I.13 Coordination Chemistry

Civil Services 2016–2026: **67** parts, **695** marks · IFoS 2016–2025: **66** parts, **620** marks

Syllabus. (i) Bonding in transition metal complexes. Valence bond theory, crystal field theory and its modifications; applications of theories in the explanation of magnetism and electronic spectra of metal complexes. (ii) Isomerism in coordination compounds; IUPAC nomenclature of coordination compounds; stereochemistry of complexes with 4 and 6 coordination numbers; chelate effect and polynuclear complexes; trans effect and its theories; kinetics of substitution reactions in square-planar complexes; thermodynamic and kinetic stability of complexes. (iii) EAN rule, synthesis, structure and reactivity of metal carbonyls; carboxylate anions, carbonyl hydrides and metal nitrosyl compounds. (iv) Complexes with aromatic systems, synthesis, structure and bonding in metal olefin complexes, alkyne complexes and cyclopentadienyl complexes; coordinative unsaturation, oxidative addition reactions, insertion reactions, fluxional molecules and their characterization; compounds with metal-metal bonds and metal atom clusters.

Marks	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
CSE	130	60	50	70	40	50	70	60	70	50	45
IFoS	100	85	119	36	38	43	46	51	46	56	

How to use this chapter. Read every question once and mark the ones that repeat. Pick three, write them by hand against the clock (about 7 minutes for 10 marks), then compare with the model answers on vkcscience.com.

2026

CSE 2026 · Q5(f) Chelate effect and chelate ring size [5 marks]

What is chelate effect? How is it affected by the ring size?

CSE 2026 · Q5(g) Ferrocene, the sandwich compound [5 marks]

Why is ferrocene termed as a sandwich compound? Explain its structure.

CSE 2026 · Q5(h) Ionisation isomerism, and three pairs of isomers [5 marks]

What is ionization isomerism? Mention the type of isomerism in the given pairs of complexes :
(i) $[Cr(H_2O)_6Cl_3]$ and $[CrCl(H_2O)_5]Cl_2 \cdot H_2O$
(ii) $[Co(NH_3)_5SO_4]NO_3$ and $[Co(NH_3)_5NO_3]SO_4$
(iii) $[Pt(NH_3)_4][PtCl_6]$ and $[Pt(NH_3)_4Cl_2][PtCl_4]$

CSE 2026 · Q6(b) Pale pink $[Co(H_2O)_6]^{2+}$ and deep blue $[CoCl_4]^{2-}$; EAN rule; EAN of four complexes [20 marks]

(i) Why is the electronic spectrum of $[Co(H_2O)_6]^{2+}$ pale pink, whereas the spectrum of $[CoCl_4]^{2-}$ is deep blue? Explain.
(ii) What is EAN rule? Calculate the EAN value of the following :
(1) $[Cr(CO)_6]$ (2) $[Fe(CN)_6]^{4-}$ (3) $[Co(NH_3)_6]^{3+}$ (4) $[Ni(NH_3)_6]^{2+}$

CSE 2026 · Q6(c) Quadruple bond and bond order 4 in $[Re_2Cl_8]^{2-}$ [10 marks]

Describe the bond order and quadruple bonding in $[Re_2Cl_8]^{2-}$ ion.

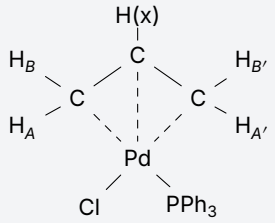
2025

CSE 2025 · Q5(f) Which complex has the larger Δ_o [10 marks]

Which complex ion has higher value of crystal field splitting energy (Δ_0)? Justify your answer.
(i) $[Co(H_2O)_6]^{3+}$ or $[Co(H_2O)_6]^{2+}$
(ii) $[Co(NH_3)_6]^{3+}$ or $[Rh(NH_3)_6]^{3+}$
(iii) $[Co(H_2O)_6]^{3+}$ or $[Co(NH_3)_6]^{3+}$

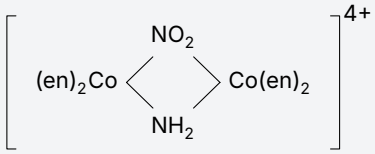
CSE 2025 · Q6(a) Rigid or fluxional: an allyl palladium complex [10 marks]

The following molecule shows the rigid or fluxional behaviour at higher temperature or in the presence of a base. Justify the answer with the help of ^1H NMR spectrum.



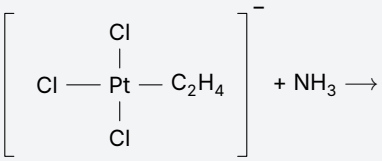
CSE 2025 · Q7(c) Stereoisomers of a doubly bridged dicobalt complex [10 marks]

Draw the possible stereoisomers of the following complex and explain their optical activity.



CSE 2025 · Q7(e) Substitution in $[PtCl_3(C_2H_4)]^-$ and the trans effect [10 marks]

Complete the following reaction and explain the mechanism with the help of pi-bonding theory.



CSE 2025 · Q8(e) Two oxidative additions of methyl iodide [10 marks]

Complete the following chemical reactions and indicate the category of these reactions. Justify your answer.
(i) $2\,[Co(CN)_5]^{3-}$ + MeI ⟶
(ii) $[Ru(CO)_3(PPh_3)_2]$ + MeI ⟶

IFoS 2025 · Q5(c) Hexaamminechromium(III) [8 marks]

Discuss the bonding in $[Cr(NH_3)_6]Cl_3$ with the help of valence bond theory. What is the magnetic nature of the complex?

