	Marks
• Transition metals are often found in coordination complexes such as $[NiCl_4]^{2-}$. What is a complex?	**8**

> **A complex contains a metal cation surrounded by ligands which bond to the cation using one or more lone pairs. The complex can be positive, negative or neutral depending on the charges on the metal and ligands.**

How does the bonding in the complex $[NiCl_4]^{2-}$ differ from the bonding in CCl_4?

> **In CCl_4, the C-Cl bonds are polar covalent; each involves the sharing of 1 electron from C and 1 electron from Cl to make a 2 electron bond.**
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> **In $[NiCl_4]^{2-}$, the Ni-Cl bonds also involve 2 electrons. However, both originate on the Cl^- ion which donates a lone pair to the Ni^{2+} ion to make the bond. This type of bond is sometimes called a 'dative' or 'coordinate' bond.**

What is a chelate complex?

> **Some ligands have more than one atom with a lone pair and can bond to a metal ion more than once. An example of this type of ligand is ethylenediamine (en) which has the formula $NH_2CH_2CH_2NH_2$. As there is a lone pair on each of the N atoms, it can bond twice to a metal ion.**
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> **Complexes containing ligands which do this are called chelate complexes.**

Why is a chelate complex generally more stable than a comparable complex without chelate ligands?

> **When a chelate ligand bonds to a metal ion, it releases other ligands: if the chelate can bond twice to a metal ion, it will release two ligands and if the chelate can bond three times to a metal ion, it will release three ligands.**
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> **If the bond strengths are similar, the enthalpy change is small. However, the release of ligands increases the entropy of the system and this favours the formation of the chelate complex.**
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> **For example, en can bond twice to a metal ion so in the reaction below, it can replace $2NH_3$ ligands:**
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> **$[Ni(NH_3)_6]^{2+}(aq) + en(aq) \rightarrow [Ni(en)(NH_3)_4]^{2+}(aq) + 2NH_3(aq)$**
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> **The reaction involves breaking 2 Ni-N bonds and making 2 Ni-N bonds, so the enthalpy change is small. There are 2 reactant molecules and 3 product molecules so the entropy has increased.**