

COORDINATION COMPOUNDS

Q.No	Question	Marks
Multiple Choice Question		
Q.90	<p>A co-ordination compound Pentaaminechloridocobalt(III)sulfate is dissolved in water. When a few drops of chemical 'A' is added to the solution, it gives white precipitate.</p> <p>Identify chemical 'A'.</p> <p>A. AgCl B. AgNO₃ C. BaSO₄ D. BaCl₂</p>	1
Q.91	<p>How many ions will be produced by the complex compound [Cr(en)₃]Cl₃ when it is dissolved in water?</p> <p>A. 2 B. 4 C. 7 D. 10</p>	1
Q.92	<p>In the complex compound Fe₄[Fe(CN)₆]₃ oxidation states of counter ion Fe and central metal ion Fe respectively are;</p> <p>A. II, III B. III, II C. IV, III D. II, II</p>	1
Q.93	<p>When a co-ordination compound is dissolved in water it produces three moles of potassium ion as cation and one mole co-ordination entity as anion. The central metal ion Fe in entity is surrounded by three didentate anionic ligands.</p> <p>What is the oxidation state of Fe ion in the compound?</p> <p>A. II B. III C. 0 D. I</p>	1

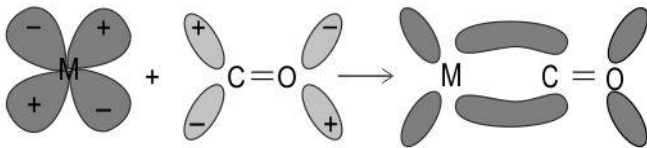


Q.94	<p>In an octahedral coordination entity the metal ion is surrounded by 6 F^- ions. If crystal field splitting energy for this complex is Δ_0 and electron pairing energy is P then which of the following expression is correct about the complex?</p> <p>A. $\Delta_0 = P$ B. $\Delta_0 < P$ C. $\Delta_0 > P$ D. $\Delta_0 \geq P$</p>	1
Q.95	<p>$[M(AA)X_2Y_2]$ is a type of a co-ordinate compound in which M= metal ion, AA= didentate ligand, X= monodentate ligand, and Y=monodentate ligand.</p> <p>Which of the following isomerisms does this compound exhibit?</p> <p>A. Co-ordination isomerism B. Linkage isomerism C. Geometrical isomerism D. Optical isomerism</p>	1
Q.96	<p>As per the Crystal field theory, which of the following is correct about the repulsion between ligands and d_{xy}, d_{yz}, d_{zx} orbitals in tetrahedral complexes?</p> <p>A. It is more than that in octahedral complexes B. It is less than that in octahedral complexes C. It is the same as in octahedral complexes D. It is zero</p>	1
Q.97	<p>Which of the following coordination compounds is diamagnetic, has 0 unpaired electrons and has an octahedral geometry?</p> <p>[Atomic number: Mn - 25, Ni - 28, Fe - 26, Cu - 29]</p> <p>A. $[MnCl_6]^{-3}$ B. $[Ni(CN)_4]^{-2}$ C. $[Fe(CN)_6]^{-4}$ D. $[CuCl_4]^{-2}$</p>	1
Free Response Questions/Subjective Questions		
Q.98	<p>In an experiment Test Tube 'A' contains $FeSO_4(NH_4)_2SO_4 \cdot 6H_2O$ solution and test tube 'B' contains $K_3[Fe(C_2O_4)_3]$ solution. On adding few drops of KSCN in the two test tubes, solution of one of the test tubes turns into red.</p> <p>i) Identify which out of two solutions in the test tubes 'A' or 'B' turns into red? ii) Give reason why does one solution give red colour precipitate with KSCN but other solution does not show any change.</p>	2



