

# Chemical Reactions And Equations

## Chapter 1



### Chemicals of Rusting



## CHAPTER 1

### CHEMICAL REACTIONS AND EQUATIONS

**Chemical Reaction:** A chemical reaction is a process in which one or more substances, also called reactants, are converted to one or more different substances, known as products. Substances are either chemical elements or compounds. The following activities are as given below:

1. Magnesium ribbon burns with a dazzling white flame and changes into a white powder. This powder is magnesium oxide. It is formed due to the reaction between magnesium and oxygen present in the air.
2. Take lead nitrate solution in a test tube; add potassium iodide solution to this, and then we observed that lead (II) iodide and potassium nitrate is formed.
3. Take a few zinc granules in a conical flask, add dilute hydrochloric acid or Sulphuric acid to this, and then we observed that hydrogen gas is evolved.

From the above three activities, that any of the following observations helps us to determine whether a chemical reaction has taken place-

- Change in state
- Change in colour
- Evolution of gas
- Change in temperature.

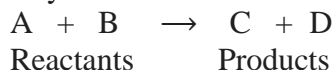
#### Chemical Equations:

Chemical equations are symbolic representations of chemical reactions in which the reactants and the products are expressed in terms of their respective chemical formulae.

#### Rules for writing chemical equation:

Certain rules have to be followed while writing a chemical equation.

1. The reactants taking part in the reaction are written in terms of their symbols or molecular formulae on the left-hand side of the equation.
2. A plus (+) sign is added between the formulae of the reactants.
3. The products of reaction are written in terms of their symbols or molecular formulae on the right-hand side of the equation.
4. A plus (+) sign is added between the formulae of the products.
5. In between the reactants and the products an arrow sign ( $\rightarrow$ ) is inserted to show which way the reaction is occurring.



In this hypothetical equation, A and B are the reactants, and C and D are the products. The arrow indicates that the reaction proceeds towards the formation of C and D.



## Representing the Direction of the Chemical Reaction

The reactants and the products can be separated by one of the following four symbols:

- In order to describe a net forward reaction, the symbol  $\rightarrow$  is used.
- In order to describe a net backward reaction, the symbol  $\leftarrow$  is used.
- In order to describe a reaction that occurs in both forward and backward directions, the symbol  $\rightleftharpoons$  is used.
- In order to describe a state of chemical equilibrium, the symbol  $\rightleftharpoons$  is used.

Multiple entities on either side of the reaction symbols describe above are separated from each other with the help of the  $+$  symbol in a chemical equation. It can be noted that the  $\rightarrow$  symbol, when used in a chemical equation, is often read as 'gives rise to' or 'yields'.

## Representing the Physical States of the Reacting Entities

These symbols may be one of the following:

- The symbol (s) describes an entity in the solid state
- The symbol (l) denotes the liquid state of an entity
- The symbol (g) implies that the entity is in the gaseous state.
- The (aq) symbol corresponding to an entity in a chemical equation denotes an aqueous solution of that entity.

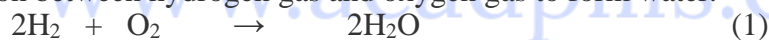
In some reactions, a reactant or a product may be in the form of a precipitate which is insoluble in the solution that the reaction is taking place in. The  $\downarrow$  symbol is written next to the chemical formula of these entities to describe them as precipitates.

## Representing the Input of Energy in a Chemical Equation:

The Greek letter delta in its capitalized form ( $\Delta$ ) is used to state that an input of heat energy is required by the reaction.

### An example for which is represented below:

The reaction between hydrogen gas and oxygen gas to form water.



Reactants

Products

The reacting entities are written on the left-hand side (2 molecules of hydrogen and one molecule of oxygen) whereas the products are written on the right-hand side (2 molecules of water is formed) of the chemical equation.

Equation (1) divided by 2 both sides and we get



Reactant

Product

The reacting entities are written on the left-hand side (1 molecules of hydrogen and half molecule of oxygen) whereas the products are written on the right-hand side (1 molecules of water) of the chemical equation.

