

CATALYSTS

413 team 4

IRON(II) AND IRON(III)

REACTION

The reaction between peroxodisulfate ions ($S_2O_8^{2-}$) and iodide ions (I^-) can be catalysed in solution by either Fe^{2+} or Fe^{3+} ions. The uncatalysed reaction is very slow because both reactants are negatively charged and, therefore, repel each other.



The catalysed reaction has two steps:



These two reactions can happen in either order, so the reaction can be catalysed by either an Fe^{2+} or Fe^{3+} solution.

MANGANATE

REACTION

This is the overall reaction occurring:

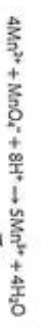


The reaction is initially slow because the two negatively charged reactants repel each other

This species acts as the catalyst once it has been formed

AUTOCATALYSIS

An autocatalyst is a product of a reaction that then acts as a catalyst for that reaction. In this case, it is Mn^{2+} that reacts with reactants as soon as it is formed:



Oxidation state of Mn gets changed from +2 or +7 to +3 - both oxidation and reduction are happening

Catalyst is reformed

Mn is now positively charged so the two reactants attract each other and the reaction happens much faster

TYPES OF CATALYST

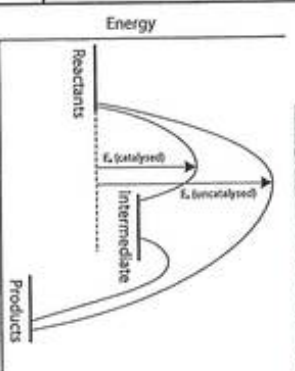
HOMOGENEOUS

A homogeneous catalyst is in the same phase as the reactants. In this case, catalysed reactions go through an intermediate species before the products form.

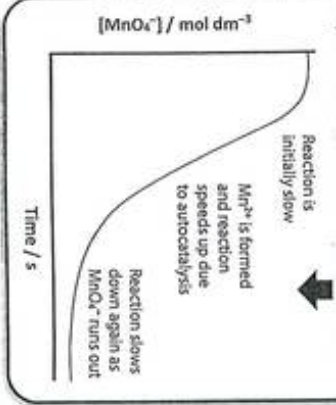
HETEROGENEOUS

A heterogeneous catalyst is in a different phase to the reactants. It is often a solid. Reactions occur at active sites on the catalyst's surface so maximising surface area is vital.

INTERMEDIATE SPECIES



In a catalysed reaction, the homogeneous catalyst binds to one of the reactants and forms an intermediate. This is often more stable / easier for the other reactant to react with, so the activation energy is lower. The intermediate then forms the products.



This graph shows how the concentration of MnO_4^- changes throughout the reaction. This data can be obtained using colorimetry of the coloured $Mn(VII)$ solution.

VANADIUM(V) OXIDE

V_2O_5 acts as a heterogeneous catalyst in the contact process, which produces sulfuric acid. H_2SO_4 in this phase of the process, V_2O_5 is used to convert sulfur dioxide to sulfur trioxide. The vanadium catalyst is heterogeneous - it is a solid.

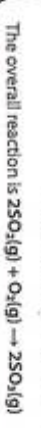
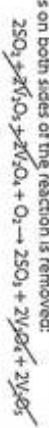


The oxidation state of vanadium changes from +5 to +4 - it is being REDUCED



The oxidation state changes back to +5 - vanadium(V) oxide is re-oxidised by oxygen to form the original vanadium(V) catalyst

To find the overall equation of the reaction, the subreactions must be balanced and combined, and then any species on both sides of the reaction is removed:



IRON: HABER PROCESS

Iron is used as a catalyst for the Haber process, which produces ammonia. The iron is usually in the form of small pellets to increase the surface area of the solid. The overall reaction is:



Iron is not used up in the reaction - it is a catalyst. Gas molecules attach (adsorb) to the surface and are held in place as they react, then the products are released (desorb).

SUPPORT MEDIUM

When using a heterogeneous catalyst, one of the important things to consider is how to maximise the surface area - the more active sites there are, the more molecules can react simultaneously and the faster the rate. This is also cheaper, as smaller amounts of catalyst can be used. Some catalysts are broken into pellets or powders, but others are coated in a thin layer over a solid support medium.

POISONING

- Over time, the active sites on a heterogeneous catalyst can become blocked by impurities in the reaction mixture. This is called **catalyst poisoning**.
- Once bound to an impurity, the active site can no longer carry out its catalytic function and, if enough sites are poisoned, the catalyst will become ineffective or completely inactive.
- As a result, the catalyst will need to be replaced regularly, which can be very expensive. Catalytic converters contain platinum, palladium and rhodium, which are all precious metals. Poisoning can be prevented by purifying the reactants before using them.