Q.99	<p>$[\text{Ni}(\text{CN})_4]^{2-}$, when kept in magnetic field, is weakly repelled where as $[\text{Co}(\text{F})_6]^{3-}$ is weakly attracted in the magnetic field. Justify with the help of orbital representation.</p> <p>(Atomic number of Ni =28, Co = 27)</p>	4
Q.100	<p>There are two samples solutions of complex compounds kept in two test tubes, A and B. Test tube 'A' contains the solution of $[\text{Co}(\text{NH}_3)_3\text{Cl}_3]$ complex, and test tube 'B' contains the solution of complex $[\text{CoCl}_2(\text{en})_2]^+$.</p> <p>If plane polarised light is allowed to pass through these solutions, which sample out of A and B can rotate plane polarised light and why?</p>	2
Q.101	<p>Given below is a reaction of the formation of a complex ML_n.</p> $[\text{M}(\text{H}_2\text{O})_n] + n\text{L} \longrightarrow \text{ML}_n + n\text{H}_2\text{O}$ <p>Write overall stability constant β_n expression for it.</p> <p>If β_n for the above reaction is 2.1×10^{13}, find out the over all dissociation constant of the complex.</p>	2
Q.102	<p>One mole of an isomer of complex $[\text{Cr}(\text{H}_2\text{O})_6]\text{Cl}_3$ when treated with AgNO_3 produces 2 moles of a white precipitate of AgCl. Write the formula of this isomer of the complex and show how the metal-ligand bonding differs in the two isomers though both are octahedral.</p>	3
Q.103	<p>A complex $[\text{Co}(\text{a})_4(\text{b})_2]\text{Br}$ is octahedral in shape. The oxidation state of Co is +3. When this complex is treated with AgNO_3 it gives one mole yellow precipitate of AgBr.</p> <p>Based on the above information show, what is the denticity and charge on the ligands a and b. Give reason for it.</p>	2
Q.104	<p>A coordination complex compound of Cr^{+3} is homoleptic and optically active. Draw the structures of optical isomers of the compound if the general formula of the complex is $[\text{M}(\text{AA})_3]^{3+}$ where M= Cr and (AA) = didentate ligand.</p>	3
Q.105	<p>Heteroleptic complexes with co-ordination number 6 show geometrical isomerism. A complex $[\text{MA}_3\text{B}_3]$ shows geometrical isomerism. If central metal ion M has +3 oxidation state. then</p> <ol style="list-style-type: none"> Predict the denticity and charge on ligands A & B in the given complex. Draw the structure of two geometrical isomers of the complex and name them. 	4
Q.106	<p>Coordination compounds are of great importance in medicinal chemistry. Explain how EDTA complex of calcium is useful in saving lives from hazardous lead metal?</p>	1
Q.107	<p>$[\text{Co}(\text{NH}_3)_6]^{3+}$ and $[\text{Co}(\text{H}_2\text{O})_6]^{2+}$ are two octahedral complexes of Co.</p>	3



	(i) Which one of them will have LESS crystal field splitting energy? (ii) Which factor influences splitting of d orbitals in these two complexes?	
Q.108	Extraction of Silver from its ore Ag_2S involves several steps. In one of the steps, NaCN is added to the solution. i) Explain the reason why NaCN is added to the solution? ii) Why Zn metal is used to recover the Ag metal? Explain with the help of chemical reactions.	3
Q.109	The image given below shows bonding in a carbonyl compound.  Answer the following questions to describe the bonding in the metal carbonyl. i) What type of bond is formed by the donation of a lone pair of electrons of CO to central metal ion? ii) What type of interaction between metal and CO ligands creates a synergic effect? iii) How is Δ_0 value affected by the interaction of CO ligands and metal ion in metal carbonyl?	5
Q.110	(i) Give a reason why all salts of sodium and potassium are white in colour. (ii) What will be the formula of Cr^{+3} complex with H_2O and Cl^- as ligands if its molar conductivity is similar to salt with the formula AB_2 . [A is the metal and B is the non-metal].	3
Q.111	(a) Mrs. Dey is a goldsmith. She got an order to make a silver bangle. Write down the equations of the reaction that is most likely to be carried out by her workers in her workshop to extract the required silver from its sulphide ore. (b) Write the distribution of the electrons in the central metal ion of the coordination complex formed after extraction of silver. Justify your answer.	4
Q.112	In an unknown complex $[\text{M}(\text{X})_4]$, the oxidation state of central metal is zero i.e. M (0). If in an experiment metal M is found to be Ni then predict whether the ligand X in the formula is CO or CN to give a stable complex. Justify your answer and predict the shape of the molecule.	2
Q.113	When AgNO_3 solution is added into the solution of a co-ordination compound $\text{PdCl}_2 \cdot 4\text{NH}_3$, it produces 2 moles of AgCl precipitate. On the basis of the information above, designate the following:	2

