

5.3.1 Transition Elements

General properties of transition metals

transition metal characteristics of elements Ti → Cu arise from an **incomplete d sub-level** in ions

these characteristics include

- formation of coloured ions,
- variable oxidation state
- catalytic activity.
- Complex ion formation,

Sc $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^1$
Ti $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^2$
V $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^3$
Cr $1s^2 2s^2 2p^6 3s^2 3p^6 4s^1 3d^5$
Mn $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^5$
Fe $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^6$
Co $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^7$
Ni $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^8$
Cu $1s^2 2s^2 2p^6 3s^2 3p^6 4s^1 3d^{10}$
Zn $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10}$

→
When forming ions lose 4s before 3d

Sc $3+ [Ar] 4s^0 3d^0$
Ti $3+ [Ar] 4s^0 3d^1$
V $3+ [Ar] 4s^0 3d^2$
Cr $3+ [Ar] 4s^0 3d^3$
Mn $2+ [Ar] 4s^0 3d^5$
Fe $3+ [Ar] 4s^0 3d^5$
Co $2+ [Ar] 4s^0 3d^7$
Ni $2+ [Ar] 4s^0 3d^8$
Cu $2+ [Ar] 4s^0 3d^9$
Zn $2+ [Ar] 4s^0 3d^{10}$

Why is Zn not a transition metal?

Zn can only form a +2 ion. In this ion the Zn^{2+} has a **complete** d orbital and so does not meet the criteria of having an incomplete d orbital in one of its ions.

Why is Sc not a transition metal?

Sc can only form a +3 ion. In this ion the Sc^{3+} has an **empty** d orbital and so does not meet the criteria of having an incomplete d orbital in one of its ions.

Typical Properties of Transition metals

The existence of more than one oxidation state for each element in its compounds

For example iron commonly forms +2 and +3, chromium commonly forms +2,+3 and +6 see page 5 of this guide for more detail.

The formation of coloured ions

There are characteristic colours for each transition metal element and the colours can vary in the different oxidation state. See the rest of the guide for many examples.

The catalytic behaviour of the elements and their compounds and their importance in the manufacture of chemicals by industry

Iron is used as a catalyst in the Haber process to produce ammonia. Manganese dioxide MnO_2 catalyses the decomposition of hydrogen peroxide. Vanadium pentoxide V_2O_5 catalyses the contact process . See 3.2.2 reaction rates for some more detail.

Complex formation

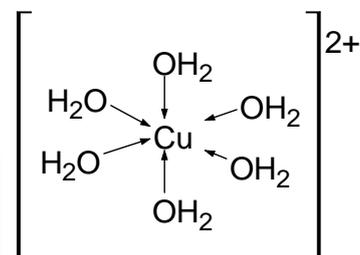
complex :is a central metal ion surrounded by ligands.

ligand.: An atom, ion or molecule which can donate a **lone electron pair**

Co-ordinate bonding is involved in complex formation.

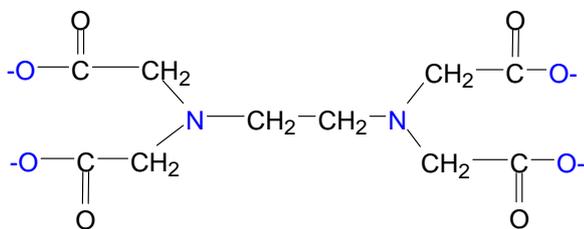
Co-ordinate bonding is when **the shared pair of electrons** in the covalent bond come from **only one of the bonding atoms**.

Co-ordination number: The number of co-ordinate bonds formed to a central metal ion.