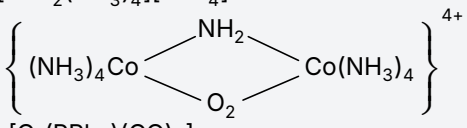
IFoS 2025 · Q5(d) Dicobalt octacarbonyl [8 marks]

Write the structure of $Co_2(CO)_8$. Explain how to differentiate between the terminal CO and bridging CO using IR spectrum.

IFoS 2025 · Q7(b) Coordination nomenclature [10 marks]

Write the IUPAC names of the following complexes:

(i) $[PtCl_2(NH_3)_4][PtCl_4]$

(ii) 

(iii) $[Cr(PPh_3)(CO)_5]$

(iv) $[CoCl(ONO)(en)_2]^+$

(v) $[PtCl_4(NH_3)_2]$

IFoS 2025 · Q7(c) Colour of iron(II) complexes; Dichloridobis(oxalato)chromate(III) [15 marks]

(i) The low-spin $[Fe(CN)_6]^{4-}$ and the high-spin $[Fe(H_2O)_6]^{2+}$ are colourless. Justify your answer. [5]

(ii) Draw the structure of geometrical isomers of the complex ion $[CrCl_2(ox)_2]^{3-}$. Can it exhibit optical isomerism? Justify your answer. [10]

IFoS 2025 · Q8(a) Alkyne–dicobalt bonding; Alkene insertion into metal bonds [15 marks]

(i) In $[Co_2(CO)_6(PhC{\equiv}CPh)]$, the acetylenic linkage (C — C) group lies above and right angles to the (Co — Co) vector. Write the structure and justify the bonding. [10]

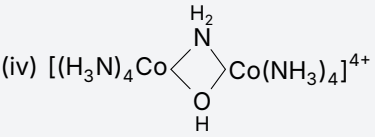
(ii) Alkene insertion is common for M–H bond but less common for M–R bond. Justify your answer. [5]

2024

CSE 2024 · Q5(c) IUPAC names of five complexes [10 marks]

Write the IUPAC nomenclature of the following complexes:

(i) $Na_2[ZnCl_4]$ (ii) $[PtCl_6]^{2-}$ (iii) $[Pt(py)_4][PtCl_4]$ (v) $Ni(CO)_4$

(iv) 

CSE 2024 · Q5(d) Zeise's salt: synthesis and structure [10 marks]

What is Zeise's salt? Outline its synthesis method. Describe its structure.

CSE 2024 · Q7(a) Splitting of d orbitals in a square-planar field [10 marks]

Show the splitting of 'd' orbitals in square planar field according to Crystal Field Theory (CFT).
Comment on the following statement:

'The difference in energy between the $d_{x^2-y^2}$ and d_{xy} orbitals in square planar field is identical to the difference between the same orbitals in the octahedral field.'

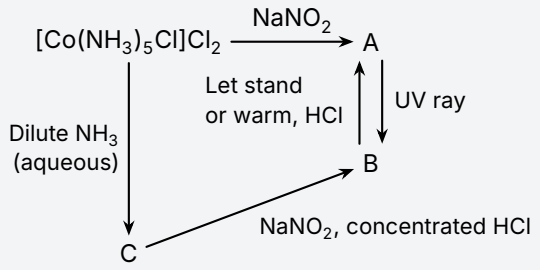
CSE 2024 · Q7(b) M–C and C–O bond orders in $Ni(CO)_4$, $[Co(CO)_4]^-$ and $[Fe(CO)_4]^{2-}$; Identify A, B and C [15 marks]

(i) The bond orders of some metal carbonyls are: *10*

	M – C bond order	C – O bond order
$Ni(CO)_4$	1.33	2.64
$[Co(CO)_4]^-$	1.89	2.14
$[Fe(CO)_4]^{2-}$	2.16	1.85

Explain the above facts.

(ii) Identify A, B and C. What is the relationship between A and B? *5*



CSE 2024 · Q7(c) $[CoF_6]^{3-}$ paramagnetic, $[Co(CN)_6]^{3-}$ diamagnetic; Structures and magnetic behaviour of $Co_2(CO)_8$ [25 marks]

(i) On the basis of Crystal Field Theory, account for the following statement:
While $[CoF_6]^{3-}$ is paramagnetic, $[Co(CN)_6]^{3-}$ is diamagnetic. *10*

(ii) Elucidate the structure(s) of $Co_2(CO)_8$. Comment on its magnetic behaviour. *15*

IFoS 2024 · Q5(b) Isomers of a cobalt $A_2B_2C_2$ complex [8 marks]

Draw the structures of possible diastereoisomers of $[Co(NH_3)_2(H_2O)_2Cl_2]Cl$. Among these isomer(s), which is/are optically active?

IFoS 2024 · Q5(c) Dicobalt octacarbonyl and infrared bands [8 marks]

Predict the structure of $Co(CO)_8$ with the help of 18-electron rule. What differences do you expect in the C = O stretching frequency(ies) between $Co(CO)_8$ and $Mn(CO)_{10}$? Explain.