	<ul style="list-style-type: none"> - coordination entity - counter ions - coordination number of central metal ion - the oxidation number of Pd 	
Q.114	<p>(i) A co-ordination compound $[\text{Co}(x)_6]^{3-}$ shows d^2sp^3 hybridisation. Identify the nature of ligand x as weak or strong.</p> <p>(ii) Explain how does the presence of ligand x affect crystal field splitting energy Δ_0 and pairing energy P.</p> <p>(atomic number of Cobalt is 27)</p>	3

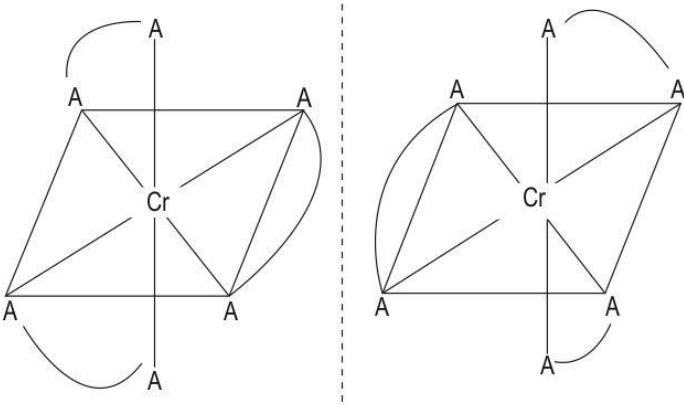
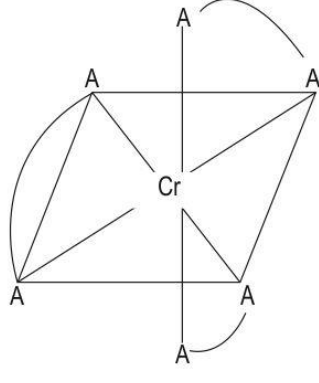


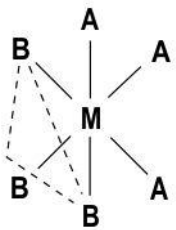
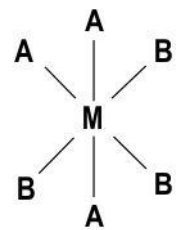
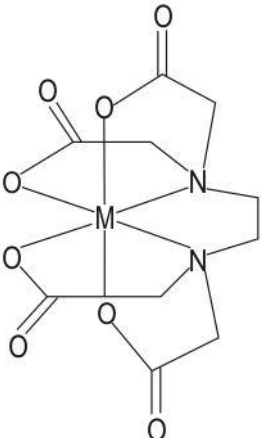
Answer Key and Marking Scheme

Q.No	Answers	Marks
Q.90	D. BaCl_2	1
Q.91	B. 4	1
Q.92	B. III, II	1
Q.93	B. III	1
Q.94	B. $\Delta_o < P$	1
Q.95	D. Optical isomerism	1
Q.96	A. It is more than that in octahedral complexes	1
Q.97	C. $[\text{Fe}(\text{CN})_6]^{-4}$	1
Q.98	<p>i) Solution of $\text{FeSO}_4(\text{NH}_4)_2\text{SO}_4 \cdot 6\text{H}_2\text{O}$ in Test Tube 'A' will turn into red. [1]</p> <p>ii) $\text{FeSO}_4(\text{NH}_4)_2\text{SO}_4 \cdot 6\text{H}_2\text{O}$ solution in Test Tube 'A' is a double salt and it ionises fully in aqueous solution. The Fe^{2+} ions in solution reacts with KSCN and give red colour due to formation of FeSCN^{2+} complex. [0.5]</p> <p>- But $\text{K}_3[\text{Fe}(\text{C}_2\text{O}_4)_3]$ is a complex. It cannot ionise fully in aqueous solution. The Fe^{2+} ion remain intact in sphere. Therefore it does not react with KSCN to give red colour. [0.5]</p>	2
Q.99	<p>- In $[\text{Ni}(\text{CN})_4]^{2-}$ oxidation state of Ni is +2 and its configuration is $[\text{Ar}] 4s^0 3d^8$</p> <p>- four CN ligands are strong ligands which allow pairing of electrons in 3d-orbitals and donate pair of electrons in next empty d s p^2 orbitals. [1]</p> <p>- since there is no unpaired electrons in it, it is diamagnetic and thus weakly repelled in the magnetic field. [1]</p> <div style="text-align: center;"> <p> Ni^{2+} : $3d$ (four boxes with pairs), $4s$ (empty), $4p$ (three empty boxes) $[\text{Ni}(\text{CN})_4]^{2-}$: $3d$ (four boxes with pairs), $4s$ (box with pair), $4p$ (two boxes with pairs, one empty) } dsp^2 </p> </div> <p>- At the same time in $[\text{Co}(\text{F})_6]^{3-}$ central atom Co is in +3 state.</p> <p>$_{27}\text{Co}^{3+}$ - $[\text{Ar}]4s^0 3d^6$</p>	4



