Broad coordination-chemistry reasoning: oxidation states, coordination numbers, characteristic reactions and classic qualitative tests.

↓

LOGIC / WORKING

Copper(II) acetate monohydrate $[Cu_2(OAc)_4(H_2O)_2]$ is a binuclear paddle-wheel dimer.

Each Cu is bonded to 4 oxygen atoms from 4 bridging acetate groups + 1 oxygen from water.

Cu-O bonds per Cu = 4 $(acetate)^{1+}$ (water) = 5.

- For both Cu centres: 5 × 2 = 10 total Cu-O bonds.

FINAL: (A) 10

SHORTCUT / EXAM TRICK

Identify the metal oxidation state and d-count first; most properties (colour, magnetism, geometry) follow from it.

COMMON MISTAKE

Skipping the oxidation-state/d-count step and guessing properties directly.

EXAM TIP

Learn the classic named tests (ring test = nitrate, Kurnakov = cis/trans Pt) — they recur in PYQs.

MEMORY TRICK

"Oxidation state → d-count → everything else." Anchor every prediction to the d-electron count.

Why the Other Options Are Wrong

Correct answer: **A**

B **6**

6 ignores the water Cu-O bonds and the dimeric paddle-wheel structure.

C **8**

8 undercounts; each Cu has 5 Cu-O bonds, giving 10 for the dimer.

D **4**

4 counts only one Cu's acetate oxygens, missing the second Cu and the waters.

Q54 In bis(dimethylglyoximato)nickel(II), the number of Ni-N, Ni-O and intramolecular hydrogen bond(s)respectively are

A. 4,0 and 2

B. 2, 2 and 2

C. 2, 2 and 0

D. 4, 0 and 1

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
General coordination chemistry, oxidation states, qualitative tests

PYQ FREQUENCY
Moderate · 6 papers

REVISION PRIORITY
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EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
"Oxidation state → d-count → everything else."
Anchor every prediction to the d-electron count.

Correct Answer A 4,0 and 2

CONCEPT

Broad coordination-chemistry reasoning: oxidation states, coordination numbers, characteristic reactions and classic qualitative tests.

↓

LOGIC / WORKING

Ni^{2+} is tested by dmg Ni^{2+} + 2dmg → $[Ni(dmg)_2]$ (Tschygaeff test)

- Red The structure of complex is Therefore Ni-N bonds = 4 Ni-O = 0 Hydrogen bonds = 2

FINAL: (A) 4,0 and 2

SHORTCUT / EXAM TRICK

Identify the metal oxidation state and d-count first; most properties (colour, magnetism, geometry) follow from it.

COMMON MISTAKE

Skipping the oxidation-state/d-count step and guessing properties directly.

EXAM TIP

Learn the classic named tests (ring test = nitrate, Kurnakov = cis/trans Pt) — they recur in PYQs.

MEMORY TRICK

“Oxidation state → d-count → everything else.” Anchor every prediction to the d-electron count.

Why the Other Options Are Wrong

Correct answer: **A**

B **2, 2 and 2**
there are 4 Ni-N bonds (two bidentate dmgH), not 2; O atoms are in H-bonds, not Ni-O bonds.

C **2, 2 and 0**
Ni binds 4 N (not 2) and there ARE 2 intramolecular H-bonds, not 0.

D **4, 0 and 1**
there are 2 intramolecular O-H···O hydrogen bonds, not 1.

Q72

The three dimensional structure of compound $[Co(Co(NH_3)_4(OH)_2)_3]Br_6$, has

A. Twelve Co-O and twelve Co-N bonds

B. Ten Co-O and ten Co-N bonds

C. Fourteen Co-O and ten Co-N bonds

D. Twelve Co-O and ten Co-N bonds

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
General coordination chemistry, oxidation states, qualitative tests

PYQ FREQUENCY
Moderate · 6 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
"Oxidation state → d-count → everything else."
Anchor every prediction to the d-electron count.

Correct Answer A Twelve Co-O and twelve Co-N bonds

CONCEPT

Broad coordination-chemistry reasoning: oxidation states, coordination numbers, characteristic reactions and classic qualitative tests.