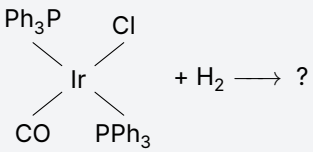
[Atomic number of Mn = 25; Co = 27]

IFoS 2024 · Q6(a) Magnetism and colour of Co(II) complexes [15 marks]

(i) Showing the crystal field splitting, calculate the spin only magnetic moment of $[CoCl_4]^{2-}$ and $[Co(H_2O)_6]^{2+}$.
(ii) The experimentally observed magnetic moment of which of these two species would deviate more from the calculated spin only value? Explain your answer.
(iii) Colour of which of these two species would be less intense? Explain your answer. 5+5+5=15

IFoS 2024 · Q7(b) Hydrogen addition to Vaska complex; Fluxionality of tetracyclopentadienyltitanium [15 marks]

(i) Write the product of the following reaction:



Explain the 'coordinative unsaturation' and 'oxidative addition' in the above reaction. 5

(ii) Explain how the fluxional behaviour of the molecule $[(\eta^1\text{–}C_5H_5)_2(\eta^5\text{–}C_5H_5)_2Ti]$ can be characterised. 10

2023

CSE 2023 · Q5(e) Trans effect: A and B from $[PtCl_4]^{2-}$ [10 marks]

Identify *A* and *B* in the substitution reaction given below:

$$[PtCl_4]^{2-} + NO_2^- \longrightarrow [A] \xrightarrow{NH_3} [B]$$

Justify by explaining the kinetic *trans*-effect using polarization theory.

CSE 2023 · Q6(b) Stereoisomers of $[Co(CN)_2(H_2O)_2(NH_3)_2]^+$ [10 marks]

Draw all possible stereoisomers for $[Co(CN)_2(H_2O)_2(NH_3)_2]^+$ complex ion.

CSE 2023 · Q6(c) IUPAC names of five complexes [10 marks]

Write the IUPAC nomenclature of the following complexes:
(i) $[Cr(H_2O)_4Cl_2]Cl$ (ii) $[Co(en)_3][Fe(CN)_6]$ (iii) $Na[Cr(H_2O)_2(ox)_2]$
(iv) $[Pd(CO)_2(H_2O)Cl]^+$ (v) $Na_4[(H_2O)_4V(\mu\text{-}OH)_2V(H_2O)_4]$

CSE 2023 · Q7(d) Electronic spectrum of $[Ni(OS(CH_3)_2)_6]^{2+}$ [10 marks]

Nickel was found to be coordinated with oxygen in the UV-visible spectrum of $[Ni(OS(CH_3)_2)_6]^{2+}$ complex ion. Predict theoretically the number of peaks and assign them to the corresponding electronic transitions.

CSE 2023 · Q8(a) Acetylferrocene and ferrocenecarboxylic acid from ferrocene [10 marks]

Sketch the synthesis of $[Fe(\eta^5-C_5H_5)(\eta^5-C_5H_4COCH_3)]$ and $[Fe(\eta^5-C_5H_5)(\eta^5-C_5H_4COOH)]$ complexes starting from $[Fe(\eta^5-C_5H_5)_2]$.

CSE 2023 · Q8(b) Spin-only magnetic moments of four complexes [10 marks]

Calculate the spin only magnetic moment ($\mu_{s.o.}$) of the central metal atom in the following complexes:
(i) $[Fe(H_2O)_5NO]^{2+}$ (ii) $[Cr(NCS)_6]^{3-}$ (iii) $[V(H_2O)_6]^{3+}$ (iv) $[Co(bpy)_3]^{2+}$

IFoS 2023 · Q5(c) Normal and inverse spinels [8 marks]

In a book, it is written that the structures of both Fe_3O_4 and Mn_3O_4 are normal spinel. With the help of CFSE, establish whether the structures written in the book are correct or not.

IFoS 2023 · Q5(d) All stereoisomers of the nickel glycinate complex [8 marks]

Draw all the possible isomers (diastereoisomers + enantiomers) for $[Ni(H_2NCH_2COO)_2(H_2O)_2]$.

IFoS 2023 · Q7(b) Structure of dimanganese decacarbonyl [15 marks]

Discuss the structure of $Mn_2(CO)_{10}$.

IFoS 2023 · Q7(c) Platinum–alkyne bonding [10 marks]

In $[Pt^0(\eta^2\text{-}PhC{\equiv}CPh)(PPh_3)_2]$, the C–C bond length is 1.32 Å and C–C–Ph bond angle is 140°. Write the structure and justify the bonding.

IFoS 2023 · Q8(a) Concerted and SN2 oxidative addition [10 marks]

Define oxidative-addition reaction. Taking suitable example, explain the following mechanisms for the oxidative-addition reaction:
(i) Concerted mechanism (ii) S_N2 mechanism

2022

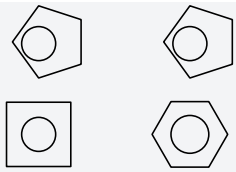
CSE 2022 · Q5(d) $[Ni(CO)_4]$ and $[Ni(CN)_4]^{4-}$: names, structures and shapes [10 marks]

Write IUPAC nomenclature of $[Ni(CO)_4]$ and $[Ni(CN)_4]^{4-}$. Give structure and draw their shapes with explanation.

CSE 2022 · Q6(a) Metal–metal bonds in $Cp_2Fe_2(CO)_4$; structure of Bi_5^{3+} [10 marks]

(i) Calculate the number of metal-metal bond in $Cp_2Fe_2(CO)_4$.
(ii) Determine the structural type of the metal atom cluster, Bi_5^{3+}.

CSE 2022 · Q6(c) Neutral mixed sandwich compound of a d^6 centre [10 marks]



Consider the above pairs of π-donor ligands:
Identify the d^6 metal ions/atom among Co(O), Mn(I), Fe(II), and Fe(III), which form neutral mixed sandwich compound. Explain.

CSE 2022 · Q6(e) Origin of the yellow colour of aqueous $FeCl_3$ [10 marks]

Aqueous solution of $FeCl_3$ is bright yellow and not pale-violet like other metal ions having high-spin d^5 configuration. Discuss the origin of the colour.

