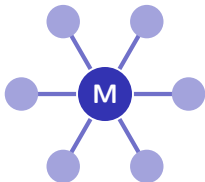


Transition Elements

A-Level Chemistry ■ Topic 28

A-Level Chemistry



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

Four key properties

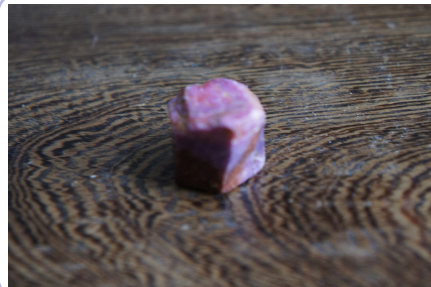
variable oxidation state 氧化态
– 3d & 4s close in energy

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

complex ions
orbitals accept

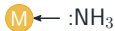
coloured 有色
electrons jump

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



ruby

Ligands and denticity



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



bidentate: 2 bonds
("en")



polydentate: many
(EDTA uses 6)

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)

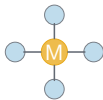
Complex shapes



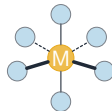
linear
CN 2



tetrahedral
CN 4



square planar
CN 4

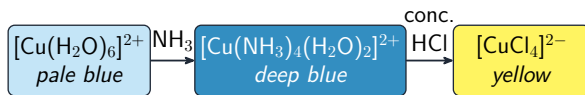


octahedral
CN 6

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

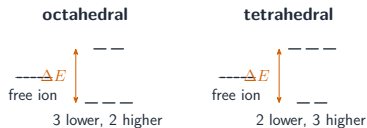
- 6 → **octahedral** 八面体形
- 4 → tetrahedral or square planar
- 2 → linear

Ligand exchange



In **ligand exchange** 配体交換 one ligand replaces another, often with a colour change. Copper(II): pale blue (water) $\rightarrow$ deep blue (NH_3) $\rightarrow$ yellow ($[\text{CuCl}_4]^{2-}$).

Why complexes are coloured



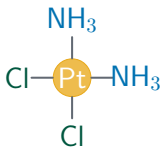
the complex absorbs light of energy ΔE , so we see the **complementary colour**

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

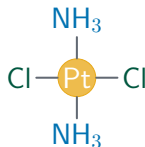
The complex absorbs light of energy ΔE ; we see the **complementary colour** 互补色. Different ligands give a different ΔE – so the colour changes.

Stereoisomerism in complexes

square planar $[\text{Pt}(\text{NH}_3)_2\text{Cl}_2]$



cis (same side)



trans (opposite)

- **cis/trans** 顺反异构 in square planar (e.g. $\text{Pt}(\text{NH}_3)_2\text{Cl}_2$) & 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).

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

$$\text{Fe}^{2+} = 5 \times 4.40 \times 10^{-4} = 2.20 \times 10^{-3}$$

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

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