It can also be observed that there are coefficients assigned to each of the symbols of the corresponding reactants and products. These coefficients of entities in a chemical equation are the exact value of the stoichiometric number for that entity.

**Balanced Chemical Equations:**

**The law of conservation of mass** that mass can neither be created nor destroyed in a chemical reaction. The total mass of the elements present in the products of a chemical reaction has to be equal to the total mass of the elements present in the reactants.

**EXAMPLE 1:**

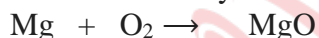
Write the chemical equation for the formation of magnesium oxide.

Step 1: Magnesium burns in oxygen to give magnesium oxide. Here, the reactants are magnesium and oxygen. The product is magnesium oxide.

Step 2: Thus, the word equation is

Magnesium + Oxygen  $\rightarrow$  Magnesium oxide

Step 3: Replacing the names with symbols and formulae, we get the chemical equation as

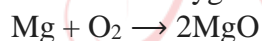


Reactants                      Products

Step 4: The numbers of atoms of the elements are

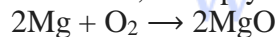
Element	Number of atoms in LHS	Number of atoms in RHS
Mg	1	1
O	2	1

To balance oxygen on both sides, multiply RHS by 2, i.e.,



Now, the number of oxygen atoms is balanced but the number of magnesium atoms is not.

Therefore, multiply magnesium on the LHS by 2. Thus, the equation becomes



this is the balanced chemical equation.

**EXAMPLE 2:**

The word-equation represented as –

Zinc + Sulphuric acid  $\longrightarrow$  Zinc sulphate + Hydrogen

The above word-equation may be represented by the following chemical equation –



Let us examine the number of atoms of different elements on both sides of the arrow.

Element	Number of atoms in reactants (LHS)	Number of atoms in products (RHS)
Zn	1	1
H	2	2
S	1	1
O	4	4

As the number of atoms of each element is the same on both sides of the arrow is a balanced chemical equation.

### EXAMPLE 3:

Let us try to balance the following chemical equation –



**Step I:** To balance a chemical equation, first draw boxes around each formula. Do not change anything inside the boxes while balancing the equation.



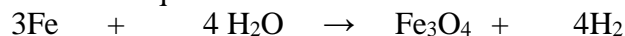
**Step II:** List the number of atoms of different elements present in the unbalanced equation.

Element	Number of atoms in reactants (LHS)	Number of atoms in products (RHS)
Fe	1	3
H	2	2
O	1	4

### Step III:

Element	Number of atoms in reactants (LHS)	Number of atoms in products (RHS)
Fe	1 x 3	3
H	2 x 4	2 x 4
O	1 x 4	4

Balanced equation:



As the number of atoms of each element is the same on both sides of the arrow is a balanced chemical equation.

### List some Examples of Chemical Equations.

A few examples of chemical equations are listed in bulleted text below.

- $\text{PCl}_5 + \text{H}_2\text{O} \rightarrow \text{H}_3\text{PO}_4 + \text{HCl}$
- $\text{SnO}_2 + \text{H}_2 \rightarrow \text{H}_2\text{O} + \text{Sn}$
- $\text{TiCl}_4 + \text{H}_2\text{O} \rightarrow \text{TiO}_2 + \text{HCl}$

- $\text{H}_3\text{PO}_4 + \text{KOH} \rightarrow \text{K}_3\text{PO}_4 + \text{H}_2\text{O}$
- $\text{Na}_2\text{S} + \text{AgI} \rightarrow \text{NaI} + \text{Ag}_2\text{S}$
- $\text{Fe} + \text{CuCl}_2 \rightarrow \text{FeCl}_3 + \text{Cu}$
- $\text{CaCl}_2 + \text{AgNO}_3 \rightarrow \text{Ca}(\text{NO}_3)_2 + \text{AgCl}\downarrow$

## TYPES OF CHEMICAL REACTIONS:

1. **Combination Reaction:** A reaction in which two or more substances combine to form a single new substance. Combination reactions can also be called synthesis reactions.

