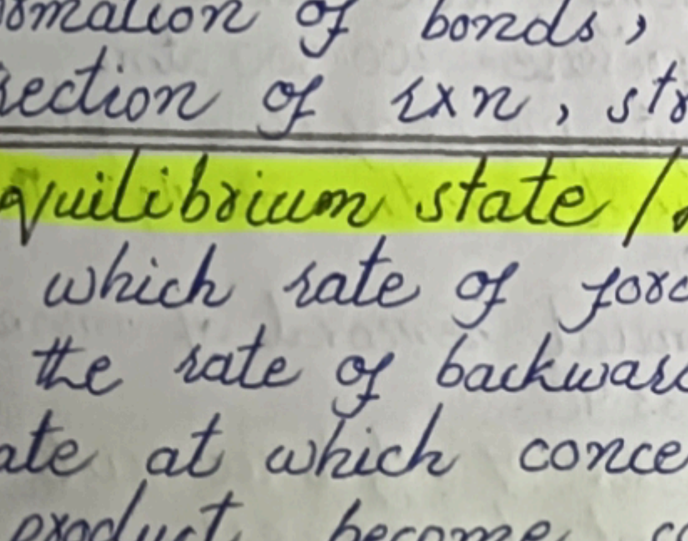
- **Irreversible reaction**: The reaction in which reactants are completely consumed & converted into product are called irreversible reaction.
example: $C + O_2 \longrightarrow CO_2$ ∴ unidirectional
- Complete reaction.
- Show by single arrow (single head)
- reaction will stop when limiting reactant is consumed - no sign of equilibrium state.

- **Reversible reaction**: in which the products once formed can react togethes to form orginal reactant.
ex: $N_2 + 3H_2 \rightleftharpoons 2NH_3$ ∴ Bidirectional.
- Symbolically represented by double headed arrow
- Rxn which proceed in both direction i.e. forward & reverse direaction.
- Rxn never goes to completion (incomplete)
- attain equilibrium state. (dynamic).

- **Macroscopic events**: refer to the phenomena that can be observed with the naked eye without considering the individual particles involved process. example: change in colours - evolution/absorption of heat, formation of ppt, change in volume/pressure, change of physical state, entropy.

- **Microscopic events**: refer to phenomena that cannot be observed with the naked eye but can be observed with microscopic - **example**: collision b/w molecule, breaking of formation of bonds, rearrangement molecule, direction of rxn, structure of atom/molecule.

Equilibrium state / Dynamic state: state at which rate of forward rxn become equal to the rate of backward rxn is eq-state - OR State at which concentration of reactant & product become constant.
e.g: $H_{2(g)}O + CO_{(g)} \rightleftharpoons CO_{2(g)} + H_{2(g)}$
→ Reactant dec & product inc → Forward rxn rate
→ reactant inc & product dec → reverse rxn rate.
→ same rate of forward = same rate of reverse.
→ carry at dynamic equilibrium rate.



time required to reach positin

Concentration = mol/dm³ unit.

Chp: 8. Chemical Equilibrium.

Law of mass action:
- C.M Guldberg & P. wage in 1864 proposed.
Statement: The rate at which substance reacts is proportional to its active mass and the rate of a chemical reaction is proportional to the product of the active masses of the reacting substances.

active mass represents the concentration of reactant & product in $mol \cdot dm^{-3}$ & represented by square bracket [ ] - in dilute solution.

Derivation of K_c:
$aA + bB \rightleftharpoons cC + dD$
reactant product
rate of forward, $R_f \propto [A]^a [B]^b$
reaction $= K_f [A]^a [B]^b$ -(i)
rate of reverse, $R_r \propto [C]^c [D]^d$
reaction $= K_r [C]^c [D]^d$ -(ii)
At equilibrium,
rate of forward rxn = rate of reverse rxn
$K_f [A]^a [B]^b = K_r [C]^c [D]^d$
$K_f = \frac{[C]^c [D]^d}{[A]^a [B]^b}$ ∴ $\frac{K_f}{K} = K_c$
$K_c = \frac{[C]^c [D]^d}{[A]^a [B]^b} = \frac{Product}{reactant}$
∴ K_f constant of Forward rxn
∴ K_r constant of reverse rxn.
K_c = equilibrium constant

Conditions for Equilibrium
1- K_c applies only at E.S. subscript "c" indicates the conc: reactants & products in moles per dm^3 at E.S.
K_c - subscript.
2. K_c does not depend on initial concentration of reactant & product but depend upon temperature

3- K_c is related to coefficient of B.C.E.
Product is numerater.
reactant is denominator.
1- Magnitude of K_c indicate position of equilibrium.
$K_c < 1$ = reactant is greater ∴ direction forward
$K_c > 1$ = product is greater direction reverse.
$K_c = 1$ → at equilibrium. same rate. $F = r$.
5- Containes should be closed if any reactant or product is in gaseous
6- Pressure, Volume & catalyst of the system should be constant.

