Edexcel Chemistry A-level

Topic 15 - Transition Metals

Flashcards

Define a transition element

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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).

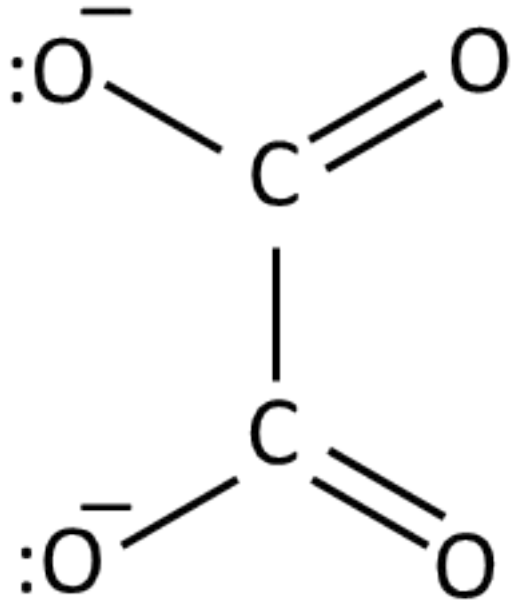
Give some examples of common monodentate ligands (4).

H_2O, NH_3, OH^-

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?

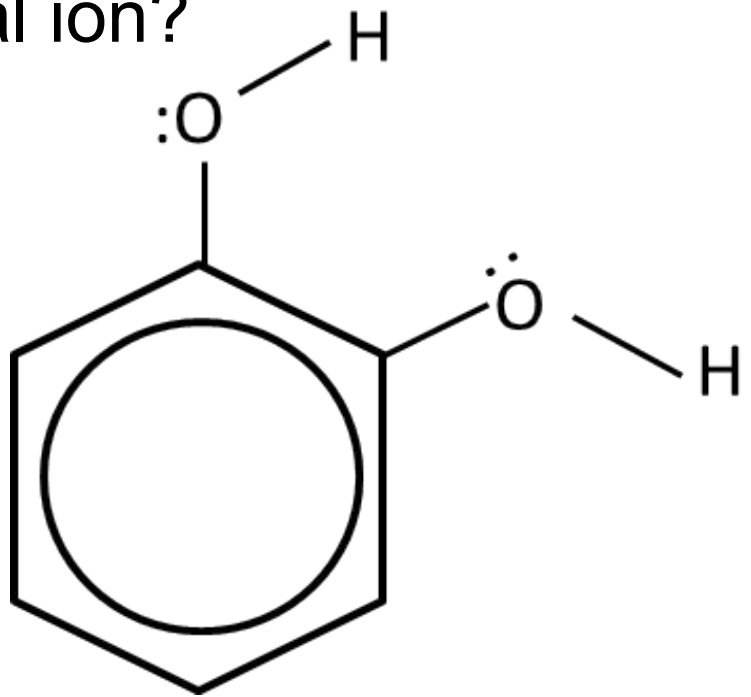
2 co-ordinate bonds



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?

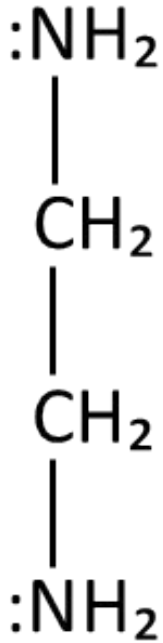
2 co-ordinate bonds



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 $NH_2CH_2CH_2NH_2$

How many coordinate bonds does this ligand form $NH_2CH_2CH_2NH_2$

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, displacee ligands that form fewer co-ordinate bonds per molecule

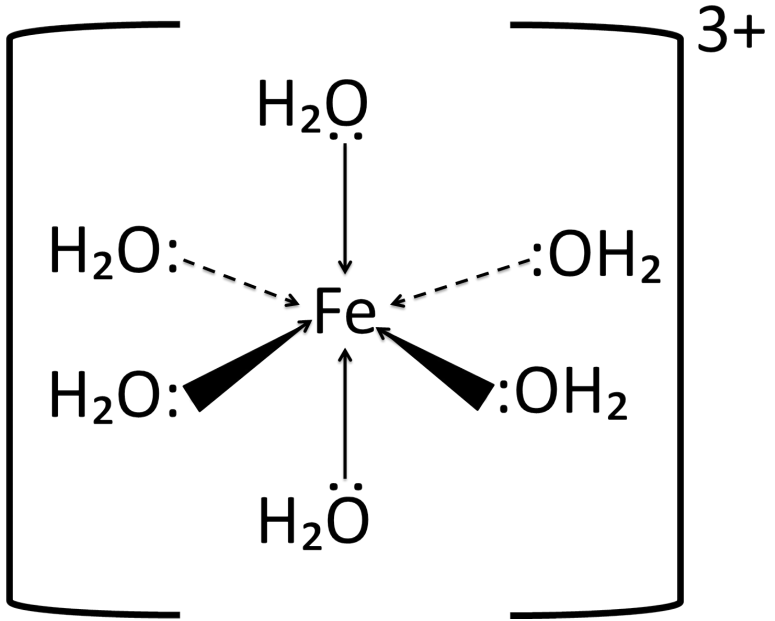
Significant increase in entropy → Gibbs' free energy change < 0 → feasible reaction

