5.2.1 Explain configurations, ligands and complex charge

Name: _____ Class: _____ Date: _____ **Total: 16 marks**

KEY WORDS evidence • conditions

Objective

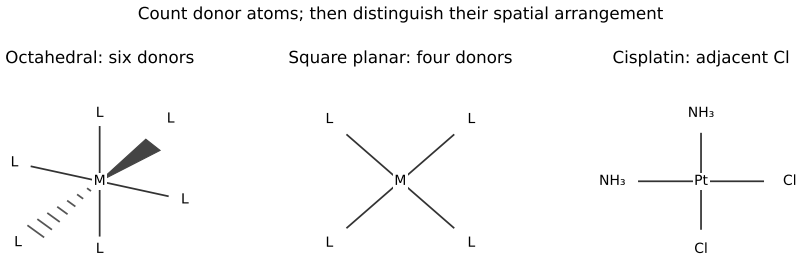
Explain configurations, ligands and complex charge. All questions and marking guidance are original.

1 Key knowledge and worked examples

A transition element forms a stable ion with an incomplete d subshell. Remove 4s electrons before 3d when forming positive ions. A ligand donates an electron pair; coordination number counts directly attached donor atoms.

■ Worked method

Fe is $[Ar]3d^6 4s^2$, so Fe^{2+} is $[Ar]3d^6$. In $[Fe(CN)_6]^{3-}$, six CN^- contribute -6; iron must be $+3$. Three neutral bidentate en ligands give six donor atoms, so $[Co(en)_3]^{3+}$ has coordination number six and cobalt(III). Colour depends on energy gaps between split d orbitals, not simply the total number of ligands.



2 Practice

2.1 Give the ground-state configurations after [Ar] for Cr and Cu. [2]

2.2 Give the configurations of Fe^{2+} and Cu^{2+} after [Ar], explaining electron removal. [3]

2.3 Explain why zinc does not meet the transition-element definition but copper does. [2]

3 Exam-style questions

3.1 Determine metal oxidation state and coordination number in $[Cr(H_2O)_4Cl_2]^+$ and $[Co(en)_3]^{3+}$. Each en ligand donates through two nitrogen atoms. [4]

3.2 Explain why replacing water ligands with ammonia can change colour, and why a d^{10} ion often lacks d–d colour. [3]

3.3 Two complexes each have coordination number four. One is tetrahedral and one square planar. Explain why coordination number alone cannot distinguish them; identify the cis relationship in square-planar cisplatin. [2]

Solutions

Original marking guidance: M1 method, A1 accuracy, B1 explanation.

2.1 Cr: $3d^5 4s^1$; Cu: $3d^{10} 4s^1$.

2.2 Fe^{2+} $3d^6$; Cu^{2+} $3d^9$; 4s electrons are removed before 3d.

2.3 Stable Zn^{2+} is d^{10}, with no incomplete d subshell; stable Cu^{2+} is d^9, incomplete.

3.1 Chromium: +3, coordination number 6. Cobalt: +3, coordination number 6. Neutral water/en do not alter charge; two Cl^- contribute -2 in the first complex.

3.2 Changing ligand changes d-orbital splitting, changing the wavelength absorbed. A full d subshell has no vacant d state for the required d–d promotion.

3.3 The same four donor atoms can occupy different arrangements. In cisplatin the two Cl ligands are adjacent, not opposite.