1.  $\text{CaO}(\text{s}) + \text{H}_2\text{O}(\text{l}) \longrightarrow \text{Ca}(\text{OH})_2(\text{aq})$   
(Quick lime) (Slaked lime)
2.  $\text{Ca}(\text{OH})_2(\text{aq}) + \text{CO}_2(\text{g}) \longrightarrow \text{CaCO}_3(\text{s}) + \text{H}_2\text{O}(\text{l})$   
(Calcium hydroxide) (Calcium carbonate)
3.  $\text{C}(\text{s}) + \text{O}_2(\text{g}) \longrightarrow \text{CO}_2(\text{g})$
4.  $2\text{H}_2(\text{g}) + \text{O}_2(\text{g}) \longrightarrow 2\text{H}_2\text{O}(\text{l})$
5.  $\text{CH}_4(\text{g}) + 2\text{O}_2(\text{g}) \longrightarrow \text{CO}_2(\text{g}) + 2\text{H}_2\text{O}(\text{g})$
6.  $\text{C}_6\text{H}_{12}\text{O}_6(\text{aq}) + 6\text{O}_2(\text{aq}) \longrightarrow 6\text{CO}_2(\text{aq}) + 6\text{H}_2\text{O}(\text{l}) + \text{energy}$   
(Glucose)

2. **Decomposition Reaction:** A reaction in which a compound breaks down into two or more simpler substances.

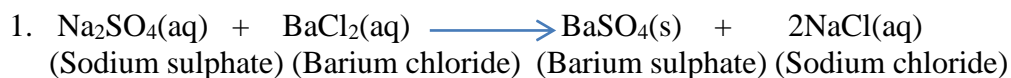
Most decomposition reactions require an input of energy in the form of heat, light, or electricity.

1.  $2\text{FeSO}_4(\text{s}) \xrightarrow{\text{Heat}} \text{Fe}_2\text{O}_3(\text{s}) + \text{SO}_2(\text{g}) + \text{SO}_3(\text{g})$   
(Ferrous sulphate) (Ferric oxide)
2.  $\text{CaCO}_3(\text{s}) \xrightarrow{\text{Heat}} \text{CaO}(\text{s}) + \text{CO}_2(\text{g})$   
(Limestone) (Quick lime)
3.  $2\text{AgCl}(\text{s}) \xrightarrow{\text{Sunlight}} 2\text{Ag}(\text{s}) + \text{Cl}_2(\text{g})$
4.  $2\text{Pb}(\text{NO}_3)_2(\text{s}) \xrightarrow{\text{Heat}} 2\text{PbO}(\text{s}) + 4\text{NO}_2(\text{g}) + \text{O}_2(\text{g})$   
(Lead nitrate) (Lead oxide) (Nitrogen dioxide) (Oxygen)
5.  $2\text{AgBr}(\text{s}) \xrightarrow{\text{Sunlight}} 2\text{Ag}(\text{s}) + \text{Br}_2(\text{g})$

3. **Displacement Reaction:** A chemical reaction in which a more reactive element displaces a less reactive element from its aqueous salt solution.

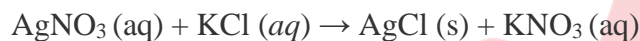
1.  $\text{Fe}(\text{s}) + \text{CuSO}_4(\text{aq}) \longrightarrow \text{FeSO}_4(\text{aq}) + \text{Cu}(\text{s})$   
(Copper sulphate) (Iron sulphate)
2.  $\text{Zn}(\text{s}) + \text{CuSO}_4(\text{aq}) \longrightarrow \text{ZnSO}_4(\text{aq}) + \text{Cu}(\text{s})$   
(Copper sulphate) (Zinc sulphate)
3.  $\text{Pb}(\text{s}) + \text{CuCl}_2(\text{aq}) \longrightarrow \text{PbCl}_2(\text{aq}) + \text{Cu}(\text{s})$   
(Copper chloride) (Lead chloride)

**4. Double Displacement Reaction:** A chemical reaction in which ions get exchanged between two reactants which form a new compound is called a double displacement reaction.



