

WJEC (Wales) Chemistry A-level

Topic 3.4 - Chemistry of the d-block Transition Metals

Flashcards

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What is a transition metal?



What is a transition metal?

A transition metal is a d-block element that forms 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 3p orbital?

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

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

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



What are some general properties of transition metals?



What are some general properties of transition metals?

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



Give examples of transition metals that have variable oxidation states



Give examples of transition metals that have variable oxidation states



Why do transition metals have variable oxidation states?



Why do transition metals have variable oxidation states?

Variable oxidation states arise because the electrons in the 4s and 3d orbitals have very similar energies. This means that a relatively similar amount of energy is required to gain or lose different numbers of electrons.



What are the most common oxidation states of Cr?



What are the most common oxidation states of Cr?

+2

+3

+6



What are the most common oxidation states of Mn?



What are the most common oxidation states of Mn?

+2

+4

+7



What are the most common oxidation states of Fe?



What are the most common oxidation states of Fe?

+2

+3



What are the most common oxidation states of Cu?



What are the most common oxidation states of Cu?

+1

+2



What are the most common oxidation states of Co?



What are the most common oxidation states of Co?

+2

+3



What colour are aqueous solutions of compounds containing Cr^{3+} ions?



What colour are aqueous solutions of compounds containing Cr^{3+} ions?

Green



What colour are aqueous solutions of compounds containing CrO_4^{2-} ions?



What colour are aqueous solutions of compounds containing CrO_4^{2-} ions?

Yellow



What colour are aqueous solutions of compounds containing $\text{Cr}_2\text{O}_7^{2-}$ ions?



What colour are aqueous solutions of compounds containing $\text{Cr}_2\text{O}_7^{2-}$ ions?

Orange



What colour are aqueous solutions of compounds containing MnO_4^- ions?



What colour are aqueous solutions of compounds containing MnO_4^- ions?

Purple



What colour are aqueous solutions of compounds containing Co^{2+} ions?



What colour are aqueous solutions of compounds containing Co^{2+} ions?

Pink



What colour are aqueous solutions of compounds containing Fe^{2+} ions?



What colour are aqueous solutions of compounds containing Fe^{2+} ions?

Green



What colour are aqueous solutions of compounds containing Fe^{3+} ions?



What colour are aqueous solutions of compounds containing Fe^{3+} ions?

Brown



What colour are aqueous solutions of compounds containing Cu^{2+} ions?



What colour are aqueous solutions of compounds containing Cu^{2+} ions?

Blue



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 (coordinate) bonding.

This is a type of covalent bond in which both of the electrons being shared are donated 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 the visible light are absorbed when electrons jump up to higher energy 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 creates the colour of the complex.



What can lead to a colour change in a transition metal complex?



What can lead to a colour change in a transition metal complex?

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



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°



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°



What is the shape of the
 $[\text{Cu}(\text{NH}_3)_4(\text{H}_2\text{O})_2]^{2+}$ complex?



What is the shape of the $[\text{Cu}(\text{NH}_3)_4(\text{H}_2\text{O})_2]^{2+}$ complex?

Octahedral

Bond angle: 90°



What is a ligand exchange reaction?



What is a ligand exchange reaction?

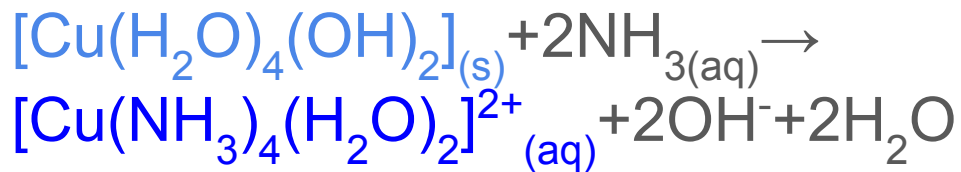
A ligand exchange is a chemical reaction involving the replacement of ligands in a complex by a different set of ligands:



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



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

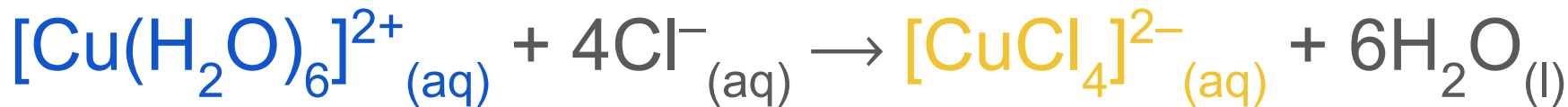


The blue solution forms a light blue precipitate. This dissolves in excess ammonia to form a dark blue solution.

