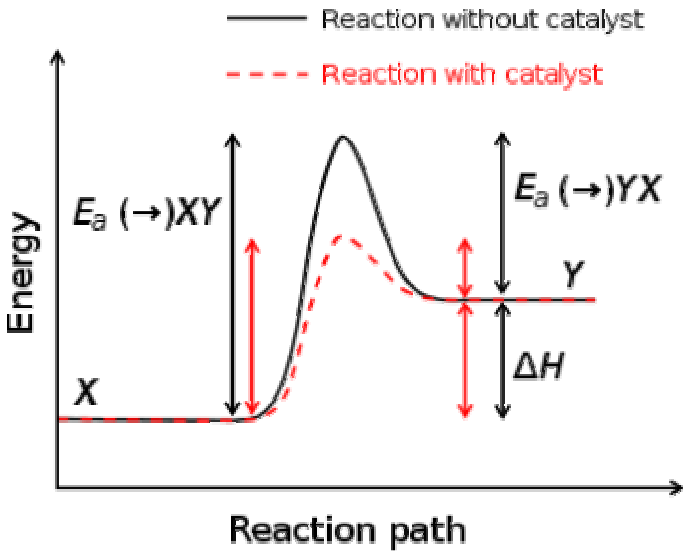
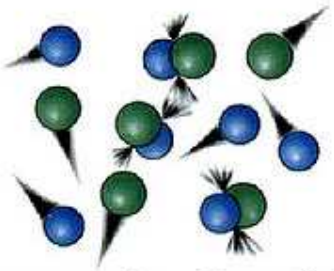
Catalysis

Catalysis is the process in which the rate of a chemical reaction is either increased or decreased by means of a chemical substance known as a catalyst. Catalysts are reagents that participate in the chemical reaction, the catalyst may participate in multiple chemical transformations however will not get consumed during the reaction itself. Catalysts that speed the reaction are called positive catalysts. Catalysts that slow down the reaction are called negative catalysts or inhibitors. Substances that increase the activity of catalysts are called promoters and substances that deactivate catalysts are called catalytic poisons.

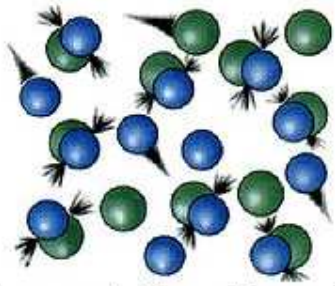


For a reaction to take place a bond must break (within reagents) simultaneously a bond must be formed (product).

Catalysts are able to lower the activation energy so less energy is needed to start the reaction. In terms of the collision theory for a reaction to take place molecules must be able to collide, have sufficient energy to overcome the E (E>Ea) and also have the correct orientation. This theory is based on the idea that reactant particles must collide for a reaction to occur, but only a certain fraction of the total collisions have the energy to connect effectively and cause the reactants to transform into products.

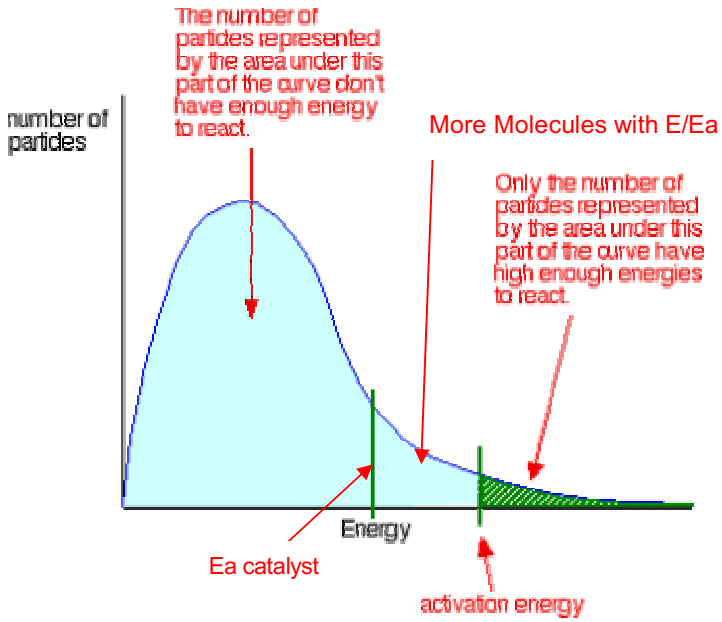


Low concentration = Few collisions



High concentration = More collisions

This is because only a por tion of the molecules have enough energy and the right orientation at the moment of impact to break any existing bonds and form new ones. The minimal amount of energy needed for this to occur is known as activation energy. Particles from different elements react with each other by releasing activation energy as they hit each other. If the elements react with each other, the collision is called successful, but if the concentration of at least one of the elements is too low, there will be fewer particles for the other elements to react with and the reaction will happen much more slowly. As temperature increases, the average kinetic energy and speed of the molecules increases but this only slightly increases the number of collisions. The rate of the reaction in creases with temperature increase because a higher fraction of the collisions overcome the activation energy.



