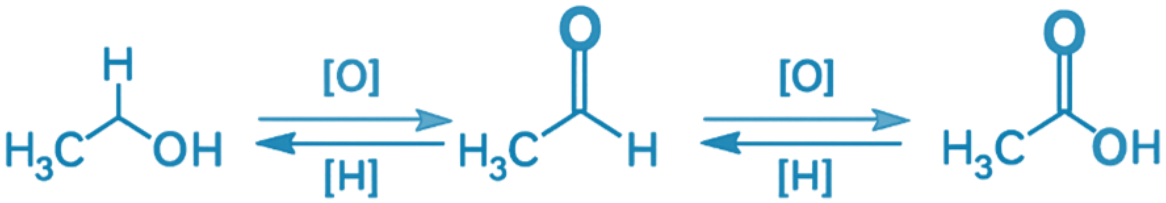
Oxidation Reduction Reaction

Oxidation-Reduction Reactions (Redox Reactions)

Overview

- Oxidation–Reduction reactions, often referred to as redox reactions, are chemical processes that involve the transfer of electrons between substances.
- One substance loses electrons (is oxidized), while another gains electrons (is reduced).
- These reactions are crucial in both biological systems (like cellular respiration) and industrial processes (like corrosion and metal extraction).
- **Example:** The conversion of the ethanol to acetaldehyde, and that of acetaldehyde to acetic acid, are oxidation reactions, and the reverse reaction are reduction reactions.



Key Features:

- **Electron transfer:** The main concept behind redox reactions is the movement of electrons from one species to another.
- **Oxidation and reduction occur simultaneously:** One can't happen without the other.
- **Involves changes in oxidation numbers:** Tracking these helps identify what is oxidized and what is reduced.

Example:

- Consider the reaction between sodium and chlorine:

$$2Na + Cl_2 \rightarrow 2NaCl$$

- Sodium (**Na**) loses an electron:

$$Na \rightarrow Na^+ + e^- \rightarrow \text{oxidation}$$

- Chlorine (**Cl_2**) gains an electron:

$$Cl_2 + 2e^- \rightarrow 2Cl^- \rightarrow \text{reduction}$$

- Thus, this is a redox reaction.

Definition of Oxidation

Overview

- Oxidation is the loss of electrons by a molecule, atom, or ion.

- Historically, it referred to reactions involving oxygen (like rusting), but the modern definition focuses on electron transfer and changes in oxidation states.

Ways to Identify Oxidation:

- Loss of electrons
- Increase in oxidation number
- Gain of oxygen atoms
- Loss of hydrogen atoms

Key characteristics of oxidation:

- Electron loss
- Oxidation number increases
- May involve addition of oxygen or removal of hydrogen

Example 1:

$$Na \rightarrow Na^{+} + e^{-}$$

- Sodium (Na) loses one electron to become Na^{+}.
- Sodium is **oxidized**.

Example 2:

$$Fe^{2+} \rightarrow Fe^{3+} + e^{-}$$

- Iron (Fe^{2+}) loses one electron to become Fe^{3+}.
- This is also oxidation.

Definition of Reduction

Overview

- Reduction is the gain of electrons by an atom, ion, or molecule.
- Just as oxidation involves electron loss, reduction is its counterpart, involving electron acceptance.
- The term comes from the idea that the gain of electrons often "reduces" the positive charge of a substance.

Ways to Identify Reduction:

- Gain of electrons
- Decrease in oxidation number
- Loss of oxygen atoms

- Gain of hydrogen atoms (especially in organic/biochemical contexts)

Key characteristics of reduction:

- Electron gain
- Oxidation number decreases
- May involve removal of oxygen or addition of hydrogen

Example 1:

$$Cl_2 + 2e^- \rightarrow 2Cl^-$$

- Each chlorine atom gains one electron to form chloride ions (Cl^-).
- Chlorine is reduced.

Example 2:

$$Cu^{2+} + 2e^- \rightarrow Cu$$

- Copper ion gains two electrons and becomes metallic copper.
- This is a reduction process.
- Reduction always occurs alongside oxidation, because electrons lost by one substance must be gained by another.

