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### **Abstract.**

Oxidation-reduction (redox) reactions are fundamental chemical processes involving the transfer of electrons between species. These reactions encompass diverse types, including combination, decomposition, displacement, and disproportionation reactions. Understanding their mechanisms and applications is crucial in fields ranging from chemistry to biology and environmental science. This review categorizes and explores various types of redox reactions, highlighting their significance and practical implications.

**Keywords:** Redox reactions, oxidation, reduction, electron transfer, chemical reactions, combination reactions, decomposition reactions, displacement reactions, disproportionation reactions.

### **Аннотация**

Окислительно-восстановительные (окислительно-восстановительные) реакции — это фундаментальные химические процессы, связанные с переносом электронов между видами. Эти реакции охватывают различные типы, включая реакции соединения, разложения, смещения и диспропорционирования. Понимание их механизмов и применения имеет решающее значение в самых разных областях: от химии до биологии и наук об окружающей среде. В этом обзоре классифицируются и исследуются различные типы окислительно-восстановительных реакций, подчеркивая их значение и практическое значение.

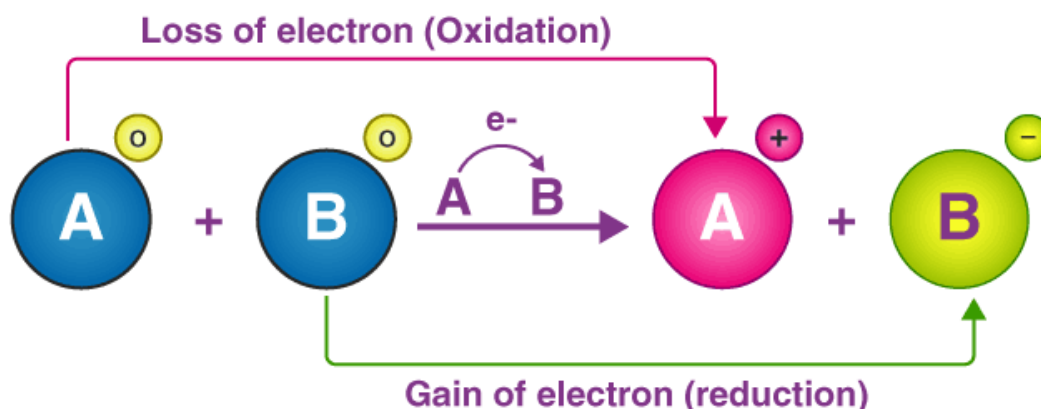
**Ключевые слова:** окислительно-восстановительные реакции, окисление, восстановление, перенос электрона, химические реакции, реакции соединения, реакции разложения, реакции замещения, реакции диспропорционирования.

### **Introduction to Redox Reactions**

Redox reactions are a type of chemical reaction in which the oxidation states of atoms are changed. They are commonly named after the reactions between oxygen and an element or compound, in which they gain or lose electrons. In chemistry, "redox" refers to a reduction-oxidation reaction. These reaction types do

not refer to the physical concept of reduction or oxidation reactions. There are mainly three parts in a redox reaction: the zero oxidation state reaction, the change of electron transfer reaction, and the difference in electron transfer number. The term "electron transfer" refers to the transfer of  $z$  and  $n$  numbers of electrons, where  $n$  is a variable.

A redox reaction is a fancier name given to a reaction that involves changes. In the oxidation process, both the amount and state of electrons are increased. However, in the mind of oxidation and reduction, a reduction must be done. An increase in the amount and state of electrons. Such reactions are called redox reactions. Since the oxidation process also causes the state of the electrons to change, the oxidation reaction is often more widespread in everyday life and industrial processes. Therefore, people are more familiar with the terms of oxidation and reduction. During a redox reaction, a pair of molecules that have their oxidation numbers changed in the reaction are known as an oxidizing agent and a reducing agent. In this case, the chemical that gains electrons is called the oxidizing agent and the chemical that gives electrons is called the reducing agent.



### Definition and Basics

In a number of chemical reactions that involve electron exchanges between chemical species (atoms, ions, molecules), both oxidation and reduction occur simultaneously in order to accomplish the electron exchanges. These combined reactions have a special name: redox reactions. They have broad application from the field of electronics to biological processes.