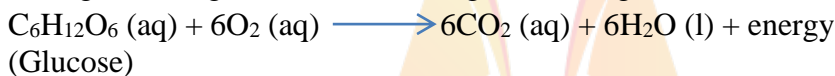
**5. Precipitation reaction:** A precipitation reaction is a chemical reaction that occurs in aqueous solution and forms precipitates. The insoluble salt that falls out of the solution is known as the precipitate. It can occur when two solutions containing different salts are mixed, and a cation/anion pair in the resulting combined solution forms an insoluble salt. For example,

Aqueous silver nitrate ( $\text{AgNO}_3$ ) is added to a solution containing potassium chloride ( $\text{KCl}$ ), and the precipitation of a white solid, silver chloride ( $\text{AgCl}$ ), is observed:



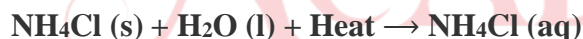
### EXOTHERMIC AND ENDOTHERMIC CHEMICAL REACTIONS:

**EXOTHERMIC CHEMICAL REACTIONS:** Reactions in which heat is released along with the formation of products are called exothermic reactions. For examples:



**ENDOTHERMIC CHEMICAL REACTIONS:** A reaction that the system absorbs energy from its surroundings in the form of heat.

When ammonium chloride ( $\text{NH}_4\text{Cl}$ ) is dissolved in water, an endothermic reaction takes place. The salt dissociates into ammonium ( $\text{NH}_4^+$ ) and chloride ( $\text{Cl}^-$ ) ions. The chemical equation can be written as follows:



Other Endothermic Processes:

- (i) The melting of ice to form water.
- (ii) Evaporation of liquid water, forming water vapour.
- (iii) Sublimation of solid  $\text{CO}_2$ .
- (iv) The baking of bread.

**OXIDATION:** Oxidation refers to the loss of electrons or increase in oxidation state by a molecule, atom, or ion.

**REDUCTION:** Reduction refers to the gain of electrons or decrease in oxidation state by a molecule, atom, or ion.

**REDOX REACTIONS:** A reduction-oxidation or redox reaction is a type of chemical reaction in which reduction and oxidation occur at the same time.

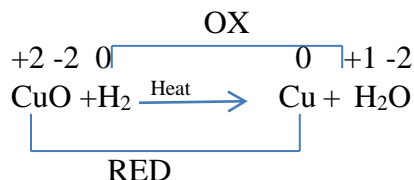
**OXIDATION:** If a substance gains oxygen during a reaction, it is said to be oxidised. For example:



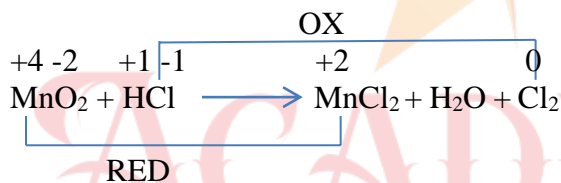
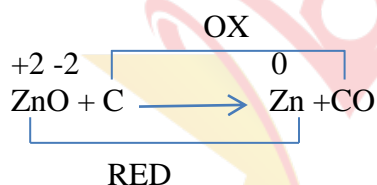
**REDUCTION:** If substance loses oxygen during a reaction, it is said to, be reduced. For example:



**REDOX REACTIONS:** If one reactant gets oxidised while other gets reduced during a reaction. Such reactions are called oxidation-reduction reaction or Redox reaction.



Some other examples of Redox reactions are:



### Multiple Choice Questions:

Q1. Identify x and y in the following reaction:  $\text{Cu} + x\text{HNO}_3 \rightarrow \text{Cu}(\text{NO}_3)_2 + y\text{NO}_2 + 2\text{H}_2\text{O}$

- (a) 4 and 2
- (b) 3 and 5
- (c) 2 and 3
- (d) 4 and 4

Q2. Which of the following can be decomposed by the action of sunlight?

- (a) Potassium bromide
- (b) Silver bromide
- (c) Magnesium oxide
- (d) Sodium chloride

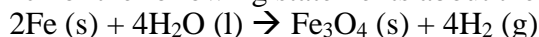
Q3. The carbonate of lead is a white solid. It decomposes when heated to form carbon dioxide and a yellow solid oxide 'X'. What is X?