CSE 2022 · Q7(a) An optically active square-planar complex [10 marks]

Cite one example of an optically active tetracoordinated complex compound where the metal ion and donor atoms lie on a plane. Justify your answer.

CSE 2022 · Q7(e) Magnetic behaviour of copper(II) acetate and $[Cu(CN)_4]^{3-}$ [10 marks]

Compare and comment on the magnetic properties of the following complexes:
(i) $[Cu(OAc)_2]_2$ (ii) $[Cu(CN)_4]^{3-}$

CSE 2022 · Q8(a) The more stable linkage isomer of a cyanide-bridged complex [10 marks]

Which one is more stable between the two isomers? Explain.
$[(H_3N)_5Cr-CN-Cr(CN)_5]$
$[(H_3N)_5Cr-NC-Cr(CN)_5]$

IFoS 2022 · Q5(c) Oxidation of cobalt ammine [8 marks]

Explain why $[Co(H_2O)_6]^{2+}$ is stable but $[Co(NH_3)_6]^{2+}$ is readily oxidized to $[Co(NH_3)_6]^{3+}$ in air.

IFoS 2022 · Q5(d) Absorption bands of aqueous V(III) [8 marks]

For the complex $[V(H_2O)_6]^{3+}$, how many absorption bands are expected in principle in its UV-Vis spectra and why? Show the ground state to excited state transition for each band.

IFoS 2022 · Q6(c) Octahedral and tetrahedral splitting; Magnetism of octahedral and tetrahedral Ni(II) [15 marks]

(i) Draw the crystal field splitting diagram of d-orbitals in octahedral and tetrahedral fields. In which case would the energy difference (Δ) between the two states be lower? Why would it be so? 8
(ii) Calculate the spin only magnetic moment for Ni^{2+} (d^8) in octahedral and tetrahedral complexes. In which case is the experimental value expected to be much higher than the calculated spin only value? Give reasons. 7

IFoS 2022 · Q7(b) Square-planar substitution and trans effect; Fluxional molecules and variable-temperature NMR [15 marks]

(i) Give a mechanism for substitution reaction in square planar complexes. Hence, give an explanation for 'Trans effect'. 10
(ii) What do you understand by 'fluxional molecule'? Taking an example of your choice, show how the fluxional behaviour can be characterized with the help of a spectroscopic technique. 5

2021

CSE 2021 · Q5(d) Geometrical isomers and stereoisomers of $M(AB)b_2c_2$ [10 marks]

How many geometrical isomers and stereoisomers are possible in the coordination compounds of the type $(AB)Mb_2c_2$(AB—bidentate ligand)?

CSE 2021 · Q7(b) Bonding in two fluxional molecules from variable-temperature ^1H NMR [20 marks]

How would you account for bonding in the following fluxional molecules based on ^1H NMR spectral studies at variable temperatures?
(i) $(C_5H_5)_4Ti$ (ii) $C_3(CH_3)_4Fe(CO)_4$

CSE 2021 · Q8(c) Linear and bent nitrosyl in $[Ru(PPh_3)_2Cl(NO)_2]^+$ [20 marks]

In the coordination compound $[Ru(PPh_3)_2Cl(NO)_2]^+$, one NO ligand bonds linearly while the other is bent. Explain the different modes of bonding of NO ligands in this molecule and expected M—N bond orders.

IFoS 2021 · Q5(d) Effective atomic number rule [8 marks]

What is EAN rule? Is this rule followed by the complexes given below?
(i) $Cr(CO)_6$ (ii) $Ni(CO)_4$ (iii) $Fe(CO)_9$

IFoS 2021 · Q6(c) Cis and trans dichlorotetraamminecobalt(III) [10 marks]

What is Stereoisomerism? Explain isomerism in $[Co(NH_3)_4Cl_2]^+$ emphasizing on structure and colour of the complex.

IFoS 2021 · Q7(c) Pi donors and acceptors in octahedral complexes [10 marks]

How do π-donor and π-acceptor ligands affect the spectral properties of metal complexes? Explain with MO diagram.

IFoS 2021 · Q8(a) Structures from coordination names [15 marks]

Draw the chemical structures of the following coordination compounds:
(i) Potassium trans-dichlorodinitro platinate (II)
(ii) 1,6 dichloro-2,3-dinitro-ethylene diamine platinum (IV)
(iii) trans tetraammine dichloro cobalt (III) ion
(iv) Ammonium iron (II) sulphate (Mohr's salt)
(v) μ-amido-μ-superoxo bis (tetraammine) cobalt (III)

2020

CSE 2020 · Q4(d) Diamagnetic $[Ni(CN)_4]^{2-}$ and paramagnetic $[NiCl_4]^{2-}$ [10 marks]

The complex $[Ni(CN)_4]^{2-}$ is diamagnetic, but $[NiCl_4]^{2-}$ is paramagnetic and has two unpaired electrons. Explain these observations and deduce the structure of two complexes.

CSE 2020 · Q4(e) Why d–d transitions are forbidden, weak, and yet observed [10 marks]

Why are d-d electronic transition forbidden? Why are they weakly absorbing and why do they occur at all?

