Coordination Compounds

Standard difficulty · 20 questions · 40 marks · Time: 42 minutes

Name: _____ Date: _____ Score: ____ / 40

Show your working for Sections B and C. Answers are on the last page — try every question first!

Section A — Choose the correct answer — 8 × 1 = 8 marks

1. The number of donor atoms bound to the central metal is its:

(a) atomic number **(b)** denticity

(c) oxidation state **(d)** coordination number

2. The oxidation state of Fe in $K_2[Fe(en)(NO_2)_4]$ is:

(a) +2 **(b)** +3 **(c)** +1 **(d)** +4

3. The coordination number of Cu in $[Cu(H_2O)_4]Cl_2$ is:

(a) 6 **(b)** 2 **(c)** 3 **(d)** 4

4. The IUPAC name of $K_4[CoCl_6]$ is:

(a) potassium hexachloridocobaltate(II) **(b)** potassium hexachloridocobaltate(III)

(c) potassium hexachloridocobalt(II) **(d)** tetrapotassium hexachloridocobaltate(II)

5. The number of geometrical isomers of $[Co(en)_2Cl_2]^+$ (octahedral) is:

(a) 2 (cis and trans; the cis form is optically active)

(b) none

(c) 2 (cis and trans)

(d) 3

6. The hybridisation and shape of $[Ni(CN)_4]^{2-}$ are:

(a) d^2sp^3, octahedral **(b)** dsp^2, square planar

(c) sp^3d^2, octahedral **(d)** sp^3, tetrahedral

7. One mole of $CrCl_3 \cdot 6H_2O$ (dark green) ($[Cr(H_2O)_4Cl_2]Cl \cdot 2H_2O$) is treated with excess $AgNO_3$. The number of moles of AgCl precipitated is:

(a) 3 **(b)** 2 **(c)** 1 **(d)** 0

8. Assertion (A): $[FeF_6]^{3-}$ is diamagnetic.
Reason (R): A complex is diamagnetic when all its electrons are paired and paramagnetic when some are unpaired.

(a) Both A and R are true, and R is the correct explanation of A.

(b) Both A and R are true, but R is not the correct explanation of A.

(c) A is true, but R is false.

(d) A is false, but R is true.

Section B — Short answer — 8 × 2 = 16 marks

9. What is the difference between a double salt and a complex compound?

10. For $[Cu(H_2O)_2Cl_2]$, give the oxidation state and coordination number of the metal, and write its IUPAC name.

11. Write the formula of hexaaquamanganese(II) chloride.

12. A d^7 metal ion sits in an octahedral weak field. Write its t_2g/e_g configuration, and find the number of unpaired electrons and the crystal field stabilisation energy (ignore pairing energy).

13. $PtCl_4 \cdot 2NH_3$ is written as $[Pt(NH_3)_2Cl_4]$. How many moles of AgCl does one mole give with excess $AgNO_3$, and how many ions does it give in solution?

14. How many geometrical isomers does $[Cr(H_2O)_4Cl_2]^+$ (octahedral) have? Name them if there are any.

15. Using valence bond theory, give the hybridisation, shape and magnetic behaviour of $[CoCl_4]^{2-}$.

16. Find the spin-only magnetic moment of a d^2 ion in an octahedral strong field.

Section C — Word problems — 4 × 4 = 16 marks

17. Explain the bonding, shape and magnetic behaviour of $[Co(NH_3)_6]^{3+}$ using valence bond theory.

18. For $[Zn(NH_3)_4]^{2+}$, find the oxidation state of the metal, its d-electron count, the hybridisation and shape, the number of unpaired electrons and the spin-only magnetic moment.

19. Co^{2+} (d^7) forms an octahedral complex with en (strong field) and another with H_2O (weak field). For each, give the t_2g/e_g configuration, the number of unpaired electrons, the magnetic moment and the CFSE (ignore pairing energy). Which is high-spin?

20. Consider the compounds $PtCl_4 \cdot 4NH_3$, $PtCl_4 \cdot 2NH_3$, $PtCl_4 \cdot 6NH_3$. Write each as a coordination compound, and give the moles of AgCl each gives per mole with excess $AgNO_3$ and the number of ions in solution.

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Answer key

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Q	Answer	Working
1	**(d) coordination number**	—
2	**(a) +2**	the oxidation state plus the ligand charges equals the charge on the complex ion
3	**(d) 4**	count the donor atoms
4	**(a) potassium hexachloridocobaltate(II)**	ligands in alphabetical order, then the metal with its oxidation state; -ate for an anionic complex
5	**(a) 2 (cis and trans; the cis form is optically active)**	—
6	**(b) dsp^2, square planar**	NCERT valence-bond example
7	**(c) 1**	only chloride ions outside the square brackets are precipitated
8	**(d) A is false, but R is true.**	A is false: it has 5 unpaired electrons. R is true.
9	**A double salt such as Mohr's salt dissociates completely into simple ions in water. A complex compound keeps its complex ion intact in water, e.g. $K_4[Fe(CN)_6]$ gives $[Fe(CN)_6]^{4-}$ and no Fe^{2+}.**	—
10	**+2; 4; diaquadichloridocopper(II)**	oxidation state = charge of complex − sum of ligand charges
11	**$[Mn(H_2O)_6]Cl_2$**	metal first in the square brackets, then the ligands; counter-ions outside
12	**t_2g^5 e_g^2; 3 unpaired; CFSE = $-0.8\Delta_0$**	Δ_0 < P: one electron in each orbital before pairing; CFSE = $(-0.4 \times 5 + 0.6 \times 2)\Delta_0$
13	**0 mol AgCl; no ions (it is a non-electrolyte)**	ions outside the brackets are free in solution
14	**2 (cis and trans)**	—
15	**sp^3; tetrahedral; paramagnetic with 3 unpaired electrons (μ ≈ 3.87 BM)**	NCERT example
16	**2 unpaired; $\sqrt{8} \approx 2.83$ BM**	t_2g^2 e_g^0
17	**Co^{3+} is $3d^6$. NH_3 makes the six 3d electrons pair in three orbitals, leaving two 3d orbitals empty. These, with 4s and three 4p orbitals, form d^2sp^3 hybrids that accept six NH_3 lone pairs. The complex is octahedral, inner-orbital and diamagnetic.**	—
18	**+2; d^{10}; sp^3, tetrahedral; 0 unpaired; 0 BM (diamagnetic)**	oxidation state from the charge; then the valence bond picture
19	**with en: t_2g^6 e_g^1, 1 unpaired, $\sqrt{3} \approx 1.73$ BM, CFSE $-1.8\Delta_0$; with H_2O: t_2g^5 e_g^2,**	strong field: pair in t_2g before using e_g

Q	Answer	Working
	3 unpaired, $\sqrt{15} \approx 3.87$ BM, CFSE $-0.8\Delta_0$; the H_2O complex is high-spin	
20	**$PtCl_4 \cdot 4NH_3 = [Pt(NH_3)_4Cl_2]Cl_2$: 2 AgCl, 3 ions; $PtCl_4 \cdot 2NH_3 = [Pt(NH_3)_2Cl_4]$: 0 AgCl, 0 ions; $PtCl_4 \cdot 6NH_3 = [Pt(NH_3)_6]Cl_4$: 4 AgCl, 5 ions**	the coordination number of the metal stays the same; ammonia replaces chloride inside the sphere