The reactions that involve losing or gaining of electron(s) correspond to two of the fundamental ways a chemical species acquire a charge. Anascentric and isoelectronic are the terms that are used to signify the process of creating a charge onto a chemical species. A reaction that involves creating a charge on a chemical species, relative to a second reactant, through an electron loss is called an oxidation reaction. And a reaction that involves creating a charge on a chemical species,

relative to a second reactant, through an electron gain is called a reduction reaction. In a particular redox reaction, a certain amount of electrons ( $ne$ ) is lost by all the chemical species involved in the oxidation reactions and simultaneously acquired by the chemical species involved in the reduction step. One of the most significant aspects of redox reactions in understanding its mechanism is the presence of a species capable of losing and another of gaining an exact number of electrons.

### Methods

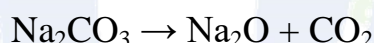
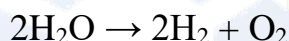
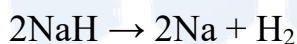
The categorization and analysis of redox reactions were based on established principles of chemical kinetics and thermodynamics as described in standard chemistry textbooks.

#### Types of Redox Reactions

1. Combination Reaction:  $( A + B \rightarrow AB )$
2. Decomposition Reaction:  $( AB \rightarrow A + B )$
3. Displacement Reaction:  $( A + BC \rightarrow AC + B )$
4. Disproportionation Reaction:  $( 2A \rightarrow A_2 + 2B )$

#### Decomposition Reaction

This kind of reaction involves the breakdown of a compound into different compounds. Examples of these types of reactions are



All the above reactions result in the breakdown of smaller chemical compounds in the form of  $AB \rightarrow A + B$

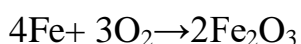
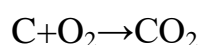
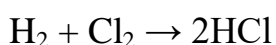
But, there is a special case that confirms that all the decomposition reactions are not redox reactions.

**For example,**  $\text{CaCO}_3 \rightarrow \text{CaO} + \text{CO}_2$

**Also Read:** Types of Reactions

#### Combination Reaction

These reactions are the opposite of decomposition reactions and hence, involve the combination of two compounds to form a single compound in the form of  $A + B \rightarrow AB$ . **For example,**



#### Displacement Reaction

In this kind of reaction, an atom or an ion in a compound is replaced by an atom or an ion of another element. It can be represented in the form of  $X + YZ \rightarrow XZ + Y$ . Further displacement reactions can be categorised into

Metal displacement reaction

Non-metal displacement reaction

Metal Displacement

In this type of reaction, a metal present in the compound is displaced by another metal. These types of reactions find their application in metallurgical processes where pure metals are obtained from their ores.

**For example,**  $\text{CuSO}_4 + \text{Zn} \rightarrow \text{Cu} + \text{ZnSO}_4$

Non-metal Displacement

In this type of reaction, we can find a hydrogen displacement and, sometimes, rarely occurring reactions involving oxygen displacement.

Disproportionation Reactions

Disproportionation reactions are known as reactions in which a single reactant is oxidized and reduced.

**For example,**  $\text{P}_4 + 3\text{NaOH} + 3\text{H}_2\text{O} \rightarrow 3\text{NaH}_2\text{PO}_2 + \text{PH}_3$

Combination reactions are a type of redox reaction where two or more elements combine to form a compound. During this process, there is a simultaneous oxidation and reduction of the elements involved. For example, when magnesium reacts with oxygen to form magnesium oxide, the magnesium undergoes oxidation while the oxygen undergoes reduction.

Decomposition Reactions

Decomposition reactions involve the breakdown of a compound into simpler substances. In redox decomposition reactions, this decomposition process is accompanied by oxidation or reduction of the compounds. An example of this is the decomposition of hydrogen peroxide into water and oxygen, where hydrogen peroxide is both oxidized and reduced.

Displacement Reactions

Displacement reactions occur when a more reactive element replaces a less reactive element in a compound. This displacement results in a redox reaction where the more reactive element undergoes oxidation, while the less reactive element undergoes reduction. A classic example of this is the reaction between zinc and copper sulfate, where zinc displaces copper from copper sulfate, leading to the formation of zinc sulfate and copper.

Redox Coupling

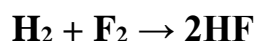
Redox coupling reactions involve coupling two redox reactions together to drive a desired chemical reaction. By linking these two reactions, it is possible to achieve a specific outcome or product. This process showcases how redox reactions can be harnessed in creative ways to facilitate various chemical reactions.

### Examples of Redox Reactions

A few examples of redox reactions, along with their oxidation and reduction half-reactions, are provided in this subsection.

