

Equilibrium

(reversible) reactions

Q-1) What is equilibrium?

> Equilibrium is obtained for reversible reactions only.

① It's Dynamic.

↳ the reactants and products are constantly reacting

② Rate of forward reaction = rate of backward reaction.

③ Concentration of reactants and products remains constant at equilibrium.

↳ the concentration doesn't change any further.

④ Occurs in a closed loop system.

↳ exchange of energy

↳ no exchange of mass.

Q-2) Le Chatelier's principle.

> If one or more factors that affect an equilibrium is changed, the position of the equilibrium shifts in the direction which reduces (opposes) the change.

Q-3) Factors affecting equilibrium position.

1. Effect of concentration.

Increase concentration of reactants.

↳ equilibrium shifts to right. (more products)

Increase concentration of products.

↳ equilibrium shifts to left.

2. Effect of temperature.

* Endothermic reactions are favoured by increase in temperature.

↳ Increase temperature, equilibrium shifts to right.

* Exothermic reactions are favoured by decrease in temperature.

↳ decrease temperature, equilibrium shifts to right.

3. Effect of pressure. (gases only)

- * Increase in pressure shifts equilibrium position to the side with less volume.
- * Decrease in pressure shifts equilibrium position to the side with more volume.
- * If the volumes on both sides are equal, then equilibrium is **NOT** affected by pressure.

4. Catalyst.

Catalyst has no effect on equilibrium position.
It only increases rate of reaction.

Q-4) Equilibrium constant K_c .

K_c = concentration constant.



$$K_c = \frac{[C]^c [D]^d}{[A]^a [B]^b}$$

[] = concentration.

* concentration = mol dm^{-3}

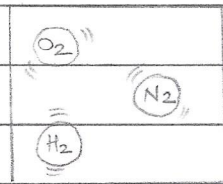
* Solid components are ignored while calculating K_c .

- * K_c has a fixed value for every chemical reaction at a particular temperature.
Endothermic reaction \rightarrow increase temp. \rightarrow more products \rightarrow K_c value increases
Exothermic reaction \rightarrow increase temp. \rightarrow less products \rightarrow K_c value decreases
- * K_c is not affected by change in concentration, pressure or catalyst.
- * The unit of K_c is different for every reaction.
- * Value of K_c for backward reaction is inverse of the value of K_c of the forward reaction.
- * The value of K_c tells us the extent to which reactants are converted to products. High value = more products formed

Q-5) Equilibrium constant K_p

K_p = partial pressure constant

Partial pressure : it's the pressure exerted by individual gas molecules present in a mixture.



$$\text{Total pressure (P)} = P_{O_2} + P_{N_2} + P_{H_2}$$



$$K_p = \frac{P_C^c \cdot P_D^d}{P_A^a \cdot P_B^b}$$

p = partial pressure.

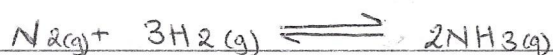
* pressure = pascal (Pa).

mole fraction = $\frac{\text{individual moles}}{\text{total moles}}$

Partial pressure = mole fraction \times total pressure.

Q-6) Equilibrium in chemical industries

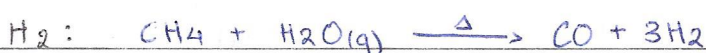
1. Haber process - production of ammonia. $\Delta H = -x \text{ kJ mol}^{-1}$



① Concentration $N_2 : H_2$
1 : 3

Raw materials

N_2 : fractional distillation of air



② Temperature.

at high temperature

- equilibrium shifts to left.

at low temperature

- equilibrium shifts to right

- But slow reaction.

Optimum temperature : 450°C

③ Pressure

at high pressure

- equilibrium shifts to right.
- But it's expensive to maintain high pressure.

Optimum pressure : $2 \times 10^8 \text{ Pa}$ ($2 \times 10^8 \text{ Pa}$) \rightarrow (200000 KPa) \rightarrow (200 atm)

④ To increase yield of NH_3

- remove NH_3 as soon as it's formed.
- recycle unreacted H_2 and N_2

⑤ Catalyst.

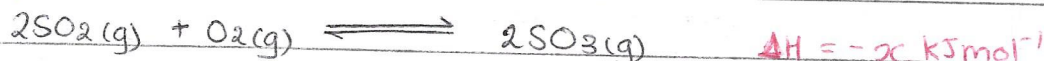
- Finely divided iron powder (Fe).

\rightarrow to increase surface area for adsorption of gas

↓
gases are attached only on surface
to increase collisions.

2. Contact process - production of sulphuric acid.

main equilibrium reaction.



① Optimum temperature : 450°C

② Optimum pressure : 101 KPa. ($\frac{1}{10} \text{ atm}$)

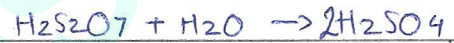
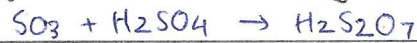
③ Catalyst : V_2O_5 (vanadium (V) oxide)

\rightarrow Equilibrium is affected by same as Haber process

④ To maximise yield.

- Remove SO_3 by adsorbing it in 98% sulfuric acid.

↳ this doesn't affect equilibrium significantly as it already is far over to the right.



Q-7) Acids and bases.

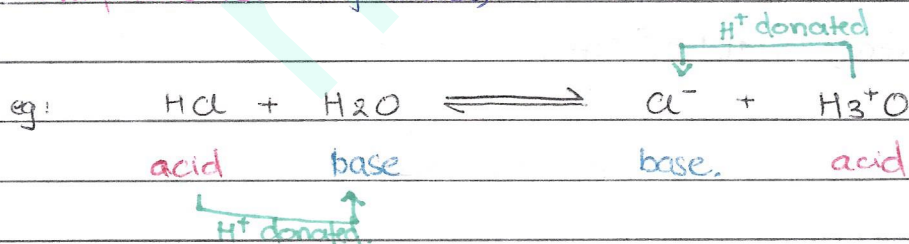
> According to Bronsted Lowry Theory:

Acid : proton (H^+) donor

Base : proton (H^+) acceptor

Substances which can act as acids or bases are known as

Amphoteric. (eg: water)



Acids/Bases which dissociate almost completely in solution are called **STRONG acids/bases**.

Acids/Bases which are only partially dissociated in solution are called **WEAK acids/bases**.

Strong acids : hydrochloric acid, sulfuric acid, nitric acid

Weak acids : ^{→ organic acids} eg: hydrogen sulfide, carbonic acid, hydrocyanic acid (HCN)

Strong bases : group I metal hydroxides and strong bases

Weak bases : ammonia, amines & some hydroxides of transition metals.