	<p>- F is a weak ligand which does not allow pairing of electrons in 'd' orbitals of Co^{3+} [1]</p> <div style="text-align: center;"> <p style="margin-left: 100px;">four unpaired electrons</p> <p style="margin-left: 150px;">12 electrons donated by six ligands</p> </div> <p>- Presence of 4 unpaired e⁻ in 'd' orbital makes it para magnetic. Thus complex is weakly attracted towards magnetic field. [1]</p> <p><i>(Note: Cut 1 marks each if images are not shown)</i></p>	
Q.100	<p>- Sample solution $[\text{CoCl}_2(\text{en})_2]$ in test tube B can rotate plane polarised light. (1)</p> <p>- The spatial arrangement of two didentate ligands ethylene diamine and two Cl monodentate ligands around the metal ion is such that it makes the molecule unsymmetrical. such molecules are optically active i.e.they can rotate plane polarised light. (1)</p>	2
Q.101	<p>$\beta_n = [\text{ML}_n] / [\text{M}(\text{H}_2\text{O})_n] [\text{L}_n]$</p> <p>over all dissociation constant (D.C.)is reciprocal of stability constant(β_n)</p> <p>Dissociation constant = $1/\beta_n$</p> <p>D.C. = $1/2.1 \times 10^{13}$</p> <p>Thus</p> <p>D.C. = 4.7×10^{-14}</p>	2
Q.102	<p>The formula of the isomer is $[\text{Cr}(\text{H}_2\text{O})_5\text{Cl}]\text{Cl}_2$</p> <p>since two mole AgCl is produced hence 2 chloro groups are present as primary valencies.</p> <p>In complex $[\text{Cr}(\text{H}_2\text{O})_6]\text{Cl}_3$ six aqua ligands make direct bond with Cr metal ion thus complex is octahedral. (1)</p> <p>Whereas in complex $[\text{Cr}(\text{H}_2\text{O})_5\text{Cl}]\text{Cl}_2 \cdot \text{H}_2\text{O}$ only 5 aqua and one Cl ligands make direct bond with metal. This complex is also octahedral. The remaining one aqua is present as water of crystallisation. (1)</p>	3
Q.103	Any complex with 6 monodentate ligands is octahedral in shape.	2