#### Example 1: Reaction between Hydrogen and Fluorine

In the reaction between hydrogen and [fluorine](#), the hydrogen is oxidized, whereas the fluorine is reduced. The reaction can be written as follows.



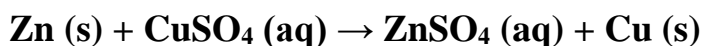
The oxidation half-reaction is:  $\text{H}_2 \rightarrow 2\text{H}^+ + 2\text{e}^-$

The reduction half-reaction is:  $\text{F}_2 + 2\text{e}^- \rightarrow 2\text{F}^-$

The hydrogen and fluorine ions go on to combine in order to form hydrogen fluoride.

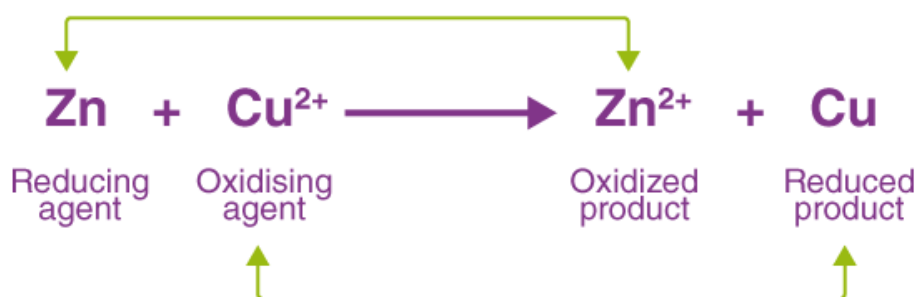
#### Example 2: Reaction between Zinc and Copper

This is a type of metal displacement reaction in which copper metal is obtained when zinc displaces the  $\text{Cu}^{2+}$  ion in the [copper sulphate solution](#), as shown in the reaction below.



The oxidation half-reaction can be written as  $\text{Zn} \rightarrow \text{Zn}^{2+} + 2\text{e}^-$

The reduction half-reaction can be written as  $\text{Cu}^{2+} + 2\text{e}^- \rightarrow \text{Cu}$



#### Example 3: Reaction between Iron and Hydrogen Peroxide

$\text{Fe}^{2+}$  is oxidized to  $\text{Fe}^{3+}$  by [hydrogen peroxide](#) when an acid is present. This reaction is provided below.



Oxidation half-reaction:  $\text{Fe}^{2+} \rightarrow \text{Fe}^{3+} + \text{e}^-$

Reduction half-reaction:  $\text{H}_2\text{O}_2 + 2\text{e}^- \rightarrow 2\text{OH}^-$

Thus, the hydroxide ion formed from the reduction of hydrogen peroxide combines with the proton donated by the acidic medium to form water.

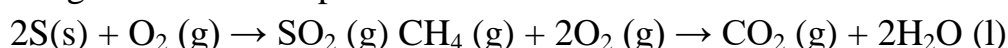
### Oxidation and Reduction Reaction

In order to understand redox reactions, let us first deal with oxidation and reduction reactions individually.

#### What Is the Oxidation Reaction?

Oxidation may be defined as the loss of electrons from a substance; the other definition of oxidation reactions states that the addition of oxygen or the more [electronegative element](#) or removal of hydrogen or the more electropositive element from a substance is called an oxidation reaction.

Following are some examples of oxidation reactions:



#### Applications of Redox Reactions

Redox reactions have a wide range of applications across different industries and everyday life. In metallurgy, redox reactions are used for extracting metals from their ores. In pharmaceuticals, redox reactions play a role in drug synthesis and formulation. Additionally, redox reactions are fundamental in environmental science, where they are involved in processes like wastewater treatment and air purification.

At the heart of every chemical change lies the concept of electron transfer, a fundamental process that drives countless reactions in our world. This transfer is the essence of redox reactions, a term encompassing both oxidation and reduction.

To understand redox reactions, we must first grasp the individual roles of oxidation and reduction.

**Oxidation** is the process where a species loses electrons, resulting in an increase in its oxidation state. This loss of electrons often involves the gain of oxygen atoms, as seen in reactions like the rusting of iron. However, the definition extends beyond oxygen, encompassing any process where electrons are relinquished.

Reaction Type	Description
Combination Reaction	Two substances combine to form a compound with higher oxidation states.
Decomposition Reaction	A compound breaks down into simpler substances, often involving oxygen loss.

