chemical kinetics

TOPIC 6

Rate of reaction: The change in concentration of any one reactant or product in unit time

$$\text{Avg. rate} = \frac{\Delta \text{ conc.}}{\text{time}} = \frac{\Delta C}{t}$$

collision theory

1. For a reaction to occur the particles must collide (but not all collisions result in a reaction)
2. Particles must collide with the correct orientation

e.g

no reaction | collision result in reaction

orientation incorrect | orientation correct

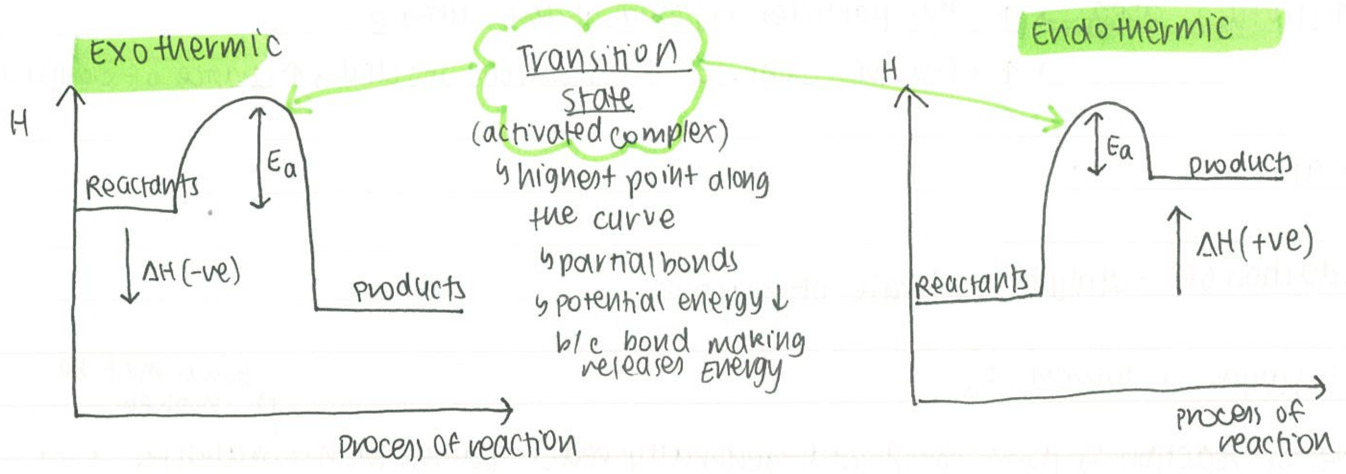
3. The colliding particles must have a minimum energy called the Activation energy

Activation energy: The minimum energy required for colliding particles to react

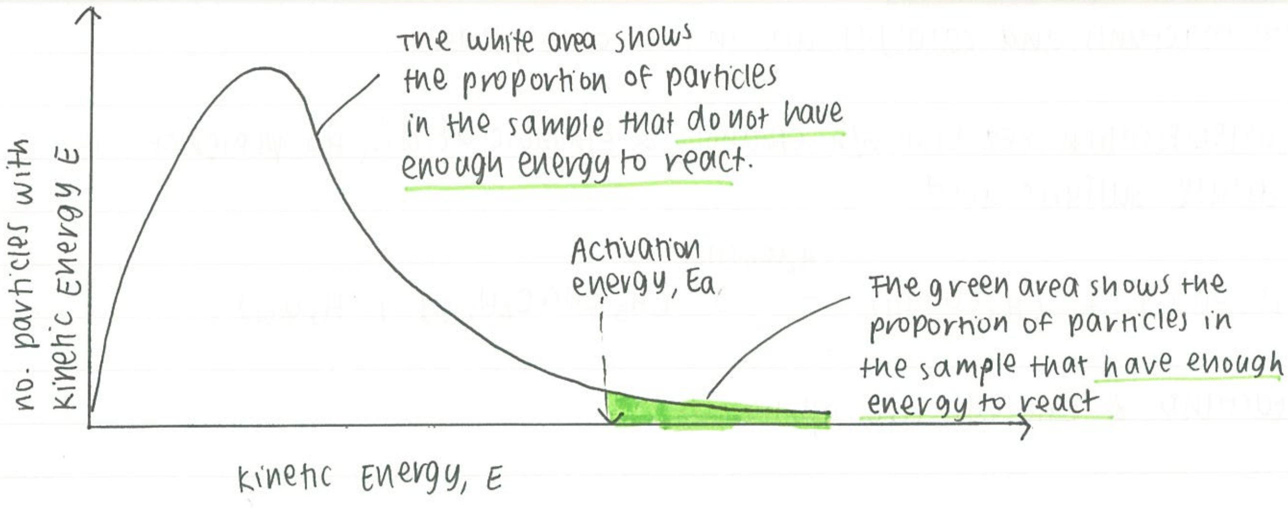
- for a reaction to occur it has to overcome activation energy (Ea)

<u>An effective collision</u>

Is a collision that will result in a reaction between colliding particles and results in a product being formed.



