$$\text{Rate} = \frac{\text{Change in the amount of reactants and products}}{\text{Time}}$$

Effect of temperature

- Rate of reaction increases with temperature.
- Particles have more kinetic energy.
- Frequency of collision increases.
- Number of effective collision increases.

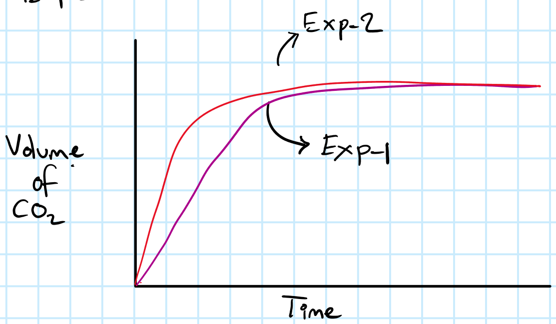
Example

$$CaCO_3 + 2HCl \longrightarrow CaCl_2 + H_2O + CO_2$$

$CaCO_3$: 20g powder

HCl: $60\ cm^3$, $1.0\ mol\,dm^{-3}$

Exp-1 at 30°C
Exp-2 at 40°C



- Due to increase of temperature, more particles (reactants) have energy greater (or equal) than the activation energy.
- Change in temperature cannot change the value of the ΔH.

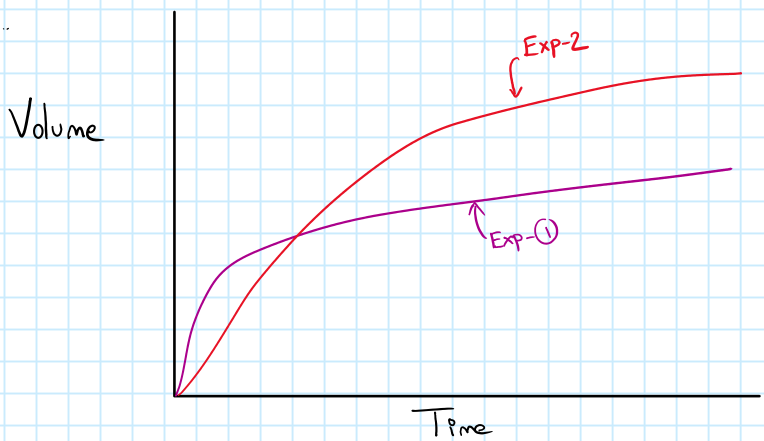
Effect of concentration

1. Rate of reaction increases with the increase of concentration of the reactants.
2. Increasing the concentration of the reactants cannot increase the kinetic energy of particles.
3. There are more particles per unit volume.
4. The frequency of collision increases.
5. The number of successful collision increases.

Examples:

Exp ① $2H_2O_{2\,(aq)} \xrightarrow{MnO_2} 2H_2O_{(l)} + O_{2\,(g)}$ ($100\ cm^3$, $1.0\ mol\,dm^{-3}$)

Exp ② $2H_2O_{2\,(aq)} \xrightarrow{MnO_2} 2H_2O_{(l)} + O_{2\,(g)}$ ($200\ cm^3$, $0.5\ mol\,dm^{-3}$)



Effect of surface area (For solid reactants only)

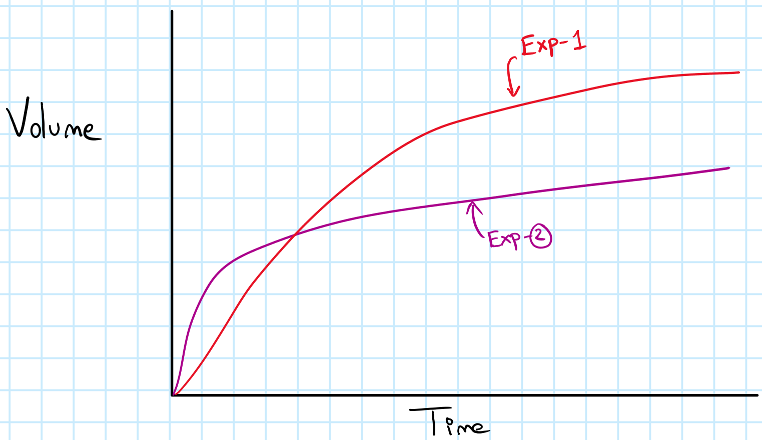
- *Rate of reaction increases with the increase of surface area of the solid reactant.*
- *More reactants are exposed to react*
- *Frequency of collision increases.*
- *Number of effective collision increases.*

Examples:

$$CaCO_3 + 2HCl \longrightarrow CaCl_2 + H_2O + CO_2$$

Exp: 1 ⟼ *20g large size*

Exp: 2 ⟼ *10g powder*



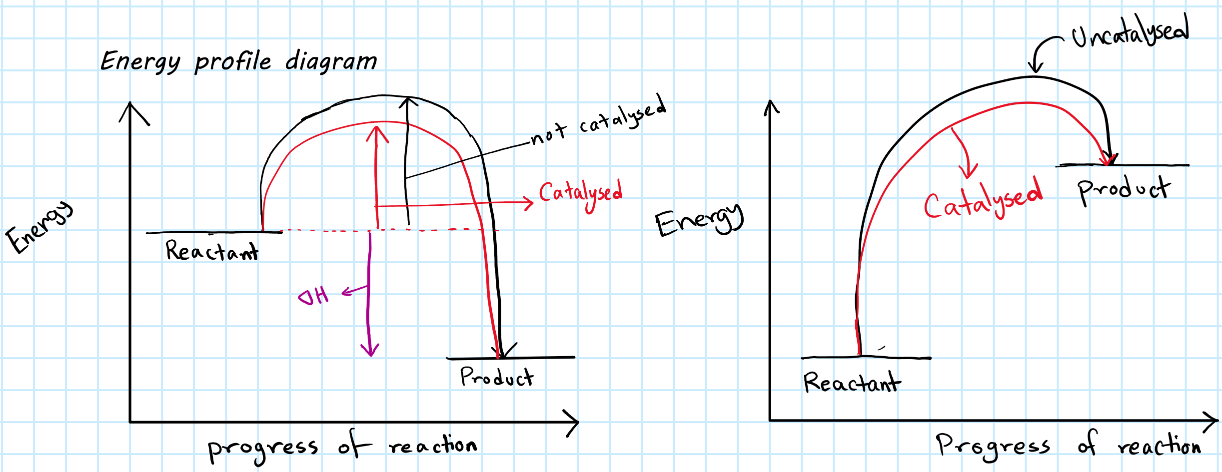
Effect of pressure

- *Rate of reaction increases with the increase of pressure.*
- *Gas molecules are much more closer.*
- *Frequency of collision increases.*
- *Number of effective collision increases.*

Catalyst

- *Substances that can speed up a chemical reaction by lowering the activation energy by creating an alternative route are called catalysts.*
- *Catalyst cannot change the value of* ΔH.
- *Catalyst cannot provide energy to the reactant.*
- *Catalyst cannot change equilibrium composition.*
- *Catalyst cannot change the yield of the reaction.*

Energy profile diagram



Catalysis

Homogenous — Heterogeneous

Homogeneous catalyst

Reactant and catalyst exists in the same physical state.

Examples:

$$CH_3CH_2OH_{(l)} + CH_3COOH \xrightleftharpoons{\text{Conc. } H_2SO_4} CH_3COOCH_2CH_{3(l)} + H_2O$$

Oxidation of SO_2

$$SO_2 + \tfrac{1}{2} O_2 \xrightarrow{NO_2} SO_3$$ Here NO_2 is acting as a catalyst.

$$SO_2 + NO_2 \longrightarrow SO_3 + NO$$

$$NO + \tfrac{1}{2} O_2 \longrightarrow NO_2$$

Reaction of persulfate

$$S_2O_8^{2-} + 2I^- \xrightarrow{Fe^{3+}} 2SO_4^{2-} + I_{2(aq)}$$

(persulfate)

- Both reactants are negatively charged.
- So, high activation energy is needed.
- The reactants repel each other.
- Without the catalyst (Fe^{3+}) the reaction between $S_2O_8^{2-}$ and I^- is very slow.
- To overcome the repulsion between two reactants the catalyst is used.

Steps of the reaction:

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

$$2Fe^{2+} + S_2O_8^{2-} \longrightarrow 2SO_4^{2-} + 2Fe^{2+}$$

$$2I^- + S_2O_8^{2-} \longrightarrow I_2 + 2SO_4^{2-}$$

Heterogenous catalyst

Reactants and catalyst exist in different physical state.

Examples:

Haber process- $N_{2(g)} + 3H_{2(g)} \underset{450^\circ C,\ 200\,atm}{\overset{FeO}{\rightleftharpoons}} 2NH_3$

Contact process- $2SO_{2(g)} + O_2 \underset{450^\circ C,\ 1\,atm}{\overset{V_2O_5}{\rightleftharpoons}} 2SO_3$

Reaction in a catalytic converter- $2NO + 2CO \xrightarrow{Rh\ \&\ Pt} 2CO_2 + N_2$

Hydrogenation of alkene- $CH_2CH_2 + H_2 \xrightarrow[\text{Heat}]{Ni} CH_3CH_3$

Decomposition of hydrogen peroxide-

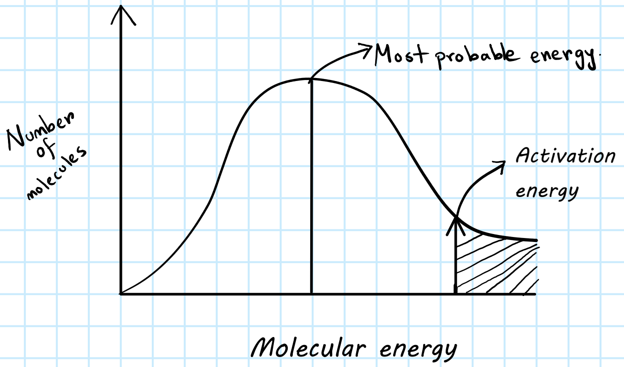
$$2H_2O_{2(aq)} \xrightarrow[\text{Heat}]{MnO_2} 2H_2O_{(l)} + O_{2(g)}$$

Enzymes

- Enzymes are biological catalyst.
- Enzymes can speed up a biological chemical reaction.
- It is specific for a particular reaction.
- Reactants are called substrates.
- Enzymes lower the activation energy.
- Substrate bind to the active site of the enzyme.
- After the reaction the enzymes are reformed.
- T higher temperature the enzymes get denatured and cannot catalyze a reaction.
- Active site is also denatured due to change in pH.

Boltzmann distribution

The effect of temperature on the rate of reaction.



- Area under the curve represents total number of molecules.
- The most probable energy is the energy that maximum amount of molecules have.
- The shaded area shows the proportion of molecules in the samples that have enough energy to cause a chemical reaction when they collide.