Equilibrium

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.

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 Kc.

Kc = concentration constant.

mol. no.

$$aA + bB \rightleftharpoons cC + dD$$

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

[ ] = concentration.

* concentration = mol dm^{-3}

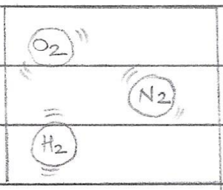
*** Solid components are ignored while calculating Kc.**

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

Q-5) Equilibrium constant Kp.

Kp = partial pressure constant

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



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

mol. no.

$$aA + bB \rightleftharpoons cC + dD$$

$$K_p = \frac{p^c_C \cdot p^d_D}{p^a_A \cdot p^b_B}$$

p = partial pressure

* pressure = pascal (Pa).

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

Partial pressure = mole fraction x total pressure.

Q-6) Equilibrium in chemical industries.

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

$$N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)}$$

(i) Concentration $N_2 : H_2$
1 : 3

Raw materials

N_2 : Fractional distilation of air

H_2 : $CH_4 + H_2O_{(g)} \xrightarrow{\Delta} CO + 3H_2$

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 : ~~[illegible]~~ (2×10^8 Pa) → (200000 KPa) → (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).
  - ↳ 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.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \qquad \Delta H = -x \text{ kJmol}^{-1}$$

① Optimum temperature : 450°c

② Optimum pressure : 101 KPa. (1-2 atm).

③ Catalyst : V_2O_5 (vanadium (V) oxide)

↳ 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.

$SO_3 + H_2SO_4 \rightarrow H_2S_2O_7$ $H_2S_2O_7 + H_2O \rightarrow 2H_2SO_4$

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)

H^+ donated

eg: $HCl + H_2O \rightleftharpoons Cl^- + H_3^+O$

acid base base. acid

H^+ donated.

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 : eg: hydrogen sulfide, carbonic acid, hydrocyanic acid (HCN) (→ organic acids)
Strong bases : group I metal hydroxides and strong bases
Weak bases : ammonia, amines & some hydroxides of transition metals.