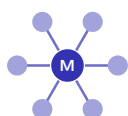


Transition Elements

A-Level Chemistry • Topic 28

A-Level Chemistry



Transition Elements

What we will cover

- 1 Four key properties
- 2 Ligands & denticity
- 3 Complex shapes
- 4 Ligand exchange
- 5 Why complexes are coloured
- 6 Isomerism & stability



transition metals are colourful

1 Properties and complexes

Transition Elements

Properties and complexes

Four key properties

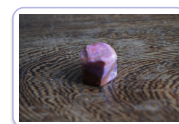
variable oxidation state 氧化态
– 3d & 4s close in energy

complex ions 配离子 – vacant d orbitals accept lone pairs

catalyst 催化剂 – more than one stable state, vacant d orbitals

coloured 有色 compounds – electrons jump split d orbitals

A **transition element** 过渡元素 forms ions with **incomplete d orbitals** (so Sc and Zn don't count).



Ruby

Transition Elements

Properties and complexes

Ligands and denticity

A **ligand** 配体 donates a **lone pair** 孤对电子 in a **dative bond** 配位键:

- **monodentate** 单齿 – 1 bond (H_2O , NH_3)
- **bidentate** 双齿 – 2 bonds (en)
- **polydentate** 多齿 – many (EDTA: 6)



monodentate: 1 bond
(H_2O , NH_3 , Cl^-)



bidentate: 2 bonds
("en")



Polydentate: many
(EDTA uses 6)

Transition Elements

Properties and complexes

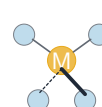
Complex shapes

The **coordination number** 配位数 (dative bonds to the metal) sets the shape:

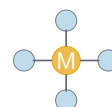
- 6 → **octahedral** 八面体形
- 4 → tetrahedral or square planar
- 2 → linear



linear
CN 2



tetrahedral
CN 4

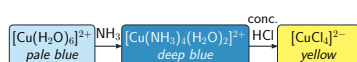


square planar
CN 4



octahedral
CN 6

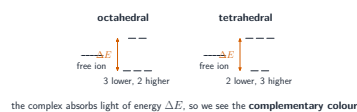
Ligand exchange



In **ligand exchange** 配体交换 one ligand replaces another, often with a colour change. Copper(II): pale blue (water) → deep blue (NH₃) → yellow ([CuCl₄]²⁻).

2 Colour and isomerism

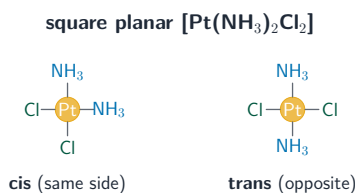
Why complexes are coloured



Ligands split the five **degenerate** 简并 d orbitals into two sets, a gap ΔE apart.

The complex absorbs light of energy ΔE ; we see the **complementary colour** 互补色. Different ligands give a different ΔE – so the colour changes.

Stereoisomerism in complexes



- **cis/trans** 顺反异构 in square planar (e.g. Pt(NH₃)₂Cl₂) & octahedral complexes
- **optical** 旋光异构 in octahedral complexes with bidentate ligands

Stability constants

K_{stab} : equilibrium for forming a complex

A **large stability constant** 稳定常数 means a very stable complex – ligand exchange moves towards the larger K_{stab} .

Use $E^\ominus$ values to predict redox feasibility (e.g. $\text{MnO}_4^-/\text{Fe}^{2+}$ titrations, purple to colourless).

3 Recap

Worked example – a redox titration

25.0 cm³ of Fe²⁺ needs 22.0 cm³ of 0.0200 mol dm⁻³ KMnO₄ (ratio 1 : 5). Find [Fe²⁺].

- Moles

$$\text{KMnO}_4 = \frac{22.0}{1000} \times 0.0200 = 4.40 \times 10^{-4}$$
- Ratio 1 : 5, so moles

$$\text{Fe}^{2+} = 5 \times 4.40 \times 10^{-4} = 2.20 \times 10^{-3}$$
- [Fe²⁺] = $\frac{2.20 \times 10^{-3}}{25.0/1000} = 0.0880 \text{ mol dm}^{-3}$

Every titration is the same three steps: moles of the known → ratio from the equation → concentration of the unknown. KMnO₄ is self-indicating – the first permanent pink.

Topic 28 – key takeaways

1 Properties

variable states, catalysts, complexes, colour

2 Ligands

donate a lone pair; mono/bi/polydentate

3 Colour

split d orbitals; see the complementary colour

4 Isomerism

cis/trans & optical; stability constants

Check yourself

- 1 What does a bidentate ligand form?
- 2 What shape has coordination number 6?
- 3 Why are transition complexes coloured?
- 4 A large stability constant means what?



Answers 1. two dative bonds 2. octahedral 3. electrons jump split d orbitals 4. a very stable complex