Class 12 Chemistry · Chapter 5: Coordination Compounds

Answer key and marking scheme · 20 marks · about 40 minutes · based on NCERT

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1. Which of the following ligands can bind a metal ion through either of two different donor atoms? [1]

(a) $C_2O_4^{2-}$ (b) $H_2NCH_2CH_2NH_2$

(c) SCN^- (d) NH_3

Answer: (c) SCN^- is ambidentate: it binds through S or through N. Oxalate and ethane-1,2-diamine are didentate, using both donor atoms at once; NH_3 has only N.

2. The formula of diamminebis(ethane-1,2-diamine)cobalt(III) chloride is [1]

(a) $[Co(NH_3)_2(en)_2Cl]Cl_2$ (b) $[Co(NH_3)_2(en)_2]Cl_2$

(c) $[Co(NH_3)_2(en)_2]Cl_3$ (d) $[Co(NH_3)(en)_2]Cl_3$

Answer: (c) Diammine is two NH_3, bis(ethane-1,2-diamine) two en; all four ligands are neutral, so the cation is $[Co(NH_3)_2(en)_2]^{3+}$ and three Cl^- balance it. No chlorido ligand is named, so Cl is not inside the bracket.

3. Platinum(IV) has a secondary valence of 6 in $PtCl_4{\cdot}4NH_3$, and all four NH_3 molecules are bound to the metal. One formula unit of the compound gives, in water, [1]

(a) 2 ions (b) 3 ions

(c) 4 ions (d) 5 ions

Answer: (b) Four NH_3 fill four of the six positions, so two Cl^- are inside: $[Pt(NH_3)_4Cl_2]Cl_2$. The two outer Cl^- and the complex cation give 3 ions.

4. The hexadentate ligand $EDTA^{4-}$ binds a metal ion through [1]

(a) six O atoms (b) four N atoms and two O atoms

(c) two N atoms and four O atoms (d) two N atoms and two O atoms

Answer: (c) $EDTA^{4-}$ is $(^-OOCCH_2)_2N{-}CH_2{-}CH_2{-}N(CH_2COO^-)_2$: each of the two N atoms and each of the four carboxylate O atoms donates a pair, six in all.

5. Which of the following is a heteroleptic complex? [1]

(a) $[Cr(CO)_6]$ (b) $[Ni(en)_3]^{2+}$

(c) $[Co(NH_3)_4(H_2O)Cl]^{2+}$ (d) $[Cu(NH_3)_4]^{2+}$

Answer: (c) A heteroleptic complex has more than one kind of donor group; $[Co(NH_3)_4(H_2O)Cl]^{2+}$ has three (NH_3, H_2O, Cl^-). The other three carry one kind each and are homoleptic.

6. Using valence bond theory, give the hybridisation and the magnetic behaviour of the tetrahedral ion $[Zn(NH_3)_4]^{2+}$. [2]

Zn^{2+} is $3d^{10}$: the 3d orbitals are full, so the vacant 4s and three 4p orbitals hybridise to sp^3, giving a tetrahedron that accepts four NH_3 pairs. All electrons are paired, so the ion is diamagnetic.

- Zn^{2+} $3d^{10}$; 4s and 4p used: sp^3 (1)
- no unpaired electron: diamagnetic (1)

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7. Name the metal present in (i) chlorophyll and (ii) vitamin B12. Name one platinum complex used to inhibit the growth of tumours. [2]

(i) Chlorophyll is a magnesium complex; (ii) vitamin B12, cyanocobalamine, is a cobalt complex. Cis-platin inhibits tumour growth.

- magnesium in chlorophyll and cobalt in vitamin B12 (1)
- cis-platin (1)

8. Write the IUPAC names of (i) $Li[AlH_4]$ and (ii) $[CuCl_2(H_2O)_2]$. [2]

(i) Li^+ is the cation; $[AlH_4]^-$ is an anion with four hydrido ligands and Al in +3 (x − 4 = −1): lithium tetrahydridoaluminate(III). (ii) A neutral molecule: ligands alphabetically, aqua before chlorido, and Cu is +2 (x − 2 = 0): diaquadichloridocopper(II).

- lithium tetrahydridoaluminate(III) (1)
- diaquadichloridocopper(II) (1)

9. Write the formulas of (i) sodium hexanitrito-N-cobaltate(III), (ii) tetraamminecopper(II) sulphate and (iii) pentacarbonyliron(0). [3]

(i) Six NO_2^- bound through N to Co^{3+} give $[Co(NO_2)_6]^{3-}$, balanced by three Na^+: $Na_3[Co(NO_2)_6]$. (ii) Four neutral NH_3 on Cu^{2+} give $[Cu(NH_3)_4]^{2+}$ with one SO_4^{2-}: $[Cu(NH_3)_4]SO_4$. (iii) $[Fe(CO)_5]$.

- $Na_3[Co(NO_2)_6]$ (1)
- $[Cu(NH_3)_4]SO_4$ (1)
- $[Fe(CO)_5]$ (1)

10. One mole of $IrCl_3{\cdot}4NH_3$ gives one mole of AgCl at once with excess $AgNO_3$(aq). Iridium has coordination number 6 in it. (a) Write its formula. (b) State the primary and the secondary valence of iridium and what each corresponds to today. (c) How many geometrical isomers can the complex ion have? [3]

(a) Only one Cl^- is ionisable, so two Cl^- join four NH_3 inside the sphere: $[Ir(NH_3)_4Cl_2]Cl$. (b) Primary valence 3, the ionisable valence, read today as the oxidation state +3; secondary valence 6, the non-ionisable valence, the coordination number. (c) $[Ir(NH_3)_4Cl_2]^+$ is octahedral $[MX_2L_4]$: two isomers, cis (Cl at 90°) and trans (Cl at 180°).

- $[Ir(NH_3)_4Cl_2]Cl$ (1)
- primary 3 = oxidation state; secondary 6 = coordination number (1)
- two: cis and trans (1)

11. Co^{2+} (Z of Co = 27) forms octahedral complexes with ligands at both ends of the spectrochemical series. Write the t_2g/eg configuration of Co^{2+} when $\Delta o < P$ and when $\Delta o > P$, and calculate the spin-only magnetic moment in each case. [3]

Co^{2+} is $3d^7$. $\Delta o < P$ (high spin): $t_2g^5eg^2$, three unpaired electrons, $\mu = \sqrt{(3 \times 5)} = \sqrt{15} = 3.87$ BM. $\Delta o > P$ (low spin): $t_2g^6eg^1$, one unpaired electron, $\mu = \sqrt{(1 \times 3)} = 1.73$ BM.

- Co^{2+} $3d^7$; $\Delta o < P$: $t_2g^5eg^2$, 3 unpaired (1)
- $\Delta o > P$: $t_2g^6eg^1$, 1 unpaired (1)
- μ = 3.87 BM and 1.73 BM (1)