Oxidizing and Reducing Agents

- **In a redox reaction:**
  - The oxidizing agent is the substance that causes oxidation by accepting electrons (it gets reduced).
  - The reducing agent is the substance that causes reduction by donating electrons (it gets oxidized).
- Think of them as the **facilitators** of redox change:
  - **Oxidizing agent**: gets **reduced** (gains electrons)
  - **Reducing agent**: gets **oxidized** (loses electrons)

Oxidizing Agent (Oxidant):

- The substance that causes oxidation of another.
- It accepts electrons (i.e., is reduced).
- It gets reduced itself during the reaction.

Reducing Agent (Reductant):

- The substance that causes reduction of another.

- It donates electrons (i.e., is oxidized).
- It gets oxidized itself during the reaction.

Example:

$$Zn + Cu^{2+} \rightarrow Zn^{2+} + Cu$$

- Zinc (Zn) loses electrons → oxidized → acts as the reducing agent
- Copper ion (Cu^{2+}) gains electrons → reduced → acts as the oxidizing agent

Another Example:

$$H_2 + F_2 \rightarrow 2HF$$

- H_2 donates electrons → oxidized → reducing agent
- F_2 accepts electrons → reduced → oxidizing agent

Oxidation of Alkenes

Formation of Epoxides

Overview

- Epoxides are three-membered cyclic ethers formed by the oxidation of alkenes.
- This reaction involves the addition of an oxygen atom across the double bond to create a strained, triangular ring structure.

Reagents Used:

- Peroxy acids (most commonly *m*-chloroperoxybenzoic acid, or mCPBA)

Mechanism:

- The reaction proceeds via a concerted mechanism, meaning the π-electrons of the alkene and the oxygen from the peroxy acid simultaneously form the epoxide ring.
- It is stereospecific: the stereochemistry of the alkene (cis or trans) is preserved in the epoxide.

General Reaction:

$$\text{Alkene} + \text{mCPBA} \rightarrow \text{Epoxide} + \text{Carboxylic acid}$$

Example:

$$CH_2 = CHCH_3 + \text{mCPBA} \rightarrow CH_2(O)CHCH_3$$

- Propene reacts with mCPBA to form propylene oxide.

Formation of Carboxylic Acids and Ketones

- Alkenes can be oxidized under strong oxidative conditions to form carboxylic acids (from terminal or monosubstituted carbons) and ketones (from internal, disubstituted carbons).

Reagents Used:

- Hot, concentrated potassium permanganate ($KMnO_4$)
- Ozone (O_3) followed by oxidative work-up (e.g., H_2O_2)

Reaction Overview:

- The double bond is completely broken.
- Each carbon involved in the double bond is oxidized:
  - If it's bonded to hydrogen, it becomes a carboxylic acid.
  - If it's bonded to two carbon atoms, it becomes a ketone.
  - If it's a terminal alkene, it can produce carbon dioxide.

Example 1:

$$CH_3CH = CH_2 \xrightarrow{[O]} CH_3COOH + CO_2$$

- Propene undergoes oxidation:
  - CH_3–CH= yields acetic acid
  - The terminal =CH_2 becomes CO_2

Example 2:

$$(CH_3)_2C = CH_2 \xrightarrow{[O]} (CH_3)_2CO + CO_2$$

- 2-methylpropene gives acetone and carbon dioxide.

Syn-Hydroxylation of Alkenes (Formation of Syn-Diols)

- Syn-hydroxylation refers to the addition of two hydroxyl (–OH) groups to the same side (cis addition) of the double bond, forming a cis-1,2-diol (also called a syn-diol).

Reagents Used:

- Cold, dilute $KMnO_4$
- Osmium tetroxide (OsO_4), often followed by a reducing agent like $NaHSO_3$ or H_2O_2

Mechanism:

- These reagents add hydroxyl groups across the double bond in a concerted, cis fashion.
- The double bond is preserved as a single bond, with both new –OH groups on the same face of the molecule.

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