CSE 2020 · Q8(c) IUPAC names of five compounds [10 marks]

Write the name of the following complexes using the IUPAC nomenclature :
(i) $[Co(NH_3)_6]Cl_3$, (ii) $Na_2[ZnCl_4]$, (iii) $[Pt(Py)_4][PtCl_4]$,
(iv) $[(NH_3)_5Co \cdot NH_3 \cdot Co(NH_3)_5](NO_3)_5$, (v) $AlK(SO_4)_2 \cdot 12\,H_2O$

CSE 2020 · Q8(d) Four short and two long Cu–F bonds in CuF_2: Jahn–Teller distortion [10 marks]

In the crystal structure of CuF_2, the Cu^{2+} is six-coordinated with four F^- at a distance of 1.93 Å and two F^- at 2.27 Å. Explain the reason(s) for this.

IFoS 2020 · Q5(b) Zeise's salt and its structure [8 marks]

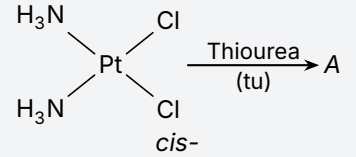
What is Zeise's salt? Discuss its structure.

IFoS 2020 · Q7(a) $[CoF_6]^{3-}$ and $[Co(CN)_6]^{3-}$: formation and magnetism [15 marks]

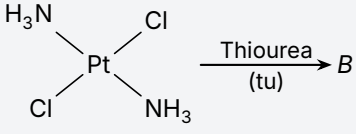
Discuss the formation of $[CoF_6]^{3-}$ and $[Co(CN)_6]^{3-}$ complex ions. Comment on their magnetic moment. [Z for Co = 27]

IFoS 2020 · Q8(a) cis- and trans-$[PtCl_2(NH_3)_2]$ with thiourea; isomers of $[Co(en)_2Cl_2]Cl$ [15 marks]

(i)



cis-



trans-

Identify *A* and *B*, and explain your answer. 8

(ii) Show all the possible isomers of $[Co(en)_2Cl_2]Cl$ and mention their categories of isomerism. [en ≡ ethylenediamine] 7

2019

CSE 2019 · Q1(b) Naming the conformations of chelate rings [10 marks]

Describe any three systems of nomenclature of conformational isomers of complexes.

CSE 2019 · Q4(c)(i) Limitations of crystal field theory and the modifications [10 marks]

What are the limitations of crystal field theory in explaining the bonding of coordination complexes. What modifications were suggested to overcome the limitations.

CSE 2019 · Q5(b) d-orbital splitting in square-pyramidal and trigonal-bipyramidal fields [10 marks]

Draw, giving reasons, the d-orbital splitting in the 5 coordinate square pyramidal and trigonal bipyramidal arrangements.

CSE 2019 · Q7(b) Tetragonal distortion and the square-planar limit [15 marks]

Why tetragonal distortions occur in octahedral complexes? Illustrate it with suitable example. What will be the result of the extreme distortion to the octahedral complex? Present the d-orbital splitting scheme in this case.

CSE 2019 · Q8(b) Chelate effect, template effect and entropy in complex stability [15 marks]

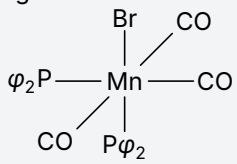
Describe with suitable examples the role of Chelate effect, Template effect and the entropy effect on the stability of complexes.

CSE 2019 · Q8(c) Structure of ferrocene and its MO description [10 marks]

Depict the structure of ferrocene and describe the bonding of it by Molecular orbital theory including orbital diagrams.

IFoS 2019 · Q1(a) Naming a manganese carbonyl phosphine complex; shape of ICl_4^- [8 marks]

(i) Using the internationally accepted naming convention for ligands in an octahedral complex of an element Mn, what name would you give to the following?



φ is Phenyl group

(ii) Predict the shape of ICl_4^-

Z, Cl = 17

Z, I = 53 4+4=8

IFoS 2019 · Q5(c) Diamagnetic $CsAuCl_3$: is there gold(II)? [8 marks]

The compound with the empirical formula $CsAuCl_3$ is diamagnetic having no metal-to-metal bonds.

(i) Is there gold(II) in the compound?

(ii) Propose a structure for the compound.

Z, Au = 79 2+6=8

IFoS 2019 · Q7(b) Metal–metal bonds; trinuclear and tetranuclear clusters [10 marks]

(i) Give reaction of two compounds containing metal-metal bonds. 5

(ii) Explain trinuclear clusters and tetranuclear clusters. 5

IFoS 2019 · Q8(b) Trans-influence versus trans-effect; Ni(II) octahedral complexes are outer-orbital [10 marks]

(i) Explain the difference between trans-influence and trans-effect using appropriate examples.

(ii) Show that all octahedral complexes of nickel(II) must be outer orbital complexes.

Z, Ni = 28 5+5=10

2018

CSE 2018 · Q5(c) Structures of two complexes; IUPAC names of two salts [10 marks]

(i) Draw the structure of the following complexes:

(A) bis (η^6-benzene) chromium (O)

(B) fac-triaquatris (dimethylamine) cobalt (III) tetraoxosulfate (VI)

(ii) Give IUPAC nomenclature of

(A) $Na[B(NO_3)_4]$ (B) $[Co(NH_3)_6][CoCl_6]$

CSE 2018 · Q6(c)(i) Geometry of $[Ni(H_2O)_6]^{2+}$ by valence bond theory [5 marks]

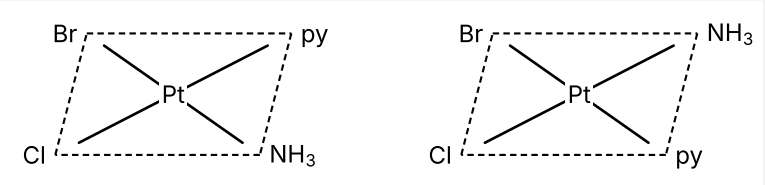
Determine the geometry of $[Ni(H_2O)_6]^{2+}$ (paramagnetic complex with two unpaired electrons) using valence bond theory.