↓

LOGIC / WORKING

It is first inorganic optically active compound discovered by Werner.

- Number of Co-O bonds = 12 Number of Co-N bonds 12

FINAL: (A) Twelve Co-O and twelve Co-N bonds

SHORTCUT / EXAM TRICK

Identify the metal oxidation state and d-count first; most properties (colour, magnetism, geometry) follow from it.

COMMON MISTAKE

Skipping the oxidation-state/d-count step and guessing properties directly.

EXAM TIP

Learn the classic named tests (ring test = nitrate, Kurnakov = cis/trans Pt) — they recur in PYQs.

MEMORY TRICK

“Oxidation state → d-count → everything else.” Anchor every prediction to the d-electron count.

Why the Other Options Are Wrong

Correct answer: **A**

B **Ten Co-O and ten Co-N bonds**
there are 12 Co-N and 12 Co-O bonds (3 outer units × 4 each, plus 6 bridging ×2), not 10 each.

C **Fourteen Co-O and ten Co-N bonds**
the Co-N count is 12, not 10.

D **Twelve Co-O and ten Co-N bonds**
both Co-O and Co-N counts are 12; '10 Co-N' is incorrect.

Q81

The oxidizing power of $[CrO_4]^{2-}$, $[MnO_4]^{2-}$ and $[FeO_4]^{2-}$ follows the order

A $[CrO_4]^{2-} < [MnO_4]^{2-} < [FeO_4]^{2-}$

B $[FeO_4]^{2-} < [MnO_4]^{2-} < [CrO_4]^{2-}$

C $[MnO_4]^{2-} < [FeO_4]^{2-} < [CrO_4]^{2-}$

D $[CrO_4]^{2-} < [FeO_4]^{2-} < [MnO_4]^{2-}$

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
General coordination chemistry, oxidation states, qualitative tests

PYQ FREQUENCY
Moderate · 6 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
“Oxidation state → d-count → everything else.”
Anchor every prediction to the d-electron count.

Correct Answer A $[CrO_4]^{2-} < [MnO_4]^{2-} < [FeO_4]^{2-}$

CONCEPT

Broad coordination-chemistry reasoning: oxidation states, coordination numbers, characteristic reactions and classic qualitative tests.

↓

LOGIC / WORKING

$[CrO_4]^{2-} < [MnO_4]^{2-} < [FeO_4]^{2-}$ All have +6 oxidation state but due to smaller size on going from Cr to Fe, Fe has very high charge density. Hence, it has very high tendency to accept electron. Hence, strongest oxidising agent.

FINAL: (A) $[CrO_4]^{2-} < [MnO_4]^{2-} < [FeO_4]^{2-}$

SHORTCUT / EXAM TRICK

Identify the metal oxidation state and d-count first; most properties (colour, magnetism, geometry) follow from it.

COMMON MISTAKE

Skipping the oxidation-state/d-count step and guessing properties directly.

EXAM TIP

Learn the classic named tests (ring test = nitrate, Kurnakov = cis/trans Pt) — they recur in PYQs.

MEMORY TRICK

“Oxidation state → d-count → everything else.” Anchor every prediction to the d-electron count.

Why the Other Options Are Wrong

Correct answer: **A**

B $[FeO_4]^{2-} < [MnO_4]^{2-} < [CrO_4]^{2-}$

this reverses the trend; oxidizing power increases Cr<Mn<Fe, not Fe<Mn<Cr.

C $[MnO_4]^{2-} < [FeO_4]^{2-} < [CrO_4]^{2-}$

the order must be monotonic with nuclear charge: Cr<Mn<Fe.

D $[CrO_4]^{2-} < [FeO_4]^{2-} < [MnO_4]^{2-}$

Fe should be the strongest oxidizer, so it cannot sit in the middle.