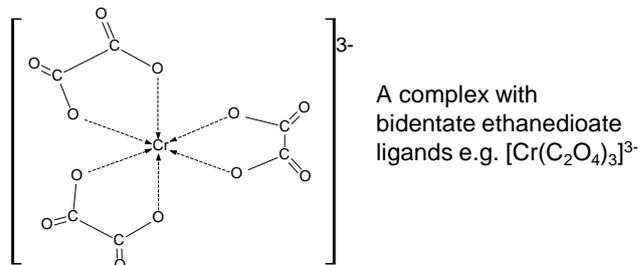
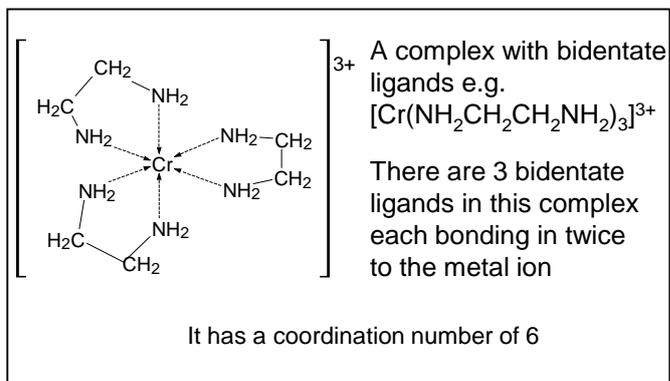
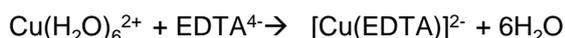
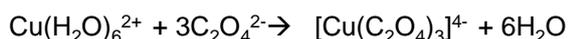
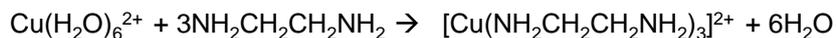
ligands can be **unidentate** (e.g. H_2O , NH_3 and Cl^-) which can form one coordinate bond per ligand or **bidentate** (e.g. $\text{NH}_2\text{CH}_2\text{CH}_2\text{NH}_2$ and ethanedioate ion $\text{C}_2\text{O}_4^{2-}$) which have two atoms with lone pairs and can form two coordinate bonds per ligand or **multidentate** (e.g. EDTA^{4-} which can form six coordinate bonds per ligand).

The EDTA^{4-} anion has the formula



with six donor sites (4O and 2N) and forms a 1:1 complex with metal(II) ions

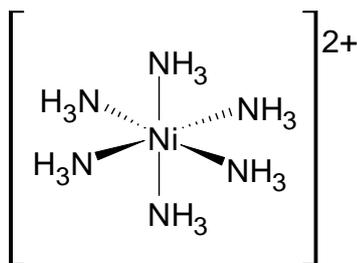
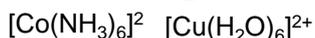
Equations to show formation of bidentate and multidentate complexes



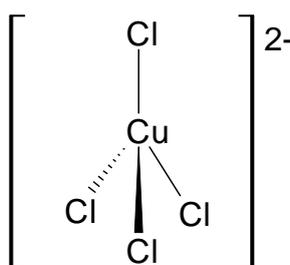
Learn the two bidentate ligands mentioned above but it is not necessary to remember the structure of EDTA

Shapes of complex ions

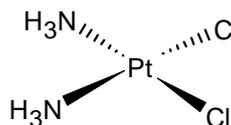
transition metal ions commonly form **octahedral** complexes with small ligands (e.g. H_2O and NH_3).



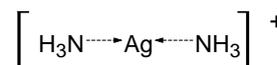
transition metal ions commonly form **tetrahedral** complexes with larger ligands (e.g. Cl^-).



square planar complexes are also formed, e.g. cisplatin



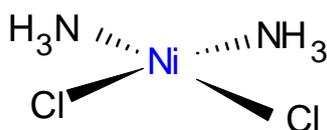
Ag^+ commonly forms **linear** complexes e.g. $[\text{Ag}(\text{NH}_3)_2]^+$, $[\text{Ag}(\text{S}_2\text{O}_3)_2]^{3-}$ and $[\text{Ag}(\text{CN})_2]^-$ (all colourless).