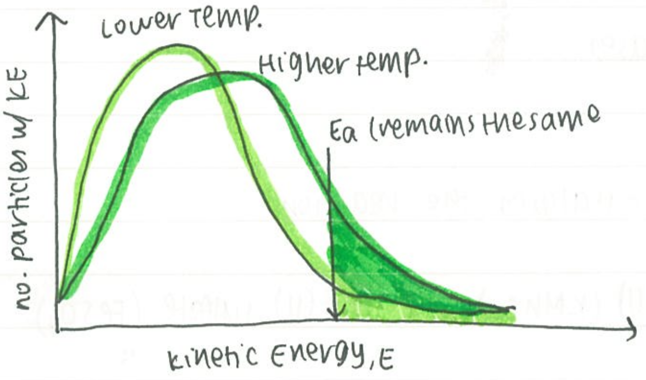
maxwell-boltzman DISTRIBUTION



- non symmetrical
- no molecules present with zero K.E
- at higher energy the line does not reach the x axis
- the area under the line represents the total no. of particles and will not change as the temperature changes

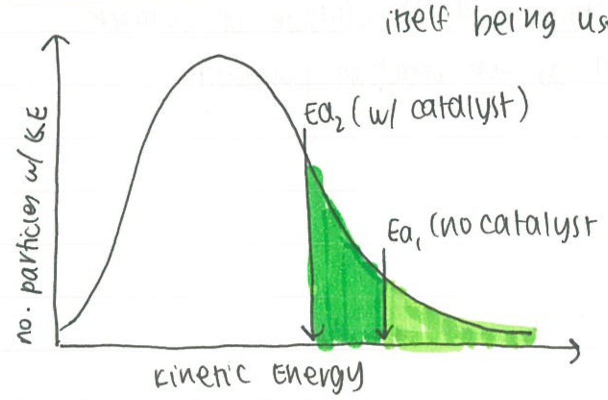
↑ temp. (shift to the right)

* curve broadens and flattens at higher temp.



Catalyst (↓ Ea)

→ a substance that increases the rate of a chemical reaction w/o itself being used up in the reaction



POSITION OF EQUILIBRIUM

-refers to the relative amounts of reactants and products present at equilibrium

E.g $2NO(g) \rightleftharpoons N_2(g) + O_2(g)$

- At 700K, the position of equilibrium = very far to **right**
  ↳ ∴ ↑ amount of N_2 and O_2 but not much NO

E.g $H_2O(l) \rightleftharpoons H^+(aq) + OH^-(aq)$

- At 298K, no. water molecules present at equilibrium is over 250 million times greater than total H^+ and OH^- ions.
  ↳ ∴ position of equilibrium lies a long way to the **left**.
  ↳ not many H^+ and OH^- ions present

Equilibrium does <u>NOT</u> imply 50% reactants and 50% products

If position of equilibrium lies a long way to the.....

① RIGHT
- ↑ amount of products (AB)
- ↓ amount of reactants (A + B)

E.g $A + B \rightleftharpoons AB$

② LEFT
- ↓ amount of products (AB)
- ↑ amount of reactants (A+B)

Le chatelier's principle

The effect of changing conditions on the position of equilibrium

If a system at equilibrium is subjected to a change, the position of the equilibrium will shift in order to minimise the effect of the change.

The effect of...

① Temperature

- always shifts to the direction that reduces the Δ temp.
- affects K_c

Type of reaction	change	when new equilibrium is reached	Effect on equilibrium position	value of K_c
Exothermic reaction (ΔH < 0)	Temp ↑	[product] ↓	←	↓
	Temp ↓	[product] ↑	→	↑
Endothermic reaction (ΔH > 0)	Temp ↑	[product] ↑	→	↑
	Temp ↓	[product] ↓	←	↓

E.g $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$ $\Delta H = -92\ kJ\ mol^{-1}$

↓

exothermic (ΔH < 0)

Forward : exo
Reverse : endo.