Q125 Mismatch among the following is

A. Sharp transition and fluorescence in lanthanides

B. Broad bands and d-d transitions

C. Very high spin-orbit coupling and transition elements

D. Charge transfer and molar absorptivity of the order of 10^1 L mol-1cm-1

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
General coordination chemistry, oxidation states, qualitative tests

PYQ FREQUENCY
Moderate · 6 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
"Oxidation state → d-count → everything else."
Anchor every prediction to the d-electron count.

Correct Answer C Very high spin-orbit coupling and transition elements

CONCEPT

Broad coordination-chemistry reasoning: oxidation states, coordination numbers, characteristic reactions and classic qualitative tests.

↓

LOGIC / WORKING

- Spin-orbit coupling is larger for the heavier atoms (Inner transition) and very small for lighter atoms.

FINAL: (C) Very high spin-orbit coupling and transition elements

SHORTCUT / EXAM TRICK

Identify the metal oxidation state and d-count first; most properties (colour, magnetism, geometry) follow from it.

COMMON MISTAKE

Skipping the oxidation-state/d-count step and guessing properties directly.

EXAM TIP

Learn the classic named tests (ring test = nitrate, Kurnakov = cis/trans Pt) — they recur in PYQs.

MEMORY TRICK

“Oxidation state → d-count → everything else.” Anchor every prediction to the d-electron count.

Why the Other Options Are Wrong

Correct answer: **C**

A **Sharp transition and fluorescence in lanthanides**

sharp lanthanide f-f transitions are a real feature, so this is not the mismatch.

B **Broad bands and d-d transitions**

broad d-d bands are correctly matched, so not the odd one out.

D **Charge transfer and molar absorptivity of the order of 10^1 L mol-1cm-1**

CT with high molar absorptivity is a correct pairing; the MISMATCH is 'very high spin-orbit coupling with transition (3d) elements' (3d metals have small, not very high, SOC).

Q139 Consider the two sets of molecules. Set A: $[AlF_6]^{3-}$, $[PF_6]^{-}$, $[SF_6]$ and $[SiF_6]^{2-}$ Set B: $[Ba(H_2O)_6]^{2+}$, $[Ca(H_2O)_6]^{2+}$, $[Mg(H_2O)_6]^{2+}$, $[Sr(H_2O)_6]^{2+}$ The slowest ligand exchange rate in Set A and Set B are, respectively

A. $[AlF_6]^{3-}$ and $[Sr(H_2O)_6]^{2+}$

B. $[SiF_6]^{2-}$ and $[Ca(H_2O)_6]^{2+}$

C. $[SF_6]$ and $[Mg(H_2O)_6]^{2+}$

D. $[PF_6]^{-}$ and $[Ca(H_2O)_6]^{2+}$

QUESTION INSIGHTS

ESTIMATED TIME
1–1.5 min

DIFFICULTY
Easy

CONCEPT TESTED
General coordination chemistry, oxidation states, qualitative tests

PYQ FREQUENCY
Moderate · 6 papers

REVISION PRIORITY
★★★☆☆

EXPECTED LEVEL
Qualifying / Part B

MEMORY HOOK
"Oxidation state → d-count → everything else."
Anchor every prediction to the d-electron count.

Correct Answer B $[SiF_6]^{2-}$ and $[Ca(H_2O)_6]^{2+}$

CONCEPT

Broad coordination-chemistry reasoning: oxidation states, coordination numbers, characteristic reactions and classic qualitative tests.

↓

LOGIC / WORKING

- As the oxidation state increases and size of central decreases ligand exchange rate decreases.

FINAL: (B) $[SiF_6]^{2-}$ **and** $[Ca(H_2O)_6]^{2+}$

SHORTCUT / EXAM TRICK

Identify the metal oxidation state and d-count first; most properties (colour, magnetism, geometry) follow from it.

COMMON MISTAKE

Skipping the oxidation-state/d-count step and guessing properties directly.

EXAM TIP

Learn the classic named tests (ring test = nitrate, Kurnakov = cis/trans Pt) — they recur in PYQs.

MEMORY TRICK

“Oxidation state → d-count → everything else.” Anchor every prediction to the d-electron count.

