

Edexcel Chemistry A-level

Topic 15 - Transition Metals

Flashcards



Define a transition element



Define a transition element

An element which forms at least one stable ion with a partially full d-shell of electrons



Where are the transition metals located in the periodic table?



Where are the transition metals located in the periodic table?

In the middle (block from Ti to Cu) - part of the d-block



What are some
characteristic physical
properties of transition
metals?



What are some characteristic physical properties of transition metals?

Metallic, good conductors of heat and electricity, hard, strong, shiny, high m.p., high b.p., low reactivity.



Some uses of iron?



Some uses of iron?

Vehicle bodies, to reinforce concrete



Some uses of titanium?



Some uses of titanium?

Jet engine parts



Some uses of copper?





Some uses of copper?

Water pipes



What are the characteristic chemical properties of transition metals (4)?



What are the characteristic chemical properties of transition metals (4)?

Variable oxidation states → take part in many redox reactions

Coloured compounds/ions in solution

Good catalysts

Form complex ions



Define the term complex ion



Define the term complex ion

Central transition metal ion surrounded by ligands (other ions/molecules) that are co-ordinated bonded to it.



Give some example of transition metals catalysts and the processes/reactions they catalyse (3)?



Give some example of transition metals catalysts and the processes/reactions they catalyse (3)?

Iron - Haber process

Vanadium (V) oxide - Contact process

MnO_2 - decomposition of H_2O_2



Which electrons do transition metals lose first when forming ions?



Which electrons do transition metals lose first when forming ions?

4s



Define the term ligand



Define the term ligand

An ion or molecule with at least one lone pair of electrons, that donates them to a transition metal ion to form a co-ordinate bond and thus a complex ion.



Define the term
mono/unidentate ligands



Define the term mono/unidentate ligands

A ligand that forms one co-ordinate bond to the central metal ion (one lone pair to donate)



Define the term bidentate
ligand.



Define the term bidentate ligand.

A ligand that forms two co-ordinate bonds to the central metal ion (2 lone pairs to donate)



Define the term multidentate ligand.



Define the term multidentate ligand.

A ligand that forms three or more co-ordinate bonds to the central metal ion



Give some examples of
common monodentate
ligands (3).



Give some examples of common monodentate ligands (4).

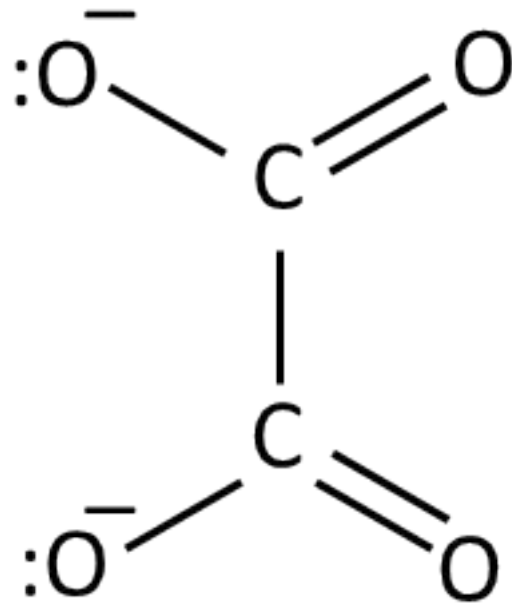


Draw ethanedioate; how many co-ordinate bonds can it form to a transition metal ion?



Draw ethanedioate; how many co-ordinate bonds can it form to a transition metal ion?