∴ ↑ temp → equilibrium shifts to the left
→ ↓ NH_3 at ↑ temp
→ shifts to endothermic direction to take in heat and minimise the effect of the change
→ endo = left (reverse)

Heat reaction mixture: Position of equilibrium shifted in endothermic direction
Cool reaction mixture: " " exothermic direction

amphoteric SUBSTANCES

water is capable of acting as both an acid and a base

Amphoteric substances can act as both an acid and a base

amphiprotic SUBSTANCES

Refers to the Bronsted-Lowry definition and indicates that a species can either accept or donate a proton H^+

> All amphiprotic substances are amphoteric but not all amphoteric substances are amphiprotic

CONJUGATE ACID-BASE PAIRS

Acids and bases exist in pairs called conjugate acid-base pairs

when an acid donates/loses a proton, it becomes its conjugate base (↓ charge)

E.g. $CH_3COOH + H_2O \rightleftharpoons CH_3COO^- + H_3O^+$ (⇌ normally in equilibrium)

CH_3COOH: Acid; CH_3COO^-: Conjugate Base

when a base accepts a proton, it becomes its conjugate acid (↑ charge)

E.g. $NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$

NH_3: Base; NH_4^+: Conjugate Acid

$$K_a = \frac{[CH_3COO^-][H^+]}{[CH_3COOH]}$$

Strong Acid

$HCl \rightarrow H^+ + Cl^-$ (dissociates fully)

$CH_3COOH \rightleftharpoons CH_3COO^- + H^+$ $K_a = 1.8$

$CH_3CH_2COOH \rightleftharpoons CH_3CH_2COO^- + H^+$ K_a

conjugate acid base pairs

worksheet Q1-15

1. $HCl + NH_3 \rightarrow NH_4^+ + Cl^-$
   (A) (B) (C·A) (C·B) ✓

2. $OH^- + HCN \rightarrow H_2O + CN^-$
   (B) (A) (C·A) (C·B) ✓

3. $PO_4^{3-} + HNO_3 \rightarrow NO_3^- + HPO_4^{2-}$
   (B) (A) (C·B) (C·A) ✓

4. $HCO_3^- + HCl \rightarrow H_2CO_3 + Cl^-$
   (B) (A) (C·A) (C·B) ✓

5. $HCO_3^- + OH^- \rightarrow H_2O + CO_3^{2-}$
   (A) (B) (C·A) (C·B) ✓

6. $NH_4^+ + H_2O \rightarrow NH_3 + H_3O^+$
   (A) (B) (C·B) (C·A) ✓

7. $C_2O_4^{2-} + HC_2H_3O_2 \rightarrow HC_2O_4^- + C_2H_3O_2^-$
   (B) (A) (C·B) (C·A)
   (C·A) (C·B)

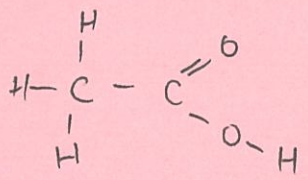
8. $HPO_4^{2-} + H_2O \rightarrow OH^- + H_2PO_4^-$
   (B) (A) (C·B) (C·A) ✓

A strong acid must have a weak conjugate base b/c if it had a strong conjugate base, then the base would quickly re-associate with a hydrogen proton

no H ⇒ can't be acid

$HCl + CH_3COOH \rightarrow$

$Cl^- + CH_3COOH_2^+$



the pH scale

ThinkIB worksheet

1. a) $10 cm^3$ of $0.1 mol dm^{-3}$ HCl (aq), pH = 1

$n = \frac{10}{100} \times 0.1$
↳ total volume
$= 0.01$ mol in $1 dm^3$

$pH = -\log[0.01]$
$= 2$

b) $n = \frac{10}{1000} \times 0.1$

$= 1 \times 10^{-3}$

$pH = -\log[1 \times 10^{-3}]$
$= 3$

c) pH = 7 b/c equal amount and conc. of acid and base

2. $10 cm^3$ of $0.1 mol dm^{-3}$ NaOH (aq), pH = 13

a) $n = \frac{10}{1000} \times 0.1$

$= 1 \times 10^{-3}$

$pOH = -\log[1 \times 10^{-3}]$
$= 3$
$\therefore pH = 14 - 3$
$= 11$ ✓

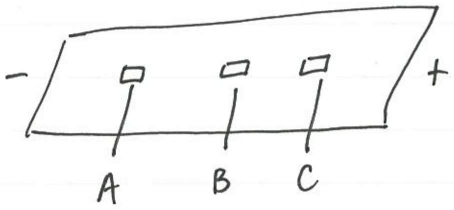
b) $n = \frac{10}{10\,000} \times 0.1$

$= 1 \times 10^{-4}$

$pOH = -\log[1 \times 10^{-4}]$
$= 4$

$\therefore pH = 14 - 4$
$= 10$ ✓

E.g sample of serine, glutamic acid, lysine in buffer pH=5.7



At pH 5.7 buffer

A is lysine b/c pH < pI (9.7)
- ∴ acts as base
- cation (accepts H^+)
- attracted to negative electrode

B is serine b/c pH = pI (5.7)
- no overall charge
- no movement in an electric field

C is glutamic acid pH > pI (3.2)
- ∴ acts as acid
- anion (donates H^+)
- attracted to +ve electrode

enzymes

- protein molecules that function as **biological catalysts**
  - ↳ suffix -ase

- substrate enters active site (A shape)
- substrate binds at active site
- catalysed reaction takes place
- products leave