20: Reaction Rates & Equilibrium

Key Kinetics and Equilibrium Terms

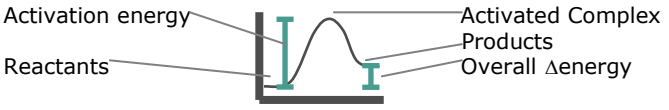
- **Kinetics:** Study of reaction rates.
- **Reaction Rate:** Rate at which reactants produce products.
- **Activation Energy (E_A):** Minimum energy a collision must have in order to produce a reaction.
- **Reaction Coordinate Diagram:** Shows energy of reactants, products, activated complex.
- **Activated Complex (or Transition State):** In-between stage—reactants have not yet broken apart and products have not yet formed.
- **Endothermic:** Energy is absorbed from the surroundings—the products have more energy than the reactants. Energy can be thought of as a reactant.
- **Exothermic:** Energy is released into the surroundings—the products have less energy than the reactants. Energy can be thought of as a product.
- **Reversible Reaction:** Reaction that can proceed in both directions.
- **Equilibrium:** When the rate of the forward and reverse of a reversible process are equal.
- **Dynamic equilibrium:** The number of reactants and products do not change, but the reaction continues to occur in both directions.
- **Equilibrium constant expression:** Equation showing the ratio of the concentration of products to reactants with the balanced equation coefficients as powers.
- **Equilibrium constant (*K*):** The value found when equilibrium concentrations are plugged into the equilibrium constant expression.
- **Homogeneous equilibrium:** When all species are the same state of matter.
- **Heterogeneous equilibrium:** When there are at least 2 different states of matter present.
- **Reaction Quotient (*Q*):** When concentrations at any time are plugged into the equilibrium constant expression. Used to determine if a system is at equilibrium.
- **Le Chatelier's Principle:** A system at equilibrium will re-adjust to reach equilibrium again when disturbed or changed, i.e. de-stress.

Collision Theory

In order for a reaction to occur, the molecules must:

- Collide.
- Collide with the correct orientation.
- Collide with the at least the Activation Energy.

Reaction Coordinate Diagrams



Factors Affecting Rate

Factors will increase rate by increasing the change that a successful collisions will occur:

- **Surface Area** - As surface area increases, rate increases.
- **Concentration** - As concentration increases, rate increases.
- **Temperature** - As temperature increases, rate increases
- **Catalyst** - Presence of a catalyst increases the rate, but has no effect on the direction of the equilibrium.

Establishing Equilibrium

Equilibrium is not established instantly. The forward reaction must produce products, which can then reform reactants. As the forward rate slows and the reverse rate increases, equilibrium will be established.

Equilibrium Constants

Writing equilibrium constant expressions:

- Write the concentration of the products over the concentration of the reactants.
- Do not include pure solids or pure liquids—only gases and solutions.
- Use the coefficients of the balanced equations as powers for each species.

Finding equilibrium constant:

- Plug in equilibrium concentrations into the equilibrium constant expression.

Reaction Quotient

Writing Reaction Quotient Expressions:

- Same as for "*K*" expressions.

Finding reaction quotient:

- Plug in concentrations at any time.

Determining if a system is at equilibrium:

- If $Q = K$, it's at equilibrium.
- If $Q > K$, the reaction will proceed to the left (remove extra products and form more reactants) to reach equilibrium.
- If $Q < K$, the reaction will proceed to the right (remove extra reactants and form more products) to reach equilibrium.

Le Chatelier's Principle

The system will try to un-do what you did (un-change or de-stress).

Le Chatelier's Principle Mnemonic:
Le Chatelier is to less the change (stress) added = "*Le Chatelier is Lesser (the) Change.*"

Change Made	Reaction will shift towards (Counter-Change)
Add reactant	Products
Remove reactant	Reactants
Add a product	Reactants
Remove a product	Products
Decrease volume	Side with least gas particles
Increase volume	Side with most gas particles

- For endothermic reactions, think of energy (temperature) as a reactant: **Reactants + heat → Products**
  Increase in *T* will shift to the product side (**right**).
- For exothermic reactions, think of energy (temperature) as a product: **Reactants → Products + heat**
  Increase in *T* will shift to the reactant side (**left**).

Changes that do not affect equilibrium:

- Adding/removing a pure solid or liquid.
- Adding/removing a non-reactive gas.
- Changing the volume of a reaction with equal number of gas particles on each side.
- Adding a catalyst.

How to Use This Cheat Sheet: These are the keys related to this topic. Try to read through it carefully twice then write it out on a blank sheet of paper. Review it again before the exams.