2 co-ordinate bonds

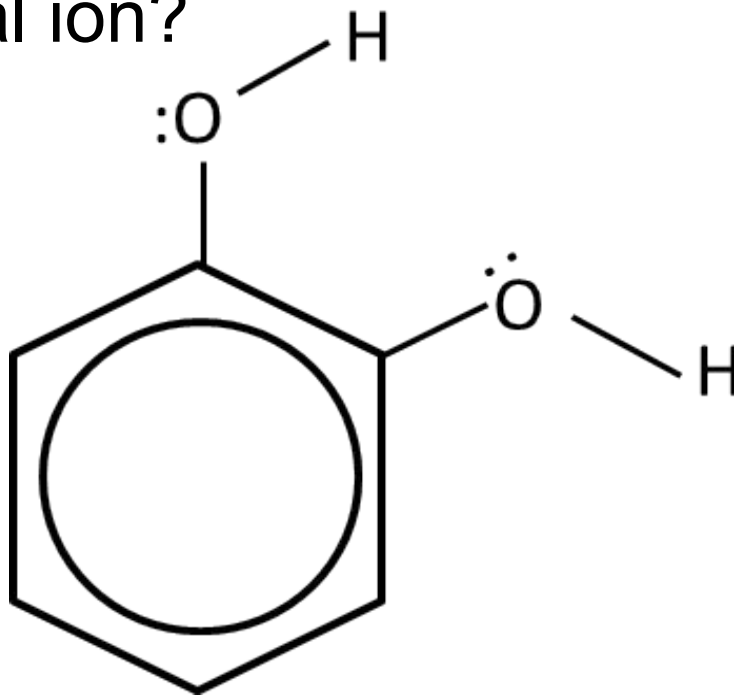


Draw benzene-1,2-diol; how many co-ordinate bonds can it form to a transition metal ion?



Draw benzene-1,2-diol; how many co-ordinate bonds can it form to a transition metal ion?

2 co-ordinate bonds

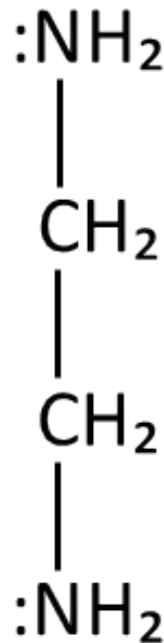


Draw ethane-1,2-diamine.
What is its shortened
name? How many
co-ordinate bonds does it
form?



Draw ethane-1,2-diamine. What is its shortened name? How many co-ordinate bonds does it form?

2 co-ordinate bonds, shortened name = en



How many co-ordinate
bonds does EDTA^{4-} form?



How many co-ordinate bonds does EDTA^{4-} form?

Six



How many coordinate
bonds does this ligand form

$$\text{NH}_2\text{CH}_2\text{CH}_2\text{NH}_2$$


How many coordinate bonds does this ligand form $\text{NH}_2\text{CH}_2\text{CH}_2\text{NH}_2$

2

Therefore it is a bidentate ligand



Define the term coordination number



Define the term coordination number

The number of co-ordinate bonds the metal ion has formed to surrounding ligands



What is the Chelate effect?



What is the Chelate effect?

Chelate complexes with multidentate ligands are favoured over monodentate ligands or ligands that form fewer coordinate bonds per molecule



Explain the Chelate effect in terms of entropy and the reaction that is occurring



Explain the Chelate effect in terms of entropy and the reaction that is occurring

Number of molecules increases when multidentate ligands, e.g. EDTA, displace ligands that form fewer co-ordinate bonds per molecule

Significant increase in entropy \rightarrow Gibbs' free energy change $< 0 \rightarrow$ feasible reaction

A more stable complex ion is formed

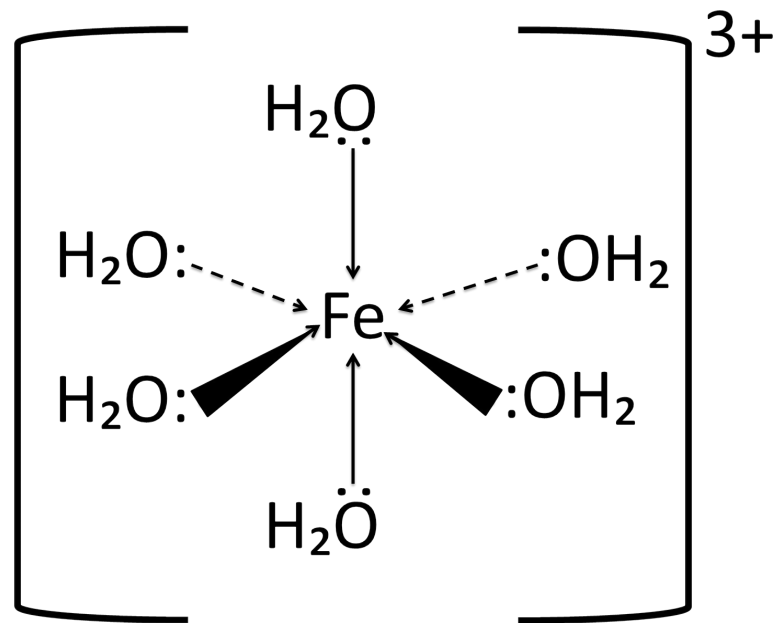


What ion is usually formed when a transition metal compound is dissolved in water? What shape is it? Draw an example