Why the Other Options Are Wrong

Correct answer: **B**

A

$[AlF_6]^{3-}$ and $[Sr(H_2O)_6]^{2+}$

AlF_6^{3-}/Sr aqua is not the pair with the required isoelectronic/structural relationship.

C

$[SF_6]$ and $[Mg(H_2O)_6]^{2+}$

SF_6 is neutral molecular and Mg aqua does not fit the intended comparison.

D

$[PF_6]^-$ and $[Ca(H_2O)_6]^{2+}$

PF_6^- pairing does not give the correct match; SiF_6^{2-} with $Ca(H_2O)_6^{2+}$ is intended.

TOPIC REVISION

Coordination Chemistry – General

6 PYQs · Last-minute revision

TOPIC SUMMARY

Broad coordination-chemistry reasoning: oxidation states, coordination numbers, characteristic reactions and classic qualitative tests.

IMPORTANT FORMULA SHEET

d-count = group − oxidation state
CN set by ligand size & charge
Colour ⇐ d–d / CT transitions
- Named tests: ring, Kurnakov

FREQUENTLY ASKED CONCEPTS

Oxidation states
Coordination number
Qualitative tests
- Structure–property links

COMMON MISTAKES & QUICK NOTES

Watch out:
Skipping the oxidation-state/d-count step and guessing properties directly.
Last-minute:
Identify the metal oxidation state and d-count first; most properties (colour, magnetism, geometry) follow from it.

MOST-REPEATED PYQs & EXPECTED IN EXAM

PYQs in this topic: Q30 Q54 Q72 Q81 Q125 Q139

Expect **1 question(s)** next session on **General coordination chemistry, oxidation states, qualitative tests.**

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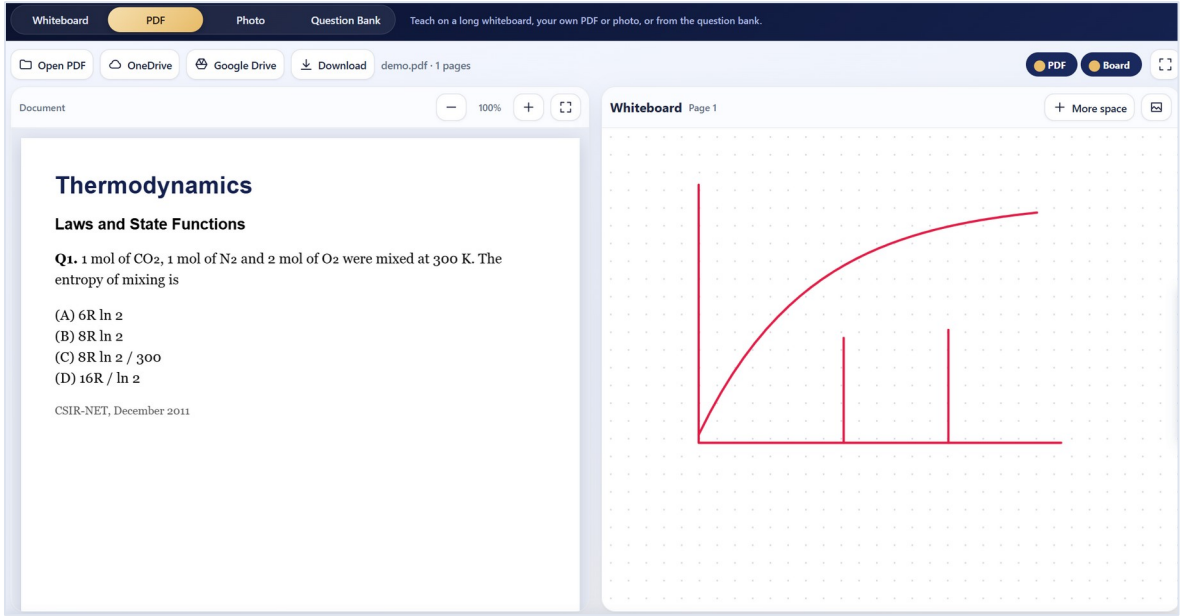
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