Rate of Reaction

- **Rate of reaction measures →**
- How fast reactants are used up and how fast products are made.

- **Rate (Mol dm^{-3} S^{-1}) =** change in concentration of reactant/product
  ----
  time for change to take place

- Concentration is represented by square brackets around the molecule.

- **As the reaction proceeds, concentration decreases, leading to →**
- Fewer collisions per second between reactant particles.
- The rate slowing down.

- **Rate of reaction is determined by measuring the concentration of a substance at time intervals →**
- Rate is equal to the slope of the curve.
- Tangent is drawn – gradient is calculated.

- **Initial rate →** the change in concentration of a reactant, of product, per unit time at the start of the reaction when t=0.

Half-Lives

- **Exponential decay →**
- Many natural processes have a constant half-life – value halves every half-time.

- **Radioactive decay →**
- Constant half-life of a radioactive element is the time taken for half the element to decay.
- Used to measure element stability and in radio-carbon dating.

Equilibrium Constant

- **A dynamic equilibrium is established in a closed system when →**
- The rate of the forward reaction is the same as the reverse reaction.
- The concentrations of the reactants and products remain the same.

- **Equilibrium law →** the relative proportions of reactants and products present at equilibrium.

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

- **Kc →** the equilibrium constant for concentrations.

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

[A] = concentration of A in $moldm^{-3}$
a = number of moles of A

- **Homogeneous equilibrum →** all species making up the reactants and products are in the same physical states.
- **Heterogeneous equilibrium →** species are in different states.

Strong & Weak Acids

- The strength of an acid (HA) is the extent of its dissociation into H^+ and A^- ions.

- **Strong acids dissociate completely in aqueous solution.**
- **Examples →**
- HCl, HNO_3, H_2SO_4, HBr, HI, $HClO_4$.

- **Weak acids only partially dissociate.**
- **Example:** $CH_3COOH \leftrightarrow H^+ + CH_3COO^-$.
- Equilibrium lies well to the left.

- **Acid dissociation constant (Ka) →** measures the extent of acid dissociation.

- **Weak acid:** $HA \leftrightarrow H^+ + A^-$.
- A large Ka value → large extent of dissociation → a strong acid.

- **pKa = -log Ka**
- **$Ka = 10^{-pKa}$**

$$K_a = \frac{[H^+][A^-]}{[HA]}$$

simplified

$$K_a = \frac{[H^+]^2}{[HA]}$$

Buffer Solutions

- **Buffer solution →** a mixture that minimises pH changes on addition of **small** amounts of acid or base.

- **A buffer solution is a mixture of →**
- A weak acid, HA.
- Its conjugate base, A^-.
- **A buffer can be made from a weak acid and the salt of a weak acid.**

- **Example →**
- In the CH_3COOH/CH_3COONa buffer system →
- The weak acid dissociates partially: $CH_3COOH \leftrightarrow H^+ + CH_3COO^-$.
- The salt dissociates completely: $CH_3COONa \rightarrow CH_3COO^- + Na^+$.

- **The high concentration of the conjugate base pushes the equilibrium of the weak acid to the left.**
- Therefore, the concentration of H^+ ions is very small.

- **Buffer equilibrium:** $HA \leftrightarrow H^+ + A^-$.
- The weak acid (HA) removes added alkali.
- The conjugate base (A^-) removes added acid.

Born-Haber Cycles

- **The cycle begins with the elements in their standard states at zero energy.**
- This is known as the datum line.

- **Endothermic** → ΔH points upwards.
- **Exothermic** → ΔH points downwards.

- The ionic solid is on the lowest energy level.

Redox

- **Oxidation →** loss of electrons.
- **Reduction →** gain of electrons.

- **Oxidising agent →** is reduced and accepts electrons.
- **Reducing agent →** is oxidised and donates electrons.

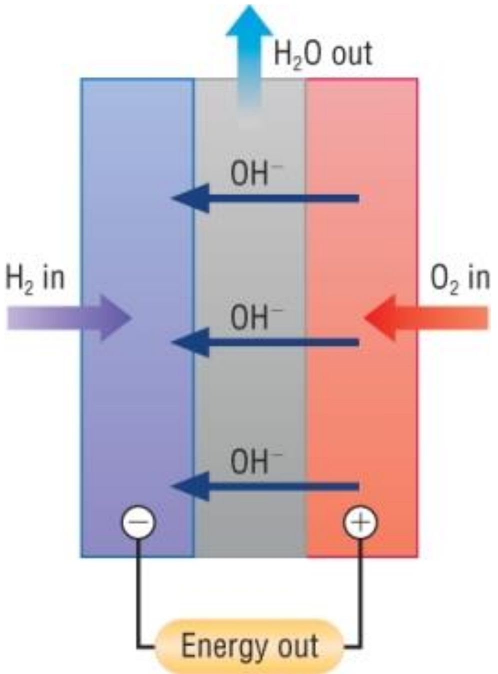
- **Balancing redox equations →**
- Complete half equations.
- Sometimes add H^+, OH^- or H_2O.
- In acidic conditions, add H^+.
- In alkaline, add OH^-.

Storage & Fuel Cells

- **Fuel cells →**
- The hydrogen-oxygen fuel cell uses energy from the reaction of a fuel with oxygen to create a voltage.
- The reactants flow in and products flow out while the electrolyte remains in the cell.
- Fuel cells can operate continuously so long as the fuel and oxygen continue to flow into the cell.
- Electricity is generated when oxygen and hydrogen make water.

- **Hydrogen –Oxygen Fuel Cell Equations →**
- $H_2 + 2OH^- \rightarrow 2H_2O + 2e^-$
- $\frac{1}{2} O_2 + 2H_2O + 2e^- \rightarrow 2OH^-$

- **Overall Equation:** $H_2 + \frac{1}{2} O_2 \rightarrow H_2O$



Hydrogen for the Future

- **Fuel-cell vehicles (FVC's) →**
- Uses hydrogen gas or hydrogen-rich fuels.
- Hydrogen-rich fuels (e.g. methanol) are mixed with water and converted into hydrogen gas at 250-300°c by an onboard "reformer".

- **Using methanol instead of hydrogen gas →**
- Liquid fuel is easier to store than gas.
- Methanol can be generated from biomass.
- Carbon dioxide is waste product – greenhouse gas.

- **Advantages of fuel-cell vehicles →**
- Less pollution and carbon dioxide – hydrogen-rich fuels produce only small amounts of carbon dioxide and air pollutants.
- Greater efficiency – petrol engines are less than 20% efficient in converting chemical energy – hydrogen fuel-cell vehicles are 40-60% efficient.