CSE 2018 · Q6(c)(ii) Orgel-diagram assignment of the bands of $[Ni(H_2O)_6]^{2+}$; 10Dq [10 marks]

Using Orgel diagram, assign the absorption bands of $[Ni(H_2O)_6]^{2+}$ at 8500, 13800 and 25300 cm^{-1} in solution. Calculate the 10 Dq value.

CSE 2018 · Q7(d) Two isomers of $[PtBrCl(NH_3)(py)]$ from $[PtCl_4]^{2-}$ by the trans effect [10 marks]

How do you prepare the above isomers starting from $[PtCl_4]^{2-}$ using the concept of trans effect?
(Order of trans directing ability: $Br^- > Cl^- > py > NH_3$)



CSE 2018 · Q8(a)(ii) Number of Re–Re bonds in $[Re_2Cl_8]^{2-}$ [5 marks]

Determine the number of metal-metal bond(s) in $[Re_2Cl_8]^{2-}$ (Z = 75) using simplified MO energy level diagram.

CSE 2018 · Q8(d) Stereoisomers of $[PtCl_2Br_2(NH_3)_2]$ [10 marks]

Draw all possible stereoisomers of $[PtCl_2Br_2(NH_3)_2]$.

IFoS 2018 · Q5(a) Isomers of $[Co(NH_3)_5(NO_2)]Cl_2$ [8 marks]

How many isomers are possible for $[Co(NH_3)_5(NO_2)]Cl_2$? Draw their structures and mention their names.

IFoS 2018 · Q5(b) Labile and non-labile complexes [8 marks]

What are labile and non-labile complexes? Identify labile and non-labile complexes from the following :
(i) $[Ni(H_2O)_6]^{2+}$
(ii) $[Co(NH_3)_5(H_2O)]^{3+}$

IFoS 2018 · Q5(c) Fischer carbene from $W(CO)_6$, PhLi and Me_3O^+ [8 marks]

Identify the intermediate and the product in the following reaction sequence :

$$W(CO)_6 \xrightarrow{PhLi} \text{Intermediate} \xrightarrow[\downarrow\ LiBF_4,\ Me_2O]{[Me_3O]^+\ BF_4^-} \text{Product}$$

IFoS 2018 · Q6(a) d-electron configuration of a Co(II) complex with μ = 4.0 BM [15 marks]

The magnetic moment of a certain Co(II) octahedral complex is 4·0 μ_B. What is its *d*-electron configuration?

IFoS 2018 · Q6(b) ν(CO) in $Ni(CO)_4$, $[Co(CO)_4]^-$ and $[Fe(CO)_4]^{2-}$ [15 marks]

Explain the variation in ν_{CO} (cm^{-1}) of the following isoelectronic metal carbonyls :

Compound	ν_{CO} *(cm^{-1})*
$Ni(CO)_4$	2060
$[Co(CO)_4]^-$	1890
$[Fe(CO)_4]^{2-}$	1790

IFoS 2018 · Q6(c) Geometrical isomers of $[Ru(H_2O)_3Cl_3]$ [10 marks]

How many geometrical isomers are possible for $[Ru(H_2O)_3Cl_3]$? Draw their structures and indicate their names.

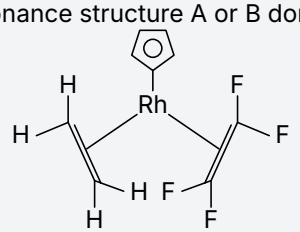
IFoS 2018 · Q7(a) Structures and electron counts of $Co_2(CO)_8$ and $Mn_2(CO)_{10}$ [15 marks]

Draw the structures of the following metal carbonyls and show electron counting for each one of the complexes :
(i) $Co_2(CO)_8$

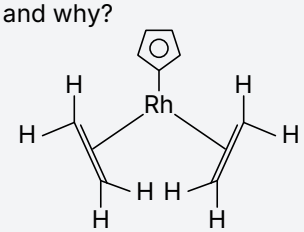
(ii) $Mn_2(CO)_{10}$

IFoS 2018 · Q7(b) Metal–olefin complexes: π-complex versus metallacyclopropane [15 marks]

Draw two resonance structures (A and B) for metal olefin complex, $L_nM(C_2X_4)$. In which of the following complexes does the resonance structure A or B dominate and why?



(i)



(ii)

IFoS 2018 · Q7(c) Chelate effect: log K of Cd^{2+} with en and with NH_3 [10 marks]

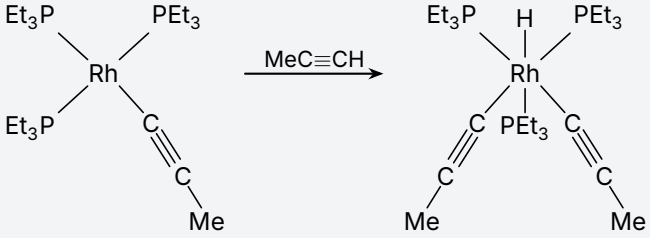
Consider the following equations and explain the observed trend in log K values. en refers to ethylenediamine, $H_2NCH_2CH_2NH_2$.