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



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



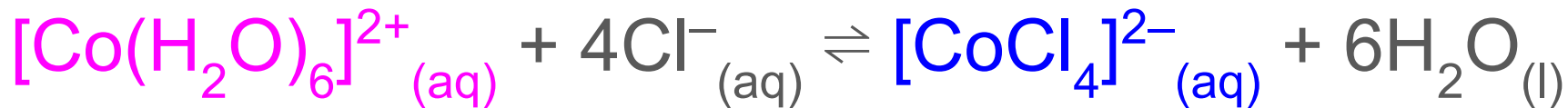
The blue solution forms a yellow solution.



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



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



The pink solution forms a dark blue solution.



What colour are the compounds $[\text{CoCl}_4]^{2-}$
and $[\text{CuCl}_4]^{2-}$?



What colour are the compounds $[\text{CoCl}_4]^{2-}$ and $[\text{CuCl}_4]^{2-}$?

$[\text{CuCl}_4]^{2-} \rightarrow \text{Green}$

$[\text{CoCl}_4]^{2-} \rightarrow \text{Blue}$



What colour are the compounds
 $[\text{Co}(\text{H}_2\text{O})_6]^{2+}$ and $[\text{Cu}(\text{H}_2\text{O})_6]^{2+}$?



What colour are the compounds $[\text{Co}(\text{H}_2\text{O})_6]^{2+}$ and $[\text{Cu}(\text{H}_2\text{O})_6]^{2+}$?

$[\text{Cu}(\text{H}_2\text{O})_6]^{2+} \rightarrow$ Blue

$[\text{Co}(\text{H}_2\text{O})_6]^{2+} \rightarrow$ Pink



What colour is the compound
 $[\text{Cu}(\text{NH}_3)_4(\text{H}_2\text{O})_2]^{2+}$?



What colour is the compound $[\text{Cu}(\text{NH}_3)_4(\text{H}_2\text{O})_2]^{2+}$?

Blue



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.



What catalyst is used in the hydrogenation of alkenes? Is it homogeneous or heterogeneous?



What catalyst is used in the hydrogenation of alkenes? Is it homogeneous or heterogeneous?

Nickel

Heterogeneous



What catalyst is used in the haber process? Is it homogeneous or heterogeneous?



What catalyst is used in the haber process? Is it homogeneous or heterogeneous?

Iron

Heterogeneous



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°C

Vanadium oxide catalyst (V_2O_5)

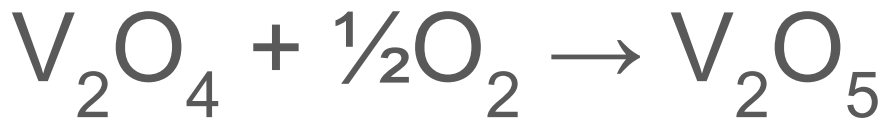
Pressure of 2 atm



Write the 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



What catalyst is used in the decomposition of hydrogen peroxide? Is it homogeneous or heterogeneous?



What catalyst is used in the decomposition of hydrogen peroxide? Is it homogeneous or heterogeneous?

Manganese(IV) oxide

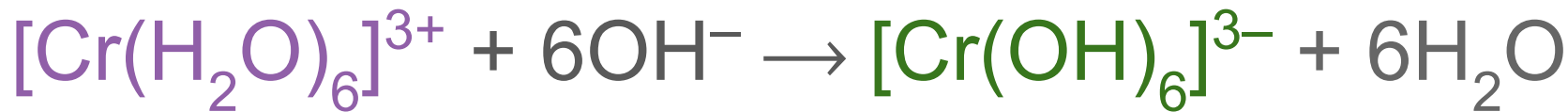
Homogeneous



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
Fe(II) ions with excess NaOH



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



The green solution forms a green precipitate.



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



The orange solution forms a brown precipitate.



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

