

# Edexcel IAL Chemistry

## A-Level

### Topic 17 - Transition Metals and their Chemistry

Flashcards



# What is a transition metal?



## What is a transition metal?

A transition metal is a d-block element that can form one or more stable ions with partially filled d-orbitals.



Which two elements in the d-block of the periodic table are not technically transition metals?



Which two elements in the d-block of the periodic table are not technically transition metals?

Scandium and zinc.

They do not form ions with an incomplete d-subshell.



Which two elements in the periodic table are exceptions to the rule that the 4s orbital is filled before the 3d orbital?



Which two elements in the periodic table are exceptions to the rule that the 4s orbital is filled before the 3d orbital?

Chromium and copper. The 4s orbital only fills with one electron as this gives them a more stable configuration in the 3d orbital.

Chromium:  $[\text{Ar}]4s^13d^5$

Copper:  $[\text{Ar}]4s^13d^{10}$



What are some of the main properties of transition metals?



## What are some of the main properties of transition metals?

- They have variable oxidation states.
- They form complex ions involving monodentate and bidentate ligands.
- They form coloured ions in solution.
- They can catalyse reactions either as elements or in compounds.



Use examples to show that transition metals have variable oxidation states



Use examples to show that transition metals have variable oxidation states



.....



# What is a ligand?



# What is a ligand?

A ligand is an ion or molecule that bonds to a central metal atom to form a complex ion.



What type of bonding is involved in the formation of metal complex ions?



What type of bonding is involved in the formation of metal complex ions?

Dative covalent (coordinate) bonding.

This is a type of covalent bond in which both of the electrons being shared come from the same atom.



# What is a complex ion?



# What is a complex ion?

A complex ion is a central metal ion surrounded by ligands.



‘Aqueous solutions of transition metal ions are usually \_\_\_\_\_’

Fill in the gap



'Aqueous solutions of transition metal ions are usually \_\_\_\_\_' Fill in the gap

Coloured



# What is meant by coordination number?



What is meant by coordination number?

The number of dative bonds formed with a central metal ion.



# Why do transition metals form coloured complexes?



## Why do transition metals form coloured complexes?

When visible light hits a transition metal ion, electrons are excited to higher energy levels. Some frequencies of visible light are absorbed when electrons jump up to higher orbitals. The rest of the frequencies of visible light are transmitted or reflected. These frequencies combine to make the complement of the colour of the absorbed frequencies. This causes the colour of the complex seen.



Why are some aqueous ions and complex ions colourless?



# Why are some aqueous ions and complex ions colourless?

If there are no electrons in the d-subshell then the ion is colourless. Similarly if the d orbitals are full, then there are no empty orbitals to which the electrons can be excited and so the ions will be colourless.



What factors can cause a colour change  
in a transition metal ion?



What factors can cause a colour change in a transition metal ion?

- Change in oxidation number of the ion.
- Change in the identity of the ligand.
- Change in coordination number of the complex.



What are monodentate ligands? Give an example



# What are monodentate ligands? Give an example

Monodentate ligands have only one atom that bonds to the central metal ion.

Examples include:

- $\text{NH}_3$
- $\text{H}_2\text{O}$
- $\text{OH}^-$



What are bidentate ligands? Give an example



What are bidentate ligands? Give an example

Bidentate ligands have two atoms that bond to the central metal ion.

Examples include:



What are hexadentate ligands? Give an example



What are hexadentate ligands? Give an example

Hexadentate ligands have six atoms that bond to the central metal ion.

Examples include:

- EDTA<sup>4-</sup>



Describe the ligand exchange that occurs in haemoglobin



## Describe the ligand exchange that occurs in haemoglobin

Haemoglobin is an iron(II) complex which has a polydentate ligand.

Ligand exchange occurs when an oxygen molecule bound to haemoglobin is replaced by a carbon monoxide molecule.



What are the different colours of vanadium in its different oxidation states?



What are the different colours of vanadium in its different oxidation states?

Oxidation state	Colour of compound
+2	Violet
+3	Green
+4	Blue
+5	Yellow



How can the dichromate ion,  $\text{Cr}_2\text{O}_7^{2-}$ , be converted to  $\text{Cr}^{2+}$  and  $\text{Cr}^{3+}$  ions?



How can the dichromate(VI) ion,  $\text{Cr}_2\text{O}_7^{2-}$ , be converted to  $\text{Cr}^{2+}$  and  $\text{Cr}^{3+}$  ions?