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^o Values
$V^{3+}(aq) + e^- \Rightarrow V^{2+}(aq)$	- 0.26 V
$Zn^{2+} + 2e^- \Rightarrow Zn$	-0.76V

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

$2V^{3+}(aq) + Zn \Rightarrow Zn^{2+} + V^{2+}(aq)$

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 $[Ag(NH_3)_2)]^+$ ion?

What is the use of the complex $[Ag(NH_3)_2)]^+$ 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

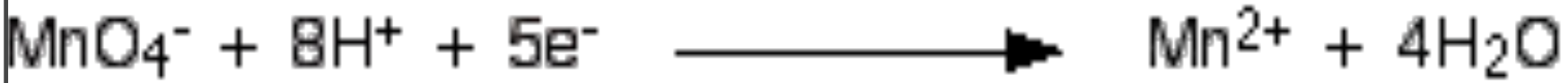
What colour is Mn^{2+}?

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 $Cr_2O_7^{2-}$?

What colour is $Cr_2O_7^{2-}$?

Orange

What colour is Cr^{3+}?

What colour is Cr^{3+}?

Green

Write a half equation for the reduction of $Cr_2O_7^{2-}$ to Cr^{3+}.

Write a half equation for the reduction of $Cr_2O_7^{2-}$ to Cr^{3+}.

$$Cr_2O_7^{2-} + 14H^+ + 6e^- \longrightarrow 2Cr^{3+} + 7H_2O$$

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

$$Cr_2O_7^{2-} + 14H^+ + 4Zn \Rightarrow 2Cr^{2+} + 7H_2O + 4\,Zn^{2+}$$

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

Reduction : $H_2O_2 + 2e- \Rightarrow 2OH^-$

Oxidation: $[Cr(OH)6]^{3-} + 2OH- \Rightarrow CrO_4^{2-} + 3e- + 4H_2O$

$2[Cr(OH)6]^{3-} + 3H_2O_2 \Rightarrow 2CrO_4^{2-} + 2OH^- + 8H_2O$

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

$$2\,CrO_4^{2-} + 2H^+ \rightleftharpoons Cr_2O_7^{2-} + H_2O$$

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

	$[Fe(H_2O)_6]^{2+}$	$[Co(H_2O)_6]^{2+}$	$[Cu(H_2O)_6]^{2+}$	$[Fe(H_2O)_6]^{3+}$	$[Cr(H_2O)_6]^{3+}$
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

	$[Fe(H_2O)_6]^{2+}$	$[Co(H_2O)_6]^{2+}$	$[Cu(H_2O)_6]^{2+}$	$[Fe(H_2O)_6]^{3+}$	$[Cr(H_2O)_6]^{3+}$
Colour of aqua ion	Pale Green	Pink	Pale Blue	Violet	Red/Ruby
Colour of Salt				$[Fe(H_2O)_5(OH)]^{2+}$ Brown	$[Cr(H_2O)_4Cl_2]^{+}$ Green
Precipitate with NaOH	$[Fe(H_2O)_4(OH)_2]$ Green (s)	$[Co(H_2O)_4(OH)_2]$ Blue (s)	$[Cu(H_2O)_4(OH)_2]$ Pale Blue (s)	$[Fe(H_2O)_3(OH)_3]$ Brown (s)	$[Cr(H_2O)_3(OH)_3]$ Green (s)
Reaction with Excess OH^-	$[Fe(H_2O)_4(OH)_2]$ Green (s)	$[Co(H_2O)_4(OH)_2]$ Blue (s)	$[Cu(H_2O)_4(OH)_2]$ Pale Blue (s)	$[Fe(H_2O)_3(OH)_3]$ Brown (s)	$[Cr(H_2O)_2(OH)_4]^-$ Green
Precipitate with dil NH_3	$[Fe(H_2O)_4(OH)_2]$ Green (s)	$[Co(H_2O)_4(OH)_2]$ Blue (s)	$[Cu(H_2O)_4(OH)_2]$ Pale Blue (s)	$[Fe(H_2O)_3(OH)_3]$ Brown (s)	$[Cr(H_2O)_3(OH)_3]$ Green (s)
Precipitate with excess NH_3	$[Fe(H_2O)_4(OH)_2]$ Green (s)	$[Co(NH_3)_6]^{2+}$ Yellow/Straw	$[Cu(H_2O)_2(NH_3)_4]^{2+}$ Dark/Royal Blue	$[Fe(H_2O)_3(OH)_3]$ Brown (s)	$[Cr(NH_3)_6]^{2+}$ Violet
Reaction with HCl	None	$[CoCl_4]^{2-}$ Blue	$[CuCl_4]^{2-}$ 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 CO_2 and N_2 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, Rd, Pd