	<p>The complex $[\text{Co}(\text{a})_4(\text{b})_2]\text{Br}$ is octahedral in shape hence ligands a and b are monodentate. (1)</p> <p>In any complex the sum of charges on ligands and counter ions shows oxidation state of metal ion which is +3 in Co.</p> <p>$[\text{Co}(\text{a})_4(\text{b})_2]\text{Br}$</p> <p>Br has -1 charge because 1 mole AgBr is formed.</p> <p>Since both a and b ligands are monodentate it is clear b has charge -1 and charge on a is 0</p> <p>$x + (0) + (-1 \times 2) + -1 = 0$</p> <p>$x = +3$</p> <p>Thus we can say charge on</p> <p>ligand a = 0 and b = -1 (1)</p>	
Q.104	<p>- Since complex has 3 didentate ligands there must be 6 donor atoms present around the central metal M (1)</p> <p>Six donor atoms around the metal ion suggest complex is octahedral. (1)</p> <p>The optical isomers are:</p> <div style="display: flex; justify-content: space-around; align-items: center;"> <div style="text-align: center;">  <p>d-isomer</p> <p>d-isomer</p> </div> <div style="text-align: center;">  <p>l-isomer</p> <p>l-isomer (1)</p> </div> </div>	3
Q.105	<p>1. Since oxidation state of metal ion M is +3, therefore the charge on one of the ligands is 1 and the other will have charge = 0</p> <p>while writing the formula the neutral ligand is written before anionic ligand.</p> <p>Also coordination number is 6 so there are 6 monodentate ligands.</p> <p>Hence</p>	4

	<table border="1"> <thead> <tr> <th>Ligands</th><th>Denticity</th><th>Charge</th></tr> </thead> <tbody> <tr> <td>A</td><td>monodentate</td><td>0</td></tr> <tr> <td>B</td><td>monodentate</td><td>-1</td></tr> </tbody> </table> <p>2. Two geometrical isomers are</p> <ol style="list-style-type: none"> 1. facial isomer (fac) 2. Meridional isomer(mer) <div style="display: flex; justify-content: space-around; align-items: center;">   </div>	Ligands	Denticity	Charge	A	monodentate	0	B	monodentate	-1	
Ligands	Denticity	Charge									
A	monodentate	0									
B	monodentate	-1									
Q.106	<p>- EDTA makes Lead substituted complex with poisonous lead in the body which can be easily excreted by the body. (1)</p> <div style="text-align: center;">  </div> <p>fig: EDTA complex of lead (fig. is optional) Where (M= Pb, ligand= EDTA)</p>	1									
Q.107	<p>(i) Complex $[\text{Co}(\text{H}_2\text{O})_6]^{2+}$ will have less crystal field splitting.</p> <p>(ii) The d orbital splitting here is more influenced by the charge on metal ion.</p> <p>For the similar metal ion complexes, the higher is the charge on metal ion more is the splitting energy Δ_0. Similarly lower is the charge on metal ion less is crystal field splitting. (1)</p>	3									

	<p>- In complex $[\text{Co}(\text{NH}_3)_6]^{3+}$ oxidation state of Co is +3 but in complex $[\text{Co}(\text{H}_2\text{O})_6]^{2+}$ the oxidation state of Co is +2. Therefore $[\text{Co}(\text{H}_2\text{O})_6]$ will have less crystal field splitting. (1)</p>	
Q.108	<p>i) NaCN forms a complex with the ore Ag_2S of Ag.</p> $\text{Ag}_2\text{S} + \text{NaCN} \rightarrow \text{Na}[\text{Ag}(\text{CN})_2] + \text{Na}_2\text{S} \quad (1)$ <p>It is easier to obtain Ag from ionic complex $\text{Na}[\text{Ag}(\text{CN})_2]$ than from simple covalent compounds.</p> <p>ii) To obtain metal Ag in precipitate form Zn metal is added into the solution which helps in the displacement of Ag from the complex. (1)</p> $\text{Na}[\text{Ag}(\text{CN})_2] + \text{Zn} \rightarrow \text{Na}_2[\text{Zn}(\text{CN})_4] + \text{Ag (ppt.)} \quad (1)$	3
Q.109	<p>i) The donation of a lone pair of electrons from ligand CO to metal ion forms σ bond.</p> <p>ii) In metal carbonyl the CO to Metal bond $\text{C} \rightarrow \text{M}$ is a sigma (σ) bond. There is also an overlapping of electrons from filled metal d orbitals into empty antibonding orbital of CO. This results into formation of a π bond and called back bonding. [1]</p> <p>- The $\text{M} \rightarrow \text{C}$ bond strengthens the bond between CO and the metal and this type of bonding creates a synergic effect. [1]</p> <p>(iii) Δ_0 value that is crystal field splitting energy increases in metal carbonyl. [1]</p> <p>- The ligand CO is capable of accepting an appreciable amount of electron density from the metal atom into its vacant π^* orbital. Due to this interaction Δ_0 increases. [1]</p>	5
Q.110	<p>(i) The colour of a salt arises due to two main factors:</p> <ol style="list-style-type: none"> 1. Influence of ligands present in a salt. 2. Presence of incomplete d-subshells. <p>- Both potassium and sodium lack incomplete d-orbitals. So, when light falls on such complexes no excitation of electrons occurs to higher energy levels to absorb or emit light of a certain wavelength. Hence, such salts are white in colour.</p> <p><i>[Give 0.5 mark each for points 1 and 2, and 1 mark for the explanation]</i></p> <p>(ii) A complex having molar conductivity similar to AB_2 should release 3 ions in the solution. Thus, the probable formula of the complex will be:</p>	3