- (a) Zinc oxide
- (b) Lead oxide
- (c) Silver oxide
- (d) Magnesium oxide

Q4. Identify the endothermic process from the following?

- (a)  $\text{H}_2\text{O}(\text{l}) \rightarrow \text{H}_2\text{O}(\text{g})$
- (b)  $\text{CaO}(\text{s}) + \text{H}_2\text{O}(\text{l}) \rightarrow \text{Ca}(\text{OH})_2(\text{aq})$
- (c) Combustion of methane
- (d) Addition of conc. HCl to water

Q5. Which of the following statements about the given reaction are correct?



- 1. Iron metal is getting oxidized.
- 2. Water is getting reduced.
- 3. Water is acting as reducing agent.
- 4. Water is acting as oxidizing agent.

- (a) 1, 2 and 3
- (b) 3 and 4
- (c) 1, 2 and 4
- (d) 2 and 4

Q6. When Ag is exposed to air it gets a black coating of

- (a)  $\text{AgNO}_3$
- (b)  $\text{Ag}_2\text{S}$
- (c)  $\text{Ag}_2\text{O}$
- (d)  $\text{Ag}_2\text{CO}_3$

Q7.  $\text{MnO}_2 + 4\text{HCl} \rightarrow \text{MnCl}_2 + 2\text{H}_2\text{O} + \text{Cl}_2$

Identify the substance oxidized in the above equation.

- (a)  $\text{MnCl}_2$
- (b) HCl
- (c)  $\text{H}_2\text{O}$
- (d)  $\text{MnO}_2$

Q8. Zinc reacts with silver nitrate to form which compounds?

- (a)  $\text{Zn}(\text{NO}_3)_2 + \text{Ag}$
- (b)  $\text{ZnNO}_3 + \text{Ag}$
- (c)  $\text{AgNO}_3 + \text{Zn}(\text{NO}_3)_2$
- (d)  $\text{Ag} + \text{Zn}(\text{NO}_3)_3$

Q9. In the double displacement reaction between aqueous potassium iodide and aqueous lead nitrate, a yellow precipitate of lead iodide is formed. While performing the activity if lead nitrate is not available, which of the following can be used in place of lead nitrate?

- (a) Lead sulphate (insoluble)
- (b) Lead acetate



- (c) Ammonium nitrate
- (d) Potassium sulphate

Q10. The brown gas evolved on heating of copper nitrate is

- (a) O<sub>2</sub>
- (b) NO<sub>2</sub>
- (c) N<sub>2</sub>
- (d) NO

Q11. Electrolysis of water is a decomposition reaction. The mole ratio of hydrogen and oxygen gases liberated during electrolysis of water is:

- (a) 1: 1
- (b) 2:1
- (c) 4:1
- (d) 1:2

Q12. A substance 'X' is used in white-washing and is obtained by heating limestone in the absence of air. Identify 'X'.

- (a) CaOCl<sub>2</sub>
- (b) Ca (OH)<sub>2</sub>
- (c) CaO
- (d) CaCO<sub>3</sub>

Q13.  $2\text{HNO}_3 + \text{Ca}(\text{OH})_2 \rightarrow \text{Ca}(\text{NO}_3)_2 + 2\text{H}_2\text{O}$ ; is an example of

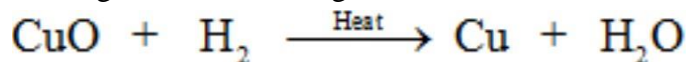
- (i) displacement reaction (ii) double displacement reaction
- (iii) neutralisation reaction (iv) combination reaction.

- (a) (i) and (ii)
- (b) (ii) and (iii)
- (c) (iii) and (iv)
- (d) (i) and (iv)

Q14. A substance X which is a group 2 element is used intensively in the cement industry. This element is present in bones also. On treatment with water, it forms a solution which turns red litmus blue. Element X is

- (a) Cu