The dichromate(VI) ion can be reduced to  $\text{Cr}^{2+}$  and  $\text{Cr}^{3+}$  ions using zinc in acidic conditions.



How can the dichromate(VI) ion,  $\text{Cr}_2\text{O}_7^{2-}$ ,  
be produced from  $\text{Cr}^{3+}$  ions?



How can the dichromate(VI) ion,  $\text{Cr}_2\text{O}_7^{2-}$ , be produced from  $\text{Cr}^{3+}$  ions?

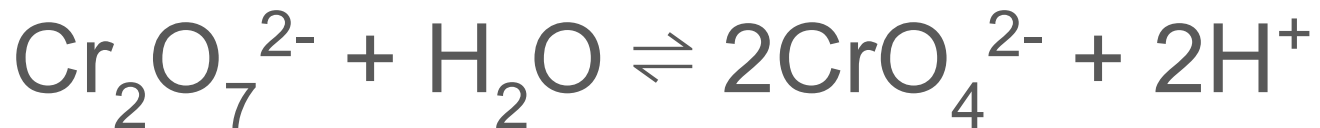
The dichromate(VI) ion can be produced from the oxidation of  $\text{Cr}^{3+}$  ions using hydrogen peroxide in alkaline conditions.



Write the equation for the conversion of dichromate(VI) ions into chromate(VI) ions



Write the equation for the conversion of dichromate(VI) ions into chromate(VI) ions



What is the shape of the  $[\text{CuCl}_2]^-$  complex?



What is the shape of the  $[\text{CuCl}_2]^-$  complex?

Linear

Bond angle:  $180^\circ$



What is the shape of the  $[\text{Pt}(\text{NH}_3)_2\text{Cl}_2]$  complex?



What is the shape of the  $[\text{Pt}(\text{NH}_3)_2\text{Cl}_2]$  complex?

Square planar

Bond angle:  $90^\circ$



What is the shape of the  $[\text{CrCl}_4]^-$  complex?



What is the shape of the  $[\text{CrCl}_4]^-$  complex?

Tetrahedral

Bond angle:  $109.5^\circ$



What is the shape of the  $[\text{Cr}(\text{NH}_3)_6]^{3+}$  complex?



What is the shape of the  $[\text{Cr}(\text{NH}_3)_6]^{3+}$  complex?

Octahedral

Bond angle:  $90^\circ$



What is the shape of the  $[\text{Cu}(\text{H}_2\text{O})_6]^{2+}$  complex?



What is the shape of the  $[\text{Cu}(\text{H}_2\text{O})_6]^{2+}$  complex?

Octahedral

Bond angle:  $90^\circ$



# What is cis-platin?



# What is cis-platin?

Cis-platin is a square planar transition metal complex used in cancer treatment.



Give the equation for the reaction of  
Cr(III) ions with excess  $\text{NH}_3$



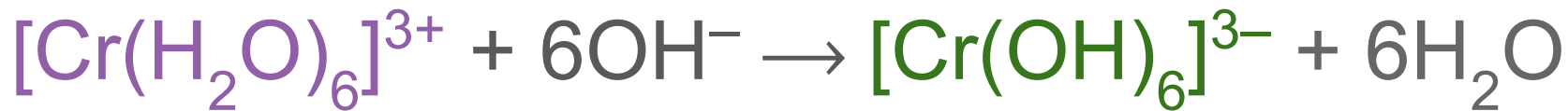
Give the equation for the reaction of Cr(III) ions with excess  $\text{NH}_3$



Give the equation for the reaction of  
Cr(III) ions with excess NaOH



Give the equation for the reaction of Cr(III) ions with excess NaOH



Give the equation for the reaction of  
Mn(II) ions with excess NH<sub>3</sub>



Give the equation for the reaction of Mn(II) ions with excess NH<sub>3</sub>



Give the equation for the reaction of  
Mn(II) ions with excess NaOH



Give the equation for the reaction of Mn(II) ions with excess NaOH



Give the equation for the reaction of  
Fe(II) ions with excess NaOH



Give the equation for the reaction of Fe(II) ions with excess NaOH



Give the equation for the reaction of  
Fe(II) ions with excess  $\text{NH}_3$



Give the equation for the reaction of Fe(II) ions with excess  $\text{NH}_3$



Give the equation for the reaction of  
Fe(III) ions with excess  $\text{NH}_3$



Give the equation for the reaction of Fe(III) ions with excess  $\text{NH}_3$



Give the equation for the reaction of  
Fe(III) ions with excess NaOH



Give the equation for the reaction of Fe(III) ions with excess NaOH



Give the equation for the reaction of  
Ni(II) ions with excess  $\text{NH}_3$



Give the equation for the reaction of Ni(II) ions with excess  $\text{NH}_3$

First  $\text{Ni}(\text{H}_2\text{O})_4(\text{OH})_2$  is formed:



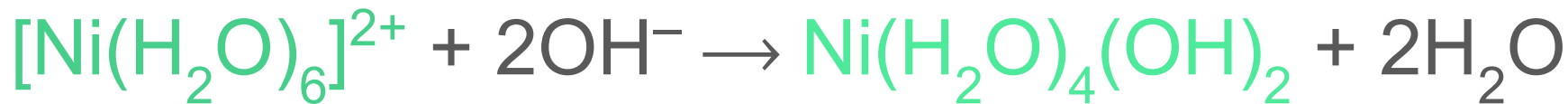
Then the  $\text{Ni}(\text{H}_2\text{O})_4(\text{OH})_2$  dissolves in the excess  $\text{NH}_3$ :



Give the equation for the reaction of  
Ni(II) ions with excess NaOH



Give the equation for the reaction of Ni(II) ions with excess NaOH



Give the equation for the reaction of  
Cu(II) ions with excess NH<sub>3</sub>

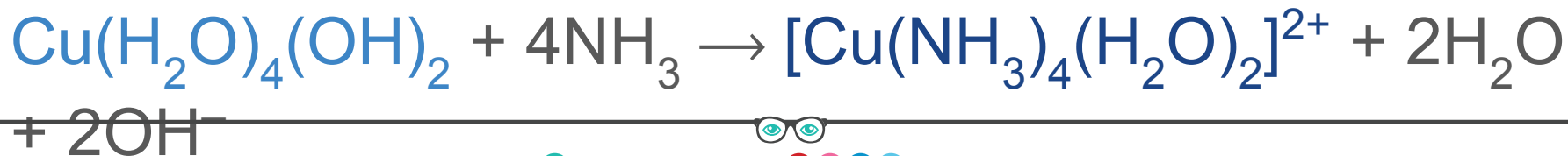


Give the equation for the reaction of Ni(II) ions with excess  $\text{NH}_3$

First  $\text{Cu}(\text{H}_2\text{O})_4(\text{OH})_2$  is formed:



Then the  $\text{Cu}(\text{H}_2\text{O})_4(\text{OH})_2$  dissolves in the excess  $\text{NH}_3$ :



Give the equation for the reaction of  
Cu(II) ions with excess NaOH



Give the equation for the reaction of Cu(II) ions with excess NaOH



# Define amphoteric



## Define amphoteric

An amphoteric compound is a molecule or ion that can act as both an acid or base.



# What is a ligand exchange reaction?



## What is a ligand exchange reaction?

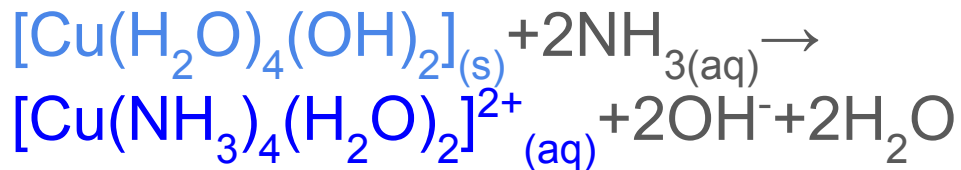
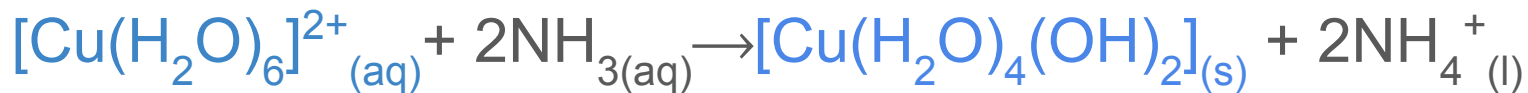
A ligand exchange is a chemical reaction involving the replacement of ligands in a complex by a different set of ligands. For example:



What is the equation and the observations for the ligand exchange reaction between copper hexaaqua ions and ammonia?



What is the equation and the observations for the ligand exchange reaction between copper hexaaqua ions and ammonia?