Catalyse CO, NO $\rightarrow$ CO_2, N_2 and C_xH_{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?

N_2 (g) + $3H_2$ (g) → $2NH_3$ (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 $S_2O_8^{2-}$ ions and I^- ions?

What is the reaction between $S_2O_8^{2-}$ ions and I^- ions?

$$S_2O_8^{2-} + 2I^- \rightarrow 2SO_4^{2-} + I_2 \text{ (all aq)}$$

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 $S_2O_8^{2-}$ 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 $S_2O_8^{2-}$ ions and I^- ions? Write two equations to show how

Fe^{2+}

$$S_2O_8^{2-} + 2Fe^{2+} \rightarrow 2Fe^{3+} + 2SO_4^{2-}$$

$$2Fe^{3+} + 2I^- \rightarrow 2Fe^{2+} + I_2$$

Define the term autocatalysis

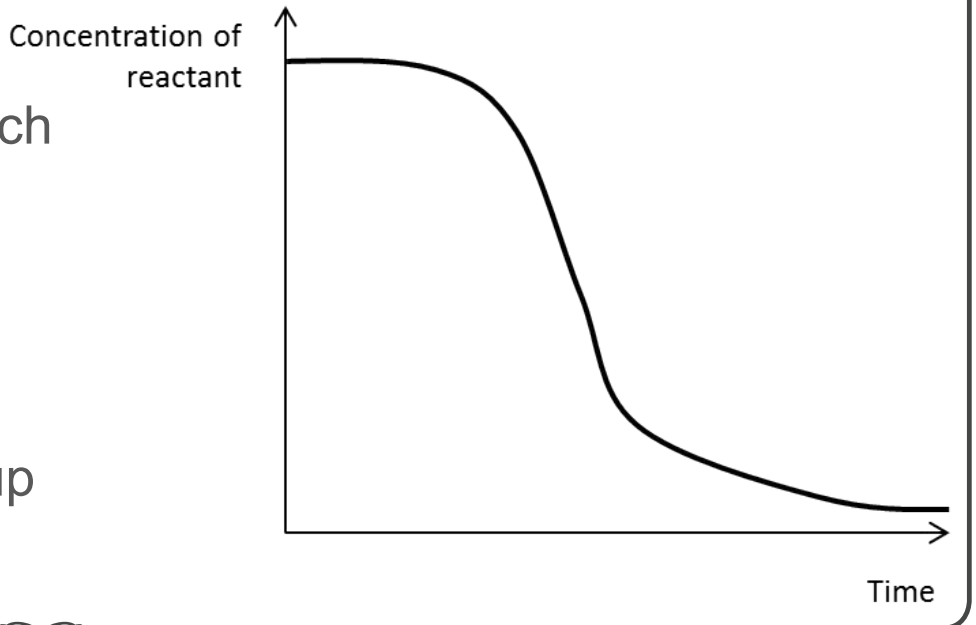
Define the term autocatalysis

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 $C_2O_4^{2-}$ ions into CO_2

Write a half equation for the conversion of $C_2O_4^{2-}$ ions into CO_2

$$C_2O_4^{2-} \rightarrow 2CO_2 + 2e^-$$

Write an equation for the reaction between $C_2O_4^{2-}$ ions and MnO_4^- ions. How does Mn^{2+} autocatalyse this reaction?

Write an equation for the reaction between $C_2O_4^{2-}$ ions and MnO_4^- ions. How does Mn^{2+} autocatalyse this reaction?

$$2MnO_4^- + 16H^+ + 5C_2O_4^{2-} \rightarrow 10CO_2 + 2Mn^{2+} + 8H_2O$$

1st stage: $MnO_4^- + 4Mn^{2+} + 8H^+ \rightarrow 4H_2O + 5Mn^{3+}$

2nd stage: $2Mn^{3+} + C_2O_4^{2-} \rightarrow 2CO_2 + 2Mn^{2+}$

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

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

Using a colorimeter