

## 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

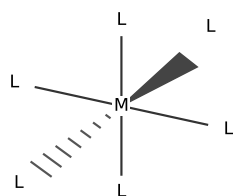
A transition element forms a stable ion with an incomplete d subshell. Remove 4s electrons before 3d when forming positive ions. A ligand donates an electron pair; coordination number counts directly attached donor atoms.

#### ■ Worked method

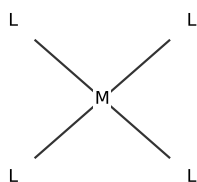
Fe is  $[\text{Ar}]3\text{d}^64\text{s}^2$ , so  $\text{Fe}^{2+}$  is  $[\text{Ar}]3\text{d}^6$ . In  $[\text{Fe}(\text{CN})_6]^{3-}$ , six  $\text{CN}^-$  contribute  $-6$ ; iron must be  $+3$ . Three neutral bidentate en ligands give six donor atoms, so  $[\text{Co}(\text{en})_3]^{3+}$  has coordination number six and cobalt(III). Colour depends on energy gaps between split d orbitals, not simply the total number of ligands.

Count donor atoms; then distinguish their spatial arrangement

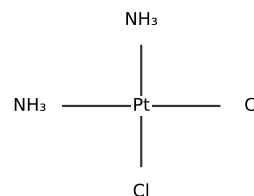
Octahedral: six donors



Square planar: four donors



Cisplatin: adjacent Cl



## 2 Practice

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

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

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

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## 3 Exam-style questions

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**3.1** Determine metal oxidation state and coordination number in  $[\text{Cr}(\text{H}_2\text{O})_4\text{Cl}_2]^+$  and  $[\text{Co}(\text{en})_3]^{3+}$ . Each en ligand donates through two nitrogen atoms. [4]

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

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**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]

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## Solutions

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

**2.1** Cr:  $3d^54s^1$ ; 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.