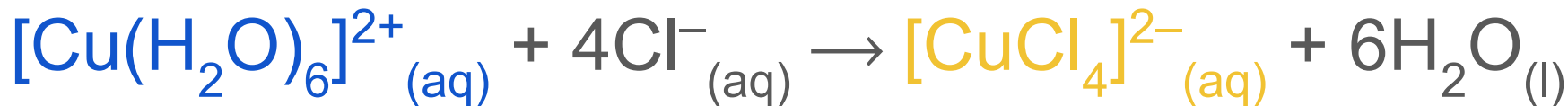
The blue solution forms a light blue precipitate. This dissolves in excess ammonia to form a dark blue solution.



What is the equation and the observations for the ligand exchange reaction between copper hexaaqua ions and chloride ions?



What is the equation and observations for the ligand exchange reaction between copper hexaaqua ions and chloride ions?



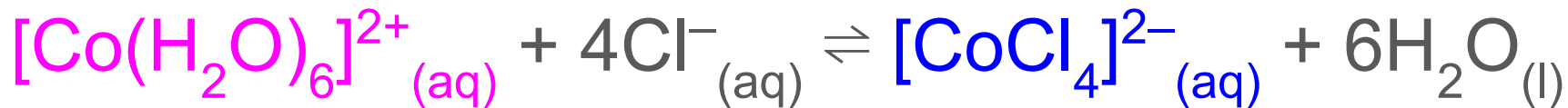
The blue solution forms a yellow solution.



What is the equation and the observations for the ligand exchange reaction between cobalt hexaaqua ions and chloride ions?



What is the equation and observations for the ligand exchange reaction between cobalt hexaaqua ions and chloride ions?



The pink solution forms a dark blue solution.



What happens, in terms of  $\Delta S_{\text{system}}$ , when monodentate ligands are replaced with bidentate and hexadentate ligands?



What happens, in terms of  $\Delta S_{\text{system}}$ , when monodentate ligands are replaced with bidentate and hexadentate ligands?

When monodentate ligands are replaced with bidentate or hexadentate ligands, there is a positive increase in  $\Delta S_{\text{system}}$  and so a more stable metal complex ion is formed.



What is the difference between a homogeneous and a heterogeneous catalyst?



## What is the difference between a homogeneous and a heterogeneous catalyst?

A homogeneous catalyst is in the same phase as the reactants and the catalysed reaction takes place via intermediate species.

A heterogeneous catalyst is in a different phase to the reactants and the reaction occurs on the surface of the catalyst.



Why do transition metals make good homogeneous catalysts?



## Why do transition metals make good homogeneous catalysts?

Transition metals have variable oxidation states, making them good homogeneous catalysts. The variable oxidation states mean they are able to oxidise and reduce reactants and intermediates to form the desired products.



Why do transition metals make good heterogeneous catalysts?



# Why do transition metals make good heterogeneous catalysts?

Using the 3d and 4s electrons of the atoms on the catalyst surface, transition metals can form weak bonds with reactants, making them more reactive.



# How does a catalytic converter work?



## How does a catalytic converter work?

A catalytic converter reduces the carbon monoxide and nitrogen monoxide emissions from internal combustion engines. It does this by adsorbing CO and NO molecules onto the surface of the catalyst to weaken the bonds. Then  $\text{CO}_2$  and  $\text{NO}_2$  molecules are desorbed from the surface of the catalyst.



# What is the Contact Process?



## What is the Contact Process?

An industrial process used to make sulfuric acid. It is made by oxidising sulfur dioxide in the presence of a solid catalyst. Sulfur trioxide is then reacted with water to form sulfuric acid.



# What conditions are required for the Contact Process?



What conditions are required for the Contact Process?

Temperature around  $450^{\circ}\text{C}$ .

Vanadium oxide catalyst ( $\text{V}_2\text{O}_5$ ).

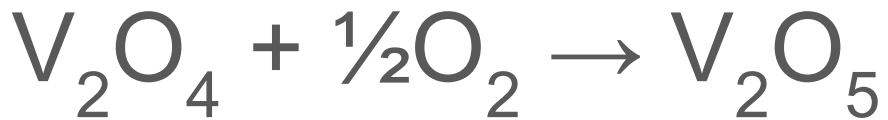
Pressure of 2 atm.



Write two equations showing how vanadium acts as a catalyst in the contact process



Write the two equations showing how vanadium acts as a catalyst in the contact process



Write two equations showing how iron acts as a catalyst in the reaction between persulfate ions and iodide ions



Write the two equations showing how iron acts as a catalyst in the reaction between persulfate ions and iodide ions