Only those particles represented by the area to the right of the activation energy will react when they collide. The great majority will not have enough energy, and will simply bounce apart. To speed up the reaction, we must first increase the number of the very energetic particles - those with energies equal to or greater than the activation energy. Increasing the temperature has exactly that effect - it changes the shape of the graph.

Increasing the temperature increases reaction rates because of the disproportionately large increase in the number of high energy collisions. It is only these collisions (possessing at least the activation energy for the reaction) which result in a reaction.

There are advantages and disadvantages of using catalyst in industrial chemical processes:

Advantages:

- Catalyst speed up the reaction of processes which makes it easier for companies to manufacture their products quickly.

- ❖ Catalyst helps to speed up the reaction of chemicals which speeds up the process which helps to save time.
- ❖ Higher yield of reactions

Disadvantages:

- ❖ They can influence the structure of the chemical which is produced in the reaction
- ❖ When catalyst happen naturally sometimes they damaged the environment, e.g. Nitric Oxide acts as a catalyst to aid in decomposition of Ozone in the ozone layer.

Homogeneous Catalyst

This has the catalyst in the same phase as the reactants. Typically everything will be present as a gas or contained in a single liquid phase . Homogenous catalysts work by promoting the movement of electrons by increasing the number of collisions. Examples of homogeneous catalysts used in industry are

- Transition of metal ions
- Transition of metal complexes
- Inorganic acids and bases
- Enzymes

Heterogeneous Catalysts

This involves the use of a catalyst in a different phase f rom the reactants. Typical examples involve a solid catalyst with the reactants as either liquids or gases. Heterogeneous catalysts work by using either adsorption, weakening and breaking of bonds and desorption by lowering the activation energy by weakeni ng the bonds and providing correct orientation and bringing molecule closer. Examples of heterogeneous catalysts used in industry are :

- The oxidation of carbon monoxide to carbon dioxide.
  $2CO\ (g) + O_2\ (g) \rightarrow 2CO_2\ (g)$
- The reduction of nitrogen monoxide back to nitrogen.
  $2NO\ (g) + 2CO\ (g) \rightarrow N_2\ (g) + 2CO_2\ (g)$
- The oxidation of hydrocarbons to water and carbon dioxide. This can occur on any of the hydrocarbons however primarily Petrol or Diesel.
  $2C_6H_6\ (g) + 15O_2 \rightarrow 12CO_2\ (g) + 6H_2O\ (l)$
- The synthesis of Ammonia is an example of a heterogeneous catalyst:
  $3H_2\ (g) + N_2\ (g) \leftrightarrow 2NH_3\ (g)$ - catalyzed by Fe(s).
- The use of Nickel in the hydrogenation of vegetable oils to produce margarine. The unsaturated fat present in the vegetable oils are converted to saturated fat by the addition of hydrogen. This in turn breaks the Carbon-carbon double bonds. In order for this reaction to be catalyzed effectively the nickel must present a large surface area so therefore must be finel y divided.
  $-CH=CH- + H_2 \rightarrow -CH_2-CH_2-$

Advantages/ Disadvantages (Comparison)

Homogeneous catalysis is used over heterogeneous for the following reasons:

Homogeneous catalysis is the opposite of heterogeneous catalysis, where the catalyst is in a different phase, usually a sol id catalyst interacting with gaseous or solution of substrate. Because the liquid reactants and the solution of the catalyst are immiscible, the petrochemical alkylation process features heterogeneous catalysis. Heterogeneous catalysis offers the advantage that products are readily separated from the catalyst. There are more complicated catalytical sites (chemically and geometrically) which gives improved s electivity to a certain product. The catalysts are usually in solution and so access to the reagents i s easier so there is improved activity and milder r eaction conditions can be used. Another advantage of the catalysts being in solution is that the heat transfer for highly exothermic or endothermic reactions is not a problem. The m echanisms are better und erstood. Advantage of heterogeneous catalysis is that the catalyst is usually solid and therefore is easier to extract and recycle.

References

http://www.chemguide.co.uk/physical/catalysis/introduction.html : I used this link to get information about heterogeneous and homogenous catalysts. It was very useful

http://www.enotes.com/science/q-and-a/what-advantages-disadvantages-catalysts-94659: I used this link to get information about the advantages and disadvantages of catalysts. It was very helpful.

http://en.wikipedia.org/wiki/Collision_theory : I used this link to get information about the collision theory. It was very valuable.

http://upload.wikimedia.org/wikipedia/commons/thumb/2/24/Activation_energy.svg/360px-Activation_energy.svg.png : I used this link to get a picture of the energy profile diagram. It was very useful.

http://en.wikipedia.org/wiki/Catalysis : I used this link to get a definition of what a catalyst is. It was very helpful.

http://en.wikipedia.org/wiki/Homogenous_catalysis : I used this link to get information about the advantages and disadvantages of homogenous and heterogeneous catalysts. It was very precise and informational.