What ion is usually formed when a transition metal compound is dissolved in water? What shape is it?
 Draw an example

Aqua ion, 6 H_2O ligands around the central metal ion. Octahedral complex ion is formed



If a transition metal ion has 2 ligands, what shape is it usually?



If a transition metal ion has 2 ligands, what shape is it usually?

Linear



If a transition metal ion has 4 ligands, what shape is it usually?



If a transition metal ion has 4 ligands, what shape is it usually?

Tetrahedral



Name an exception to the general rule that ions with 4 ligands is generally tetrahedral. What shape is it?



Name an exception to the general rule that ions with 4 ligands is generally tetrahedral. What shape is it?

Platin is square planar → forms cisplatin



What shape is a complex ion if it has 6 ligands?



What shape is a complex ion if it has 6 ligands?

Octahedral



How can complex ions display E-Z or cis-trans isomerism? What shapes of ion does this apply to?



How can complex ions display E-Z or cis-trans isomerism? What shapes of ion does this apply to?

Ligands differ in the way in which they are arranged in space

2 ligands of the same type can be on the same side of the metal ion (next to each other), which forms the E or cis isomer

2 ligands of the same type can be on opposite sides of the metal ion (not next to each other), which forms the Z or trans isomer

Applies to square planar and octahedral complex ions



What conditions are needed for a complex ion to display optical isomerism?



What conditions are needed for a complex ion display to optical isomerism?

Usually applies to octahedral molecules with 2 or more bidentate ligands, so that the mirror images are non-superimposable



What happens to Co^{2+} , Cu^{2+}
and Fe^{3+} 's coordination
numbers when Cl^- ligands
replace NH_3 or H_2O
ligands?



What happens to Co^{2+} , Cu^{2+} and Fe^{3+} 's coordination numbers when Cl^- ligands replace NH_3 or H_2O ligands?

Decreases from 4 to 6 as Cl^- is a much larger ligand than H_2O and NH_3



What is haem - its metal ion,
coordination number and
ligands?



What is haem - its metal ion, coordination number and ligands?

A molecule which makes up protein chains, with an Fe^{2+} central metal ion, which has a coordination number of 6.

4 of these bonds are to a ring system called porphyrin. 1 is to the nitrogen of a globin (protein) molecule and one is to an oxygen in an O_2 molecule



How does haemoglobin transport oxygen?



How does haemoglobin transport oxygen?

O_2 forms a weak coordinate bond to the metal ion, then is transported around the body. The bond breaks when haemoglobin reaches cells and oxygen is released



Why is CO toxic?



Why is CO toxic?

CO also coordinately bonds to the Fe^{2+} , and is a better ligand, so bonds more strongly than O_2 . Stops O_2 from bonding to haemoglobin, so O_2 cannot be transported around the body



Why are transition metal compounds coloured?



Why are transition metal compounds coloured?

They have partially filled d-orbitals and electrons are able to move between the d-orbitals.

In compounds (when ligands coordinately bond to the ion), the d-orbitals split into different energy levels.

Electrons can absorb energy in the form of photons to become excited and move to a higher energy level (excited state). Energy of photon = energy difference between levels

Energy of photon is related to frequency of light by $E = hf$

The colour corresponding to the frequency of the energy change is missing from the spectrum, so we see a combination of all the colours that aren't absorbed



What affects the colour of a transition metal compound?



What affects the colour of a transition metal compound?

ΔE affects the frequency of absorbed photons, so determines the colour.

ΔE is changed by oxidation state of the metal, number and type of ligands, shape, co-ordination number



Why is there a lack of colour in some aqueous ions and other complex ions?



