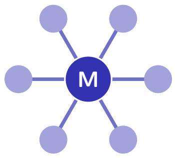
Transition Elements

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

1 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).

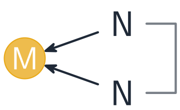
Ruby

Ligands and denticity

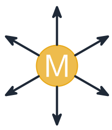
A **ligand** 配体 donates a **lone pair** 孤对电子 in a **dative bond** 配位键:

- **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")



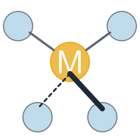
polydentate: many (EDTA uses 6)

Complex shapes

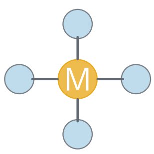
The **coordination number** 配位数 (dative bonds to the metal) sets the shape:

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

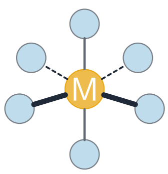
linear
CN 2



tetrahedral
CN 4



square planar
CN 4



octahedral
CN 6

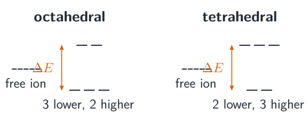
Ligand exchange

$[Cu(H_2O)_6]^{2+}$ *pale blue* $\xrightarrow{NH_3}$ $[Cu(NH_3)_4(H_2O)_2]^{2+}$ *deep blue* $\xrightarrow{\text{conc. } HCl}$ $[CuCl_4]^{2-}$ *yellow*

In **ligand exchange** 配体交换 one ligand replaces another, often with a colour change. Copper(II): pale blue (water) → deep blue (NH_3) → yellow ($[CuCl_4]^{2-}$).

2 Colour and isomerism

Why complexes are coloured



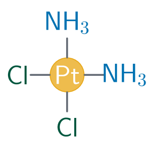
the complex absorbs light of energy ΔE, so we see the **complementary colour**

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

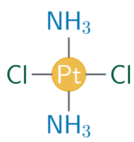
> The complex absorbs light of energy ΔE; we see the **complementary colour** 互补色. Different ligands give a different ΔE – so the colour changes.

Stereoisomerism in complexes

square planar $[Pt(NH_3)_2Cl_2]$



cis (same side)



trans (opposite)

- **cis/trans** 顺反异构 in square planar (e.g. $Pt(NH_3)_2Cl_2$) & 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. MnO_4^-/Fe^{2+} titrations, purple to colourless).

3 Recap

Worked example – a redox titration

$25.0\,\mathrm{cm}^3$ of Fe^{2+} needs $22.0\,\mathrm{cm}^3$ of $0.0200\,\mathrm{mol\,dm^{-3}}$ $KMnO_4$ (ratio $1:5$). Find $[Fe^{2+}]$.

- Moles $KMnO_4 = \dfrac{22.0}{1000} \times 0.0200 = 4.40 \times 10^{-4}$
- Ratio $1:5$, so moles $Fe^{2+} = 5 \times 4.40 \times 10^{-4} = 2.20 \times 10^{-3}$
- $[Fe^{2+}] = \dfrac{2.20 \times 10^{-3}}{25.0/1000} = 0.0880\,\mathrm{mol\,dm^{-3}}$

Every titration is the same three steps: moles of the known → ratio from the equation → concentration of the unknown. $KMnO_4$ is self-indicating – the first permanent pink.

Topic 28 – key takeaways

1 **Properties**
variable states, catalysts, complexes, colour

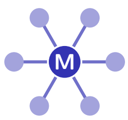
2 **Ligands**
donate a lone pair; mono/bi/polydentate

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