Reaction Type	Description
Displacement Reaction	One element displaces another in a compound, changing oxidation states.
Disproportionation Reaction	A single substance undergoes both oxidation and reduction simultaneously.

**Reduction**, on the other hand, is the process where a species gains electrons, leading to a decrease in its oxidation state. This gain of electrons can be accompanied by the loss of oxygen atoms or the addition of hydrogen atoms.

Think of oxidation and reduction as a dance where electrons are passed between partners. One species loses electrons (oxidation), while another gains them (reduction). These two processes are always coupled, occurring simultaneously in a redox reaction.

Understanding these fundamental definitions is crucial for comprehending the intricate mechanisms and diverse applications of redox reactions in various fields of science.

#### Recognizing the Pattern: Identifying Redox Reactions in Chemical Equations

At the heart of understanding redox reactions lies the ability to discern them within the framework of chemical equations. While the transfer of electrons is the defining characteristic, recognizing this transfer isn't always straightforward. The key to unlocking this pattern lies in the concept of oxidation numbers. These numbers represent the hypothetical charge an atom would have if all its bonds were purely ionic. By analyzing the changes in oxidation numbers across the reactants and products, we can pinpoint the atoms that have undergone oxidation or reduction.

For instance, consider the reaction between zinc and hydrochloric acid, resulting in zinc chloride and hydrogen gas. Examining the oxidation numbers:

- Zinc (Zn) starts with an oxidation number of 0, while in zinc chloride ( $\text{ZnCl}_2$ ), it becomes +2. This increase in oxidation number signifies oxidation.
- Hydrogen (H) in hydrochloric acid (HCl) has an oxidation number of +1, but in the product, hydrogen gas ( $\text{H}_2$ ), it reduces to 0. This decrease in oxidation number signifies reduction.

Therefore, we can confidently identify zinc as the species being oxidized and hydrogen as the species being reduced. This method of analyzing oxidation numbers provides a systematic approach to recognizing redox reactions in chemical equations.

#### Exploring the Applications: Redox Reactions in Various Fields of Science

Redox reactions are not just theoretical concepts confined to textbooks; they are the driving force behind countless processes that shape our world. From the energy that powers our devices to the materials we rely on, redox reactions play a crucial role in various fields of science and technology.

**Energy Production:** Redox reactions are the heart of energy production in batteries and fuel cells. The transfer of electrons between chemical species generates electrical energy. Batteries, ranging from those powering our smartphones to large-scale energy storage systems, rely on these reactions. Fuel cells, which convert chemical energy directly into electricity, also function based on redox processes.

**Material Science:** Redox reactions are instrumental in the synthesis and processing of various materials. For instance, in metallurgy, redox reactions are used to extract metals from their ores. The rusting of iron, a familiar example of corrosion, is a redox reaction where iron is oxidized. Redox reactions also play a role in the production of semiconductors and other advanced materials.

**Environmental Science:** Redox reactions are essential for understanding and mitigating environmental issues. The oxidation of organic matter in wastewater treatment plants uses redox reactions to break down pollutants. The nitrogen cycle, a crucial process for life, involves redox reactions that convert nitrogen between its various forms.

**Biochemistry:** Redox reactions are fundamental to life itself. Cellular respiration, the process by which organisms convert food into energy, involves a series of redox reactions. Photosynthesis, the process by which plants convert sunlight into energy, also relies on redox reactions.

**Analytical Chemistry:** Redox reactions are widely used in analytical chemistry for titrations and other quantitative analyses. Redox titrations involve using a known concentration of a redox reagent to determine the concentration of an unknown substance. This technique is essential for determining the amount of various substances in food, water, and other samples.

**In conclusion,** oxidation-reduction (redox) reactions represent a cornerstone of chemical transformations, encompassing a diverse array of processes essential to both natural phenomena and human activities. Through the classification of redox reactions into combination, decomposition, displacement, and disproportionation categories, we have gained a structured understanding of how electrons transfer between species, influencing the oxidation states and chemical properties of substances.

These reactions play pivotal roles in numerous fields, from basic chemistry to advanced industrial processes and biological systems. Their significance extends to



environmental remediation, energy production, and pharmaceutical synthesis, highlighting their practical applications and relevance in modern society.

By comprehending the mechanisms and implications of redox reactions, researchers and practitioners can harness their transformative power to innovate and solve complex challenges. Future studies will continue to explore novel applications and refine our understanding of these fundamental processes, ensuring their ongoing contribution to scientific advancement and technological progress.

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