Why is there a lack of colour in some aqueous ions and other complex ions?

Ions that have completely filled 3d energy levels (such as Zn^{2+}) and ions that have no electrons in their 3d energy levels (such as Sc^{3+}) are not coloured those that have partially filled 3d energy levels are coloured.



Fill in this table for vanadium species:

Species	Oxidation number	Colour
VO_2^+		
VO^{2+}		
V^{3+}		
V^{2+}		



Fill in this table for vanadium species:

Species	Oxidation number	Colour
VO_2^+	5+	Yellow
VO^{2+}	4+	Blue
V^{3+}	3+	Green
V^{2+}	2+	Violet



What can you use to reduce Vanadium?



What can you use to reduce Vanadium?

Zinc

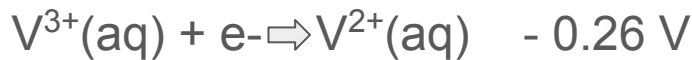


Write the equation and observation of the reduction of V^{3+} to V^{2+} using zinc



Write the equation and observation of the reduction of V^{3+} to V^{2+} using zinc

Half equations: E° Values



As zinc has a more negative electrode potential than the vanadium half equations, zinc will reduce down to V^{2+}



The colour will change green solution to violet.



What colour is Fe^{2+} 's aqua ion?



What colour is Fe^{2+} 's aqua ion?

Green



What colour is Fe^{3+} 's aqua ion?



What colour is Fe^{3+} 's aqua ion?

Pale brown



What colour is Cr^{2+} 's aqua ion?



What colour is Cr^{2+} 's aqua ion?

blue



What colour is Cr^{3+} 's aqua ion?



What colour is Cr^{3+} 's aqua ion?

red/violet



What colour is Co^{2+} 's aqua ion?



What colour is Co^{2+} 's aqua ion?

Brown



What colour is Co^{3+} 's aqua ion?



What colour is Co^{3+} 's aqua ion?

Yellow



What does a colorimeter do?



What does a colorimeter do?

Measures the absorbance of a particular wavelength of light by a solution



How would you use colorimetry experimentally?



How would you use colorimetry experimentally?

Use solutions of known concentration to create a calibration graph; find unknown concentration



What information can a colorimeter give you?



What information can a colorimeter give you?

The concentration of a certain ion in the solution



Why can transition metals have variable oxidation states?



Why can transition metals have variable oxidation states?

They have partially filled d-orbitals, so can lose 4s and 3d electrons



Which oxidation states do all transition metals have? (except Sc). Why?



Which oxidation states do all transition metals have (except Sc)? Why?

+2 due to loss of electrons from 4s orbital



When oxidation state is high, do the transition metals exist as simple ions?



When oxidation state is high, do the transition metals exist as simple ions?

No, after oxidation state of about III, metal ions covalently bond to other species



What is the use of the complex $[\text{Ag}(\text{NH}_3)_2]^+$ ion?



What is the use of the complex $[\text{Ag}(\text{NH}_3)_2]^+$ ion?

Tollens' reagent to test for aldehydes/ketones (silver mirror formed with aldehyde, no visible change with ketone)



What colour is MnO_4^- ?



What colour is MnO_4^- ?

Deep purple



What colour is Mn^{2+} ?



What colour is Mn^{2+} ?

Pink



Write a half equation for the reduction of MnO_4^- to Mn^{2+} .



Write a half equation for the reduction of MnO_4^- to Mn^{2+} .



Why are redox titrations with transition metal compounds said to be self-indicating?



Why are redox titrations with transition metal compounds said to be self-indicating?

They usually involve a colour change as the metal is changing oxidation state; sometimes an indicator is still needed/useful



What colour is $\text{Cr}_2\text{O}_7^{2-}$?





What colour is $\text{Cr}_2\text{O}_7^{2-}$?

Orange



What colour is Cr^{3+} ?



What colour is Cr^{3+} ?

Green



Write a half equation for the reduction of $\text{Cr}_2\text{O}_7^{2-}$ to Cr^{3+} .



Write a half equation for the reduction of $\text{Cr}_2\text{O}_7^{2-}$ to Cr^{3+} .