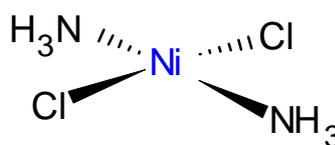
Isomerism in complex ions

Complexes can show two types of stereoisomerism: cis-trans isomerism and optical isomerism

Cis-trans isomerism in square planar complexes

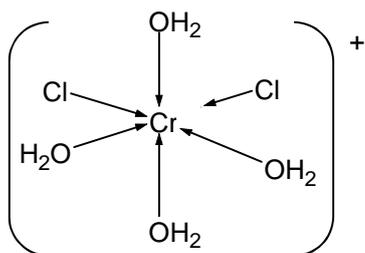


Cis- $[\text{Ni}(\text{NH}_3)_2\text{Cl}_2]$

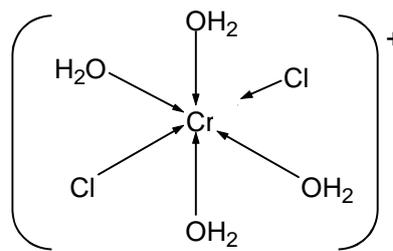


trans- $[\text{Ni}(\text{NH}_3)_2\text{Cl}_2]$

Cis-trans isomerism in octahedral complexes



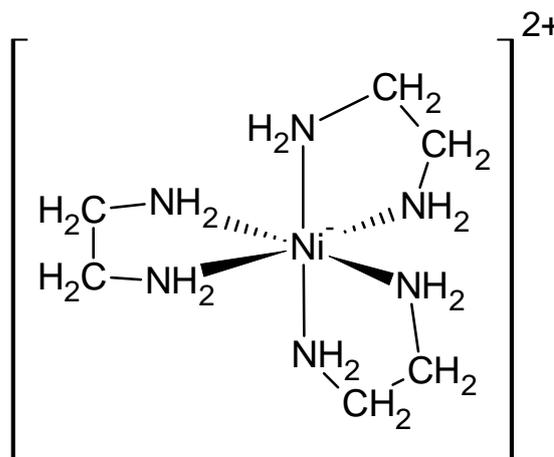
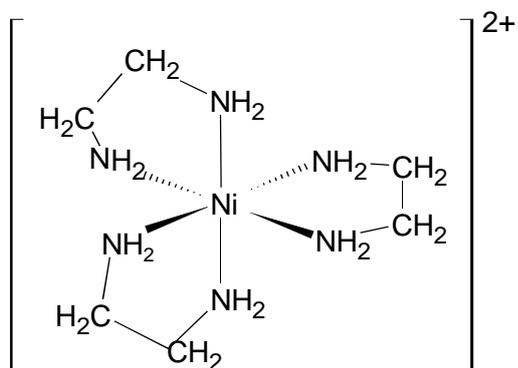
Cis-[Cr(H₂O)₄Cl₂]⁺



trans-[Cr(H₂O)₄Cl₂]⁺

Optical isomerism

Complexes with 3 bidentate ligands can form two optical isomers (non-superimposable mirror images).



Cisplatin

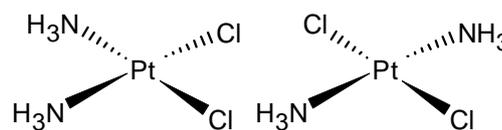
The Pt(II) complex cisplatin is used as an anticancer drug.

The cisplatin version only works as two chloride ions are displaced and the molecule joins on to the DNA. In doing this it stops the replication of cancerous cells.

In the body one Cl ligand is substituted by a water molecule
 $\text{Pt}(\text{NH}_3)_2\text{Cl}_2 + \text{H}_2\text{O} \rightarrow [\text{Pt}(\text{NH}_3)_2\text{Cl}(\text{H}_2\text{O})]^+ + \text{Cl}^-$

Be able to apply your knowledge of bonding to given information in the question to explain how it bonds to DNA molecule- generally a combination of dative covalent bonding and hydrogen bonding.

Platin binds to DNA of cancer cells and stops cancer cells dividing.



cisplatin

transplatin

It can also prevent the replication of healthy cells by bonding on to healthy DNA which may lead to unwanted side effects like hair loss.