- when moles of = moles of = no
reactant product unit.

Types of Equilibrium

Homogenous equilibrium

The type of equilibrium in which physical state of reactant & product are in same phase.

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

$2SO_{2(g)} + O_{2(g)} \rightleftharpoons 2SO_{3(g)}$

Heterogenous equilibrium

The type of equilibrium in which physical state of reactant & product is different. more than 1 phase.

$C_{(s)} + H_2O_{(g)} \rightleftharpoons CO_{(g)} + H_{2(g)}$

$C_{(s)} + O_{2(g)} \rightleftharpoons CO_{2(g)}$

$I_{2(s)} \rightleftharpoons I_{2(g)}$

$CaCO_{3(s)} \rightleftharpoons CaO_{(s)} + CO_{2(g)}$

Relationship Of K_c with K_p, K_n & K_x

$aA + bB \rightleftharpoons cC + dD$.

$K_c = \frac{\text{product}}{\text{reactant}}$ molar: C

Henry law: $P_{gas} \propto [Gas]$
At constant temp partial pressure of gas is directly proportional to its molar concentration.

K_p: E.C K_p of partial pressure

$K_p = \frac{P_C^c \times P_D^d}{P_A^a \times P_B^b} \Rightarrow K_p = K_c(RT)^{\Delta n}$

K_n: in terms of moles.

$K_n = \frac{n_C^c \times n_D^d}{n_A^a \times n_B^b} \rightarrow K_p = K_n\left(\frac{P}{n}\right)^{\Delta n}$

K_x: mole fraction.

$K_x = \frac{x_C^c \times n_D^d}{x_A^a \times x_B^b} \rightarrow K_p = K_x(P)^{\Delta n}$

$K_p = K_c(RT)^{\Delta n} = K_n\left(\frac{P}{n}\right)^{\Delta n} = K_x(P)^{\Delta n}$ - (4).

Ways to reconize equilibrium

- Physical method.

Spectrometric method.
Property is measured during the rxn without removing sample from the reaction mixture.

$N_2O_{4(g)} \rightleftharpoons 2NO_{2(g)}$
colourless reddish brown.

This method can be applied when the reactant or prodt absorbs ultraviolet, visible. infrared radiation.
$K_c \propto$ amount of radiation

Importance: reactant can be used & reused.
- reactant or product have ability to absorb radiation
- helps to find value of K_c through radiation absorbed

Chemical method: amount of reactant & product is determnd by a suitabe chemical reaction.

$CH_3COOH_{(l)} + C_2H_5OH_{(l)} \rightleftharpoons CH_3COOC_2H_{5(l)}$

- mineral acid used to catalyze the rxn.
- esterification.

Lechatelier's principle

If a change is imposed on a system at equilibrium the position of equilibrium will shift in a direction that tends to reduce the change.

Effect of concentration.

Reactant inc → Forward direction
Reactant dec ← backward.
Product inc ← bakward
Product dec → Forward.

Effect of pressure change

$P \propto \frac{1}{V}$ Boyles law.

1- Pressure inc → volume dec
2- Pressure dec → volume inc.
1 → EQ shift in direction to inc total no of molecule.
2) shift in direction to inc total no of molecule

Effect of change in temp

Endothermic reaction = temp inc = shift to forward = K_c inc.
Endothermic reaction = temp dec = forward, K_c dec
Exothermic reaction = temp inc = forward, K_c dec
Exothermic reaction = temp dec = forward, K_c inc.

No effect of catalyst bcz it proceed both forward & reverse rxn.

Applications. Synthesis of ammonia by Habers process:

$N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)}$ $\Delta H° = -92.46 KJ$

- Low temp = 400°C (673K)
- High pressure = 200-300 atm
- Catalyst = pieces of iron crystals. in fused mixture of MgO, Al_2O_3 & SiO_3.
- Continual removal of ammonia at -33.4C.

Synthesis of sulphuric acid by contact process.

- $S_{(s)} + O_{2(g)} \rightarrow SO_{2(g)}$ Formation of sulph dioxide
- $2SO_{2(g)} + O_{2(g)} \rightleftharpoons 2SO_3$ $\Delta H = -198 KJ$ oxidation.
- both are exothermic reaction.
- Conversion S.d into sulphric acid.
- low temp = 450 - 500°C
- high pressure = 2 atm.
- Adding excess oxygen to obtain high yield.