$[Cd(H_2O)_6]^{2+} + en \rightleftharpoons [Cd(en)(H_2O)_4]^{2+} + 2\,H_2O,\ \log K = 5{\cdot}84$

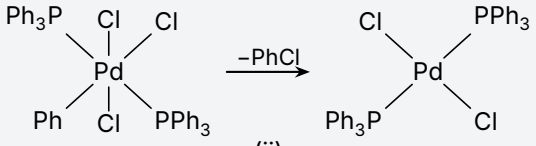
$[Cd(H_2O)_6]^{2+} + 2\,NH_3 \rightleftharpoons [Cd(NH_3)_2(H_2O)_4]^{2+} + 2\,H_2O,\ \log K = 4{\cdot}95.$

IFoS 2018 · Q8(a) Oxidative addition versus reductive elimination [15 marks]

What are the key points invoked for oxidative addition (OA) and reductive elimination (RE)? In the given two equations below, which one corresponds to OA and which one corresponds to RE and why?



(i)



(ii)

2017

CSE 2017 · Q5(d) Ferrocene: electrophilic substitution and oxidation [10 marks]

Explain the following properties of Ferrocene :

(i) Easy electrophilic substitution of its Cp ring.

(ii) Oxidation is difficult in comparison to that of cobaltocene.

CSE 2017 · Q7(a)(i) Vaska's compound: structure and oxidative addition of HCl and O_2 [15 marks]

Write Vaska's catalyst with structure and show its oxidative addition with HCl and oxygen.

CSE 2017 · Q7(a)(ii) Sodium nitroprusside from $K_4[Fe(CN)_6]$; reaction with S^{2-} [10 marks]

How is $K_4[Fe(CN)_6]$ is converted into sodium nitroprusside? Write reaction of S^{2-} ion with sodium nitroprusside.

CSE 2017 · Q8(a)(i) EAN rule applied to $[Fe(CN)_6]^{4-}$ and $[Fe(CN)_6]^{3-}$ [10 marks]

What is meant by EAN rule applied to the complexes? Apply the concept of EAN rule on the following two complexes $[Fe(CN)_6]^{4-}$ and $[Fe(CN)_6]^{3-}$ and draw your conclusion about the validity of the rule.

CSE 2017 · Q8(a)(ii) Crystal field theory; $[CoF_6]^{3-}$ versus $[Co(NH_3)_6]^{3+}$ [15 marks]

Explain crystal field theory. How does it differ from valence bond theory? How does this theory account for the fact that $[CoF_6]^{3-}$ is paramagnetic while $[Co(NH_3)_6]^{3+}$ is diamagnetic though both are octahedral.

IFoS 2017 · Q5(a) $[NiCl_4]^{2-}$ and $[Co(H_2O)_6]^{2+}$: splitting, CFSE and spin-only moment [20 marks]

Draw the structures and d-orbital splitting diagrams of (i) $[NiCl_4]^{2-}$, and (ii) $[Co(H_2O)_6]^{3+}$. Calculate their crystal-field stabilization energy (CFSE) and spin-only magnetic moment values. 10+10=20

IFoS 2017 · Q6(a) Bonding in $Cr(CO)_6$ and Zeise's salt anion [20 marks]

Explain the structure and bonding in $[Cr(CO)_6]$ and $[PtCl_3(C_2H_4)]^-$, showing metal-ligand orbital interactions, both σ-type and π-type. In each case, show the counting of valence-electrons around the metal. 10+10=20

IFoS 2017 · Q6(b) CO insertion in a rhodium alkyl complex [15 marks]

Consider CO insertion reaction in $[Rh(PPh_3)_2(CO)_2(CH_2CH_2R)]$. Draw the structure of the reactant and the product. Also identify the oxidation state of Rh in the reactant and in the product, showing valence-electron count around Rh in each case.

IFoS 2017 · Q6(c) Spin state of $[Mn(H_2O)_6]^{2+}$ from Δo and pairing energy [5 marks]

The Δ_0 value for $[Mn(H_2O)_6]^{3+}$ is 21,000 cm^{-1}. For this metal ion, the value of pairing energy is 28,000 cm^{-1}. Decide the spin-state of the complex. Briefly justify your answer.

IFoS 2017 · Q7(a) Solid-state structure of $Co_2(CO)_8$ [10 marks]

Draw the solid-state structure of $Co_2(CO)_8$ and show valence-electron count around Co atom.

IFoS 2017 · Q7(c) Geometrical isomers of $[Co(NH_3)_4Cl_2]^+$ [5 marks]

Consider the complex $[Co(NH_3)_4Cl_2]^+$. Draw the structures of possible geometrical isomers.

IFoS 2017 · Q7(d) Ferrocene: structure and 18-electron count [10 marks]

Draw the structure of ferrocene. Showing the number of electrons contributed, count the number of valence-electrons around the Fe atom.

2016

CSE 2016 · Q5(a)(i) Splitting of d orbitals in a square-planar field [5 marks]

Explain the pattern of splitting of *d*-orbitals in a square-planar ligand field. Label each energy level properly.

CSE 2016 · Q5(a)(ii) CFSE and spin-only moment of $[Co(NH_3)_6]Cl_2$ [5 marks]

Calculate the crystal-field-stabilization energy and spin-only magnetic moment of $[Co(NH_3)_6]Cl_2$.

CSE 2016 · Q5(b) Isomers of $[CoCl_2(en)_2]^+$; is there a meso form? [10 marks]

Draw labelled structures of all the possible isomers of dichloro bis (ethylene-diamine) cobalt (III) ion. Does a meso form exist? Give reason to support your answer.

CSE 2016 · Q5(c) Structure of $Fe_2(CO)_9$ and the 18-electron rule [10 marks]

Write the structure of $Fe_2(CO)_9$. Show that each Fe atom conform to the 18 electron rule.