	$[\text{Cr}(\text{H}_2\text{O})_5\text{Cl}]\text{Cl}_2 \rightleftharpoons [\text{Cr}(\text{H}_2\text{O})\text{Cl}]^{+2} + 2\text{Cl}^-$ <p><i>[Give 1 mark for the correct formula]</i></p>	
Q.111	<p>(a) The ore of silver is Silver sulphide (Ag_2S). The reactions that are most likely to be carried out in the workshop by Mrs. Dey are:</p> $\text{Ag}_2\text{S} + 2\text{NaCN} \rightarrow 2\text{Na}[\text{Ag}(\text{CN})_2] + \text{Na}_2\text{S}$ $2\text{Na}[\text{Ag}(\text{CN})_2] + \text{Zn} \rightarrow \text{Na}_2[\text{Zn}(\text{CN})_4] + 2\text{Ag}$ <p><i>[Give 1 mark for each correct equation. No marks to be awarded if the equations are not balanced.]</i></p> <p>(b) Zinc forms a tetrahedral complex in this case. As Zn^{+2} has 10 electrons in its d-shell so pairing of electrons occur and the distribution of the electrons is e^4t^6.</p> <p><i>[Give 1 for correct distribution of electrons and 1 mark for the correct reason.]</i></p>	4
Q.112	<p>In the complex $[\text{Ni}(\text{X})_4]$, unknown ligand X is CO. it is because-</p> <p>i) ligand CO is neutral which justifies zero oxidation state of Ni in the complex. (1)</p> <p>ii) Complex $[\text{Ni}(\text{CO})_4]$ is tetrahedral. It can be justified as</p> <p>$\text{Ni}(0) - [\text{Ar}]4s^2 3d^8$</p> <p>since carbonyl is strong ligand therefore</p> <p>$\text{Ni}(0) - [\text{Ar}]4s^0 3d^{10}$</p> <p>hence 4 CO ligands will occupy four sp^3 hybrid orbitals thus complex is tetrahedral. (1)</p>	2
Q.113	<p>- In any complex compound co-ordination entity is that part which contains ligands and metal ion together in a sphere. Thus</p> <p>- Coordination entity- $[\text{Pd}(\text{NH}_3)_4]^{2+}$ [0.5]</p> <p>- Counter ions are ionisable part which takes part in reaction hence counter ions are 2 Chloride ions or 2Cl^- [0.5]</p> <p>- The number of attacking sites used by ligands around the metal ion represent coordination number</p> <p>Hence coordination number is = 4 [0.5]</p> <p>- Oxidation number of Pd = +2 [0.5]</p>	2



Q.114	<p>(i)</p> <p>- In complex d^2sp^3, (n-1)d or inner d is involved in hybridisation therefore ligand X is a strong ligand. [1]</p> <p>(ii)</p> <p>- In any octahedral complex 'd' orbitals split as $t_{2g} < e_g$</p> <p>where t_{2g} is lower in energy than e_g. (0.5)</p> <p>- Central atom Co is in +3 state. The 6 electrons in d orbitals pair up due to strong ligand x (0.5)</p> <p>- Thus d- orbital configuration in complex is $t_{2g}^6 e_g^0$ (0.5)</p> <p>- pairing of electrons in lower 'd' i.e. t_{2g} shows pairing energy is lower than Δ_0 i.e. $\Delta_0 > P$. (0.5)</p>	3
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