What happens to aqua metal ions in acidic conditions?



What happens to aqua metal ions in acidic conditions?

They get reduced



Write an equation and observation of the reduction of Cr^{3+} and Cr^{2+} ions using zinc in acidic conditions



Write an equation and observation of the reduction of Cr^{3+} and Cr^{2+} ions using zinc in acidic conditions



The colour change is orange to blue.



What happens to aqua metal ions in alkaline conditions?



What happens to aqua metal ions in alkaline conditions?

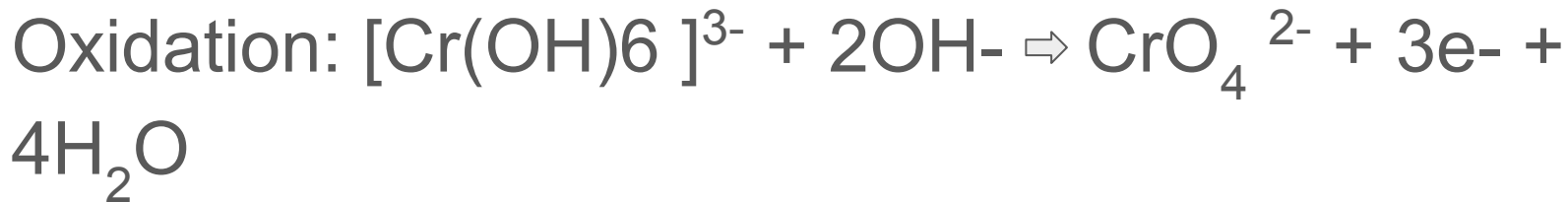
They get oxidised



Write an equation and the observation of the oxidation Cr^{3+} ions using hydrogen peroxide in alkaline conditions



Write an equation and the observation of the oxidation Cr^{3+} ions using hydrogen peroxide in alkaline conditions



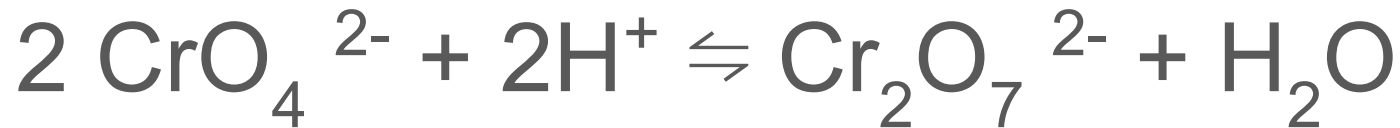
The colour changes from green to yellow solution



Write equation for the
chromate/ dichromate
equilibrium including the
colour changes



Write equation for the chromate/ dichromate equilibrium including the colour changes



Yellow solution

orange solution



What happens to aqua
metal ions in neutral
conditions?



What happens to aqua metal ions in neutral conditions?

No change



What does whether
reduction/oxidation occurs
and the readiness of the
reaction depend on?



What does whether reduction/oxidation occurs and the readiness of the reaction depend on?

E° values



What can change these E° values?



What can change these E^\ominus values?

pH, ligands involved



Complete the table

	$[\text{Fe}(\text{H}_2\text{O})_6]^{2+}$	$[\text{Co}(\text{H}_2\text{O})_6]^{2+}$	$[\text{Cu}(\text{H}_2\text{O})_6]^{2+}$	$[\text{Fe}(\text{H}_2\text{O})_6]^{3+}$	$[\text{Cr}(\text{H}_2\text{O})_6]^{3+}$
Colour of aqua ion					
Colour of Salt					
Precipitate with NaOH					
Reaction with Excess OH					
Precipitate with dil NH_3					
Precipitate with excess NH_3					
Reaction with HCl					



Complete this table

	$[\text{Fe}(\text{H}_2\text{O})_6]^{2+}$	$[\text{Co}(\text{H}_2\text{O})_6]^{2+}$	$[\text{Cu}(\text{H}_2\text{O})_6]^{2+}$	$[\text{Fe}(\text{H}_2\text{O})_6]^{3+}$	$[\text{Cr}(\text{H}_2\text{O})_6]^{3+}$
Colour of aqua ion	Pale Green	Pink	Pale Blue	Violet	Red/Ruby
Colour of Salt				$[\text{Fe}(\text{H}_2\text{O})_5(\text{OH})]^{2+}$ Brown	$[\text{Cr}(\text{H}_2\text{O})_4\text{Cl}_2]^+$ Green
Precipitate with NaOH	$[\text{Fe}(\text{H}_2\text{O})_4(\text{OH})_2]$ Green (s)	$[\text{Co}(\text{H}_2\text{O})_4(\text{OH})_2]$ Blue (s)	$[\text{Cu}(\text{H}_2\text{O})_4(\text{OH})_2]$ Pale Blue (s)	$[\text{Fe}(\text{H}_2\text{O})_3(\text{OH})_3]$ Brown (s)	$[\text{Cr}(\text{H}_2\text{O})_3(\text{OH})_3]$ Green (s)
Reaction with Excess OH^-	$[\text{Fe}(\text{H}_2\text{O})_4(\text{OH})_2]$ Green (s)	$[\text{Co}(\text{H}_2\text{O})_4(\text{OH})_2]$ Blue (s)	$[\text{Cu}(\text{H}_2\text{O})_4(\text{OH})_2]$ Pale Blue (s)	$[\text{Fe}(\text{H}_2\text{O})_3(\text{OH})_3]$ Brown (s)	$[\text{Cr}(\text{H}_2\text{O})_2(\text{OH})_4]^-$ Green
Precipitate with dil NH_3	$[\text{Fe}(\text{H}_2\text{O})_4(\text{OH})_2]$ Green (s)	$[\text{Co}(\text{H}_2\text{O})_4(\text{OH})_2]$ Blue (s)	$[\text{Cu}(\text{H}_2\text{O})_4(\text{OH})_2]$ Pale Blue (s)	$[\text{Fe}(\text{H}_2\text{O})_3(\text{OH})_3]$ Brown (s)	$[\text{Cr}(\text{H}_2\text{O})_3(\text{OH})_3]$ Green (s)
Precipitate with excess NH_3	$[\text{Fe}(\text{H}_2\text{O})_4(\text{OH})_2]$ Green (s)	$[\text{Co}(\text{NH}_3)_6]^{2+}$ Yellow/Straw	$[\text{Cu}(\text{H}_2\text{O})_3(\text{NH}_3)_4]^{2+}$ Dark/Royal Blue	$[\text{Fe}(\text{H}_2\text{O})_3(\text{OH})_3]$ Brown (s)	$[\text{Cr}(\text{NH}_3)_6]^{2+}$ Violet
Reaction with HCl	None	$[\text{CoCl}_4]^{2-}$ Blue	$[\text{CuCl}_4]^{2-}$ Yellow	None	None



Define a catalyst



Define a catalyst

A substance that increases the rate of a reaction without being chemically changed at the end of the reaction



How do catalysts usually work?



How do catalysts usually work?

Provide an alternative reaction pathway with a lower activation energy



Why are transition metals good catalysts?



Why are transition metals good catalysts?

They can exist in variable oxidation states, so can provide alternative pathways easily



Why are group 1, 2 and 3
metals not as good
catalysts?



Why are group 1, 2 and 3 metals not as good catalysts?

Only exist in one oxidation state



What are advantages of using a catalyst for a reaction?



What are advantages of using a catalyst for a reaction?

Allows reactions to proceed at lower temperatures and pressures → saves valuable energy and resources



How do catalytic converter decrease carbon monoxide and nitrogen monoxide emissions from internal combustion engines?



How do catalytic converter decrease carbon monoxide and nitrogen monoxide emissions from internal combustion engines?

- Adsorption of CO and NO molecules onto the surface of the catalyst
- Weaken of bonds and chemical reaction
- Desorption of CO₂ and N₂ product molecules from the surface of the catalyst



What metals are used in a catalytic converter and which reactions do they catalyse?



What metals are used in a catalytic converter and which reactions do they catalyse?

Pt, Rh, Pd

Catalyse CO , $\text{NO} \rightarrow \text{CO}_2$, N_2 and $\text{C}_x\text{H}_{2x+2} \rightarrow$
 H_2O , CO_2



Define a heterogeneous catalyst



Define a heterogeneous catalyst

A catalyst that is present in the reaction in a different phase to the reactants (usually a solid, with gas/liquid reactants).

Catalytic activity occurs on the solid surface as the reactants pass over it



What is an advantage of using a heterogeneous catalyst?



What is an advantage of using a heterogeneous catalyst?

No need for separation of products from catalyst



How do heterogeneous catalysts work?



How do heterogeneous catalysts work?

Reactants adsorb to the catalyst's surface at active sites. This weakens bonds within the reactants, holds reactants close together on the surface and/or in the correct orientation to react. Once the reaction has occurred, products desorb from the active sites.



What properties does the catalyst need to have to make it a good catalyst?



What properties does the catalyst need to have to make it a good catalyst?

Can't adsorb too strongly, otherwise the products will not desorb. Can't adsorb too weakly as reactant would not be held in place for long enough and bonds would not be sufficiently weakened. Need a good balance between desorption and adsorption.



How can you increase the efficiency of heterogeneous catalysts?



How can you increase the efficiency of heterogeneous catalysts?

Increase the surface area to increase the number of active sites that are present.

Also spread onto an inert support medium, e.g. ceramic, to increase the surface/mass ratio. Use ceramic honeycomb matrix/mesh/sponge.



What is catalyst poisoning?



What is catalyst poisoning?

Unwanted impurities adsorb to the catalyst's active sites and do not desorb. This blocks the active sites on the catalyst's surface



What effect does catalyst poisoning have on catalytic activity?



What effect does catalyst poisoning have on catalytic activity?

Decreases the effectiveness of the catalyst over time



How else can a catalyst be degraded?



How else can a catalyst be degraded?

Finely divided catalysts can be gradually lost from their support medium



What is the Haber process?
What catalyst is used?



What is the Haber process? What catalyst is used?

$\text{N}_2 (\text{g}) + 3\text{H}_2 (\text{g}) \rightarrow 2\text{NH}_3 (\text{g})$ Makes ammonia,
uses iron (Fe) catalyst



Define homogeneous catalyst



Define homogeneous catalyst

A catalyst that is in the same phase as the reactants.



How do homogeneous catalysts work?



How do homogeneous catalysts work?

Form intermediates to give a different reaction pathway with lower E_A



What is the reaction
between $\text{S}_2\text{O}_8^{2-}$ ions and I^-
ions?



What is the reaction between $\text{S}_2\text{O}_8^{2-}$ ions and I^- ions?



Why does the reaction
between $S_2O_8^{2-}$ ions and I^-
ions have a high E_A in
normal conditions?



Why does the reaction between $\text{S}_2\text{O}_8^{2-}$ ions and I^- ions have a high E_A in normal conditions?

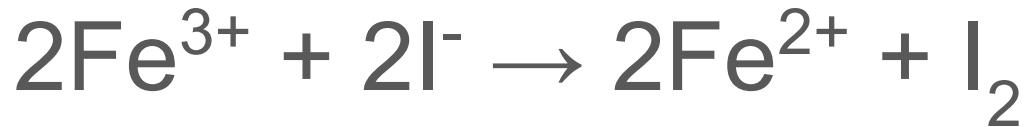
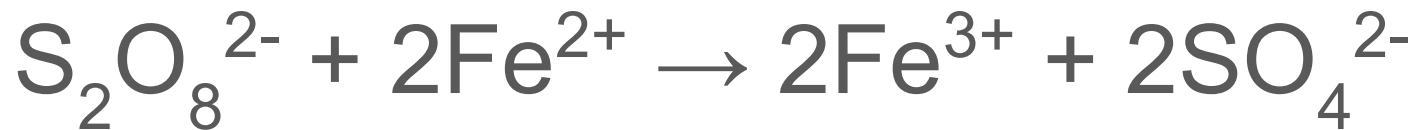
Two negative ions are reacting. They repel each other so E_A is high



Which transition metal ions catalyse the reaction between $S_2O_8^{2-}$ ions and I^- ions? Write two equations to show how.



Which transition metal ions catalyse the reaction between $\text{S}_2\text{O}_8^{2-}$ ions and I^- ions? Write two equations to show how



Define the term autocatalysis



Define the term autocatalysis

When the product of a reaction is also a catalyst for that reaction.

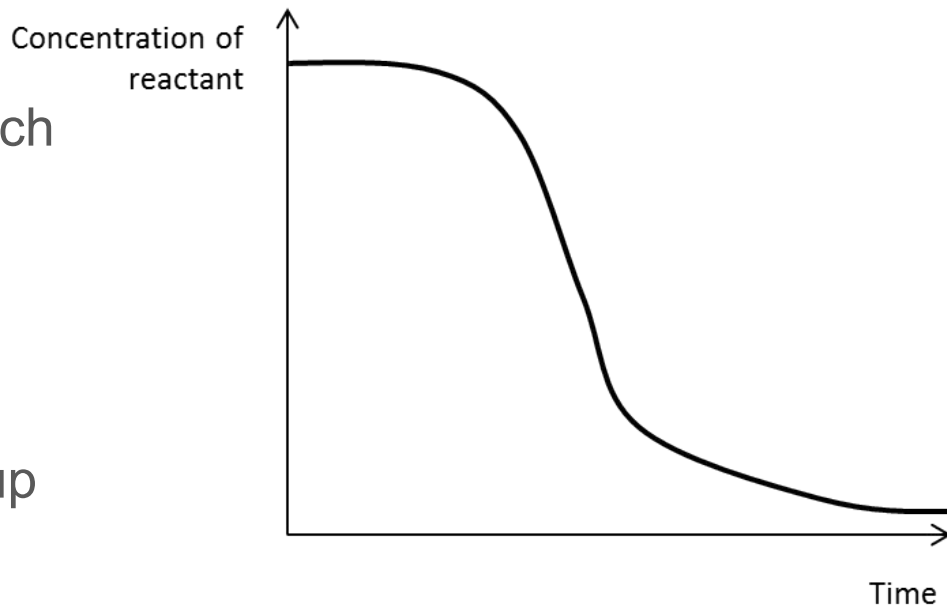


Draw a concentration of reactant against time graph for an autocatalysed reaction.
Explain each stage.



Draw a concentration of reactant against time graph for an autocatalysed reaction. Explain each stage.

Initially slow, uncatalysed as not much of catalyst has been formed
Rate increases as catalyst is made; catalysed reaction is faster
Slows down as reactants are used up



Write a half equation for the
conversion of $\text{C}_2\text{O}_4^{2-}$ ions
into CO_2



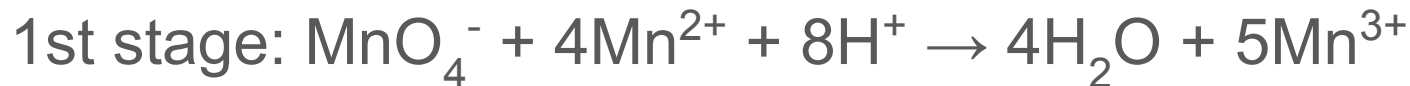
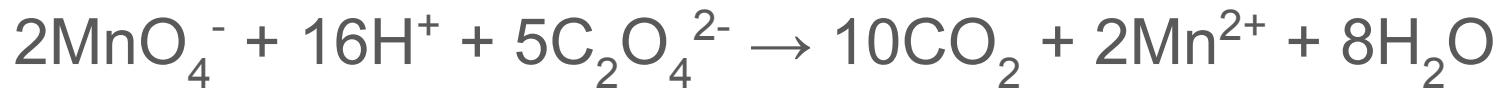
Write a half equation for the conversion of $\text{C}_2\text{O}_4^{2-}$ ions into CO_2



Write an equation for the reaction between $\text{C}_2\text{O}_4^{2-}$ ions and MnO_4^- ions. How does Mn^{2+} autocatalyse this reaction?



Write an equation for the reaction between $\text{C}_2\text{O}_4^{2-}$ ions and MnO_4^- ions. How does Mn^{2+} autocatalyse this reaction?



How can you monitor the
concentration of MnO_4^-
ions?



How can you monitor the concentration of MnO_4^- ions?

Using a colorimeter