CSE 2016 · Q5(d) Oxidative addition against insertion [10 marks]

What do you understand by an "oxidative addition" reaction? How does it differ from an "insertion-reaction"? Give one example in each case.

CSE 2016 · Q6(a)(ii) Labile complexes; lability and d-electron configuration [10 marks]

What are "labile" complexes? Outline the relationship between lability and electronic structure of a complex. Name the type of method used in the study of such complexes.

CSE 2016 · Q6(b) Crystal field stabilisation energy and the factors that fix it [15 marks]

Explain crystal-field stabilization-energy. What are the factors that affect its magnitude?

CSE 2016 · Q6(c) IUPAC names of $K_3[Fe(CN)_5NO]$ and $[Co(NO_2)_3(NH_3)_3]$ [10 marks]

Write IUPAC nomenclature of the following :
(i) $K_3[Fe(CN)_5NO]$
(ii) $[CO(NO_2)_3(NH_3)_3]$

CSE 2016 · Q7(a)(i) Metal carbonyls; Mond's process; tetrahedral $Ni(CO)_4$ [15 marks]

What are metal carbonyls? How $Ni(CO)_4$ is obtained by Mond's process? Show that the molecule $Ni(CO)_4$, has a tetrahedral structure.

CSE 2016 · Q7(c) cis- and trans-$[PtCl_2(NH_3)_2]$: synthesis by the trans effect [10 marks]

Starting with $[PtCl_4]^{2-}$, prepare diammine dichloro platinum (II). Name the isomer formed. Choose the relevant starting material and write all the steps to get the other geometrical isomer of the above product.

CSE 2016 · Q8(a)(i) Low-spin and high-spin complexes; $[CoF_6]^{3-}$ and $[Co(NH_3)_6]^{3+}$ [15 marks]

What are low-spin and high-spin complexes? Indicate spin states of CoF_6^{3-} and $Co(NH_3)_6^{3+}$ complexes. Explain their magnetic character.

CSE 2016 · Q8(b) Fluxional molecules and their detection by NMR [15 marks]

What are "Fluxional" molecules? How does *nmr* spectroscopy help the detection of fluxional character?

IFoS 2016 · Q5(b)(i) Chelate effect [5 marks]

Explain the following terms :
(i) Chelate effect

IFoS 2016 · Q5(b)(ii) Lability [5 marks]

Explain the following terms :
(ii) Lability

IFoS 2016 · Q5(c)(ii) Co^{2+} salts stable, Co^{2+} complexes easily oxidised [5 marks]

Explain why—
(ii) Co^{2+} salts are stabler than those of Co^{3+} salts, but solutions of Co^{2+} complexes get readily oxidized to Co^{3+} complexes. (At. No. of Co is 27)

IFoS 2016 · Q5(d)(ii) Splitting of d orbitals in a square-planar field [5 marks]

Explain the pattern of splitting of *d*-orbitals in a square-planar ligand field. Label each energy level.

IFoS 2016 · Q6(a)(i) Crystal field stabilisation energy and the factors that fix it [10 marks]

Explain crystal field stabilization energy (CFSE). What are the factors that affect its magnitude?

IFoS 2016 · Q6(a)(ii) CFSE and magnetic moments of $FeCl_3.6H_2O$ and $K_4[Fe(CN)_6]$ [10 marks]

Calculate CFSE and magnetic moments in case of
$FeCl_3 \cdot 6\,H_2O$ and $K_4Fe(CN)_6$

IFoS 2016 · Q6(c)(i) IUPAC names of two complexes [5 marks]

Write the IUPAC nomenclature of the following :
(1) $K_3[Fe(CN)_5 \cdot NO]$
(2) $[Co(NO_2)_3 \cdot (NH_3)_3]$

IFoS 2016 · Q6(c)(ii) Ce^{3+} colourless, Ti^{3+} purple [5 marks]

Why Ce^{3+} ion ($4f^1$) is colourless, whereas Ti^{3+} ($3d^1$) solution is purple in colour?

IFoS 2016 · Q7(a)(i) Metal carbonyls; how they are formed; tetrahedral $Ni(CO)_4$ [10 marks]

What are carbonyls? How are they formed? Show that the molecule $Ni(CO)_4$ has a tetrahedral structure.

IFoS 2016 · Q7(a)(ii) Structure of $Fe_2(CO)_9$ and the 18-electron rule [10 marks]

Write the structure of $Fe_2(CO)_9$. Show that each iron atom in the structure conforms to the 18*e* rule.

IFoS 2016 · Q7(c) Isomers of $[CoCl_2(en)_2]^+$; is there a meso form? [10 marks]

Draw labelled structures of all the possible isomers of dichloro-*bis*(ethylenediamine) cobalt(III) ion. Does a *meso*-form exist? Give reason to support your answer.

IFoS 2016 · Q8(b)(i) cis-$[PtCl_2(NH_3)_2]$ from $[PtCl_4]^{2-}$ [4 marks]

Starting with $[PtCl_4]^{2-}$, prepare diamine dichloroplatinum(II). Name the isomer formed.

IFoS 2016 · Q8(b)(ii) trans-$[PtCl_2(NH_3)_2]$: starting material and steps [6 marks]

Choose the relevant starting material and write all the steps to get the other geometrical isomer of the above product.

IFoS 2016 · Q8(c)(i) Oxidative addition [5 marks]

What do you understand by an ‘oxidative addition’ reaction?

IFoS 2016 · Q8(c)(ii) Oxidative addition against insertion [5 marks]

How does it differ from an ‘insertion reaction’? Give example in each case.