Transition metal complexes

AQA Chemistry (7405) · Full A level

Show your working where needed. Check the worked answers when you finish.

Name _____ Date _____

1. Copper and zinc

Copper and zinc are both d-block elements. Write the electron configurations of Cu^{2+} and Zn^{2+}. Decide whether each element is a transition element and justify your choices.

2. Two iron ions

An iron atom has configuration [Ar] $3d^6$ $4s^2$. Give the configurations of Fe^{2+} and Fe^{3+}, and state which electrons are removed first.

3. Compare two ligand types

Ethane-1,2-diamine has two lone-pair donors. $EDTA^{4-}$ can supply six donor atoms to the same metal ion. How many ligands of each type fill six coordination positions? Explain using coordinate bonding.

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4. Three complexes

Give the coordination number and shape of $[Fe(H_2O)_6]^{3+}$, $[CoCl_4]^{2-}$ and $[PtCl_4]^{2-}$. Identify the two complexes with equal coordination numbers but different shapes.

5. A nickel complex

A nickel(II) ion is bonded to two chloride ligands and two neutral ethane-1,2-diamine ligands. Each ethane-1,2-diamine uses both nitrogen atoms. Write the complex formula using en for ethane-1,2-diamine. Give its coordination number.

6. Two platinum complexes

Two square-planar complexes have formula $[Pt(NH_3)_2Cl_2]$. One has a Cl-Pt-Cl angle of 90° and the other 180°. Identify each isomer and state which one is used as an anticancer drug.

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7. Two nickel arrangements

Two arrangements of $[Ni(en)_3]^{2+}$ are mirror images that cannot be superimposed. Here en is ethane-1,2-diamine. Classify their isomerism and explain why counting ligands would give the wrong coordination number.

8. An unknown ligand ratio

An octahedral M^{3+} complex has charge −1. Its only ligands are water and a bidentate dicarboxylate L^{2-}. Find the number of each ligand and give the complex formula using M and L.

9. Extra challenge · Predict stereoisomers from donor positions

In octahedral $[Co(en)_2Cl_2]^{+}$ each en is neutral and bidentate, with its two nitrogen donors adjacent. Find the cobalt oxidation state and coordination number.

Draw the two placements of the chlorides. Explain which placement gives a pair of optical isomers.

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Worked answers

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1. Copper and zinc

Cu^{2+} is [Ar] $3d^9$, so copper forms an ion with an incomplete d subshell.

Zn^{2+} is [Ar] $3d^{10}$. Zinc's usual ion has a filled d subshell.

2. Two iron ions

Fe^{2+} is [Ar] $3d^6$ and Fe^{3+} is [Ar] $3d^5$.

Remove the 4s electrons before removing a 3d electron.

3. Compare two ligand types

Three en ligands fill the positions because each supplies two lone pairs. One $EDTA^{4-}$ ligand supplies six lone-pair donors. Each coordinate bond uses a pair of electrons supplied by the ligand.

4. Three complexes

$[Fe(H_2O)_6]^{3+}$ is six-coordinate and octahedral. Both $[CoCl_4]^{2-}$ and $[PtCl_4]^{2-}$ are four-coordinate. The cobalt complex is tetrahedral and the platinum(II) complex is square planar.

5. A nickel complex

Formula $[NiCl_2(en)_2]$. The charge is +2 + 2(−1) = 0. The two chlorides supply one donor atom each and the two en ligands supply two each, giving coordination number 6.

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Worked answers

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6. Two platinum complexes

The 90° complex is cis with adjacent chlorides. The 180° complex is trans with opposite chlorides. The drug is the 90° complex, cisplatin.

7. Two nickel arrangements

They are optical isomers or enantiomers. Each en makes two coordinate bonds to nickel. The three ligands give six donor atoms, so the coordination number is 6.

8. An unknown ligand ratio

Charge: +3 + x(−2) = −1, so x = 2 L^{2-} ligands.

They occupy four positions. The other two positions are occupied by two H_2O ligands. Formula $[M(L)_2(H_2O)_2]^-$.

9. Extra challenge · Predict stereoisomers from donor positions

Cobalt is +3 because x + 2(−1) = +1. Four nitrogen and two chloride donors give coordination number 6.

Place the chlorides opposite for trans. For cis place them at +x and +y on the octahedral axes. The four remaining positions are −x, −y, +z and −z.

One cis enantiomer links −x to +z and −y to −z. Its mirror image links −x to −z and −y to +z. These cannot be superimposed. The trans arrangement has mirror symmetry.

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