A-LEVEL CHEMISTRY • EXERCISE SHEET

28.4 Stereoisomerism in transition element complexes

Name: _____ Class: _____ Date: _____ **Total: 21 marks**

KEY WORDS stereoisomerism in complexes 配合物的立体异构 • cis 顺式 • geometrical 几何 • optical 旋光 • optical isomerism 旋光异构

Objective

Build the skills to answer exam questions on **stereoisomerism in complexes** 配合物的立体异构 — **geometrical** 几何 (cis/trans) and **optical** 旋光 isomerism, and the polarity of complexes.

You must be able to:

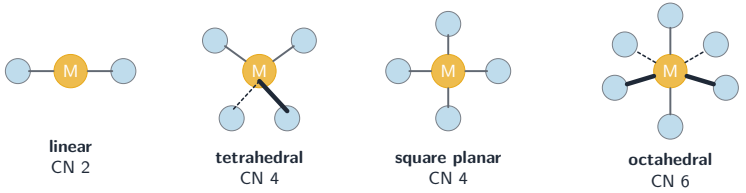
- describe cis/trans isomerism in square planar and octahedral complexes
- describe optical isomerism in octahedral complexes with bidentate ligands
- deduce the overall polarity of such complexes

1 Worked examples

■ Geometrical and optical isomerism

square planar $[Pt(NH_3)_2Cl_2]$

Cis/trans in $[Pt(NH_3)_2Cl_2]$: the two identical ligands are adjacent (cis) or opposite (trans)



Complex shapes underlie their stereoisomerism

- **geometrical (cis/trans):** square planar (e.g. $[Pt(NH_3)_2Cl_2]$) and octahedral (e.g. $[Co(NH_3)_4(H_2O)_2]^{2+}$).
- **optical:** octahedral complexes with bidentate ligands (e.g. $[Ni(en)_3]^{2+}$) have two non-superimposable mirror images.

Polarity: a *cis* form may be polar (dipoles do not cancel); the matching *trans* form is often non-polar.

2 Practice

2.1 Name the type of stereoisomerism shown by $[Pt(NH_3)_2Cl_2]$. [1]

2.2 State what makes a complex show optical isomerism. [1]

3 Exam-style questions

3.1 Optical isomerism is shown by: [1]

- **A** $[CuCl_4]^{2-}$
- **B** $[Ni(en)_3]^{2+}$
- **C** $[Cu(H_2O)_6]^{2+}$
- **D** $[Ag(NH_3)_2]^{+}$

3.2 The *trans* isomer of a square planar complex is often: [1]

- **A** polar
- **B** non-polar (dipoles cancel)
- **C** optically active
- **D** coloured only

3.3 (a) Draw the cis and trans isomers of the square planar complex $[Pt(NH_3)_2Cl_2]$. [2]

(b) Explain why $[Ni(en)_3]^{2+}$ shows optical isomerism. [2]

3.4 State, with a reason, which of the cis or trans form of $[Pt(NH_3)_2Cl_2]$ is polar. [2]

3.5 The complex $[Pt(NH_3)_2Cl_2]$ is square planar; $[Co(NH_3)_4Cl_2]^+$ is octahedral; $[Ni(NH_2CH_2CH_2NH_2)_3]^2$ is octahedral with three bidentate ligands.

(a) Draw the two geometrical isomers of $[Pt(NH_3)_2Cl_2]$ and label each cis or trans. [3]

(b) Explain which of the two is polar, and why the other is not. [2]

(c) State how many geometrical isomers $[Co(NH_3)_4Cl_2]^+$ has, and describe how they differ. [2]

(d) Explain what makes $[Ni(NH_2CH_2CH_2NH_2)_3]^{2+}$ **optically** active, and describe how the two forms could be told apart. [4]

Solutions

2.1 geometrical (cis/trans) isomerism.

2.2 it has two non-superimposable mirror images (e.g. an octahedral complex with bidentate ligands).

3.1 B. $[Ni(en)_3]^{2+}$ (octahedral with three bidentate ligands) shows optical isomerism.

3.2 B. In the trans form the dipoles cancel, so it is non-polar.

3.3 (a) cis — the two NH_3 (and two Cl) adjacent; trans — the two NH_3 (and two Cl) opposite.
(b) it is octahedral with three bidentate (en) ligands, giving two non-superimposable mirror images (enantiomers).

3.4 the cis form is polar; its two Pt–Cl dipoles are on the same side and do not cancel, while in the trans form they are opposite and cancel.

3.5 (a) Square planar with Pt at the centre; **cis** has the two Cl on adjacent corners, **trans** has them opposite.
(b) The **cis** isomer is polar: its two Pt–Cl bond dipoles point to the same side and add, whereas in the trans isomer they point in exactly opposite directions and cancel, so the molecule has no overall dipole.
(c) Two: in the *cis* form the two chloride ligands occupy adjacent (90°) positions, in the *trans* form they are opposite (180°).
(d) The three bidentate ligands wrap round the metal in a propeller arrangement, so the complex has no plane of symmetry; it is therefore **chiral** and exists as two non-superimposable mirror images (optical isomers / enantiomers). They rotate the plane of plane-polarised light by equal amounts in **opposite** directions, which a polarimeter detects; in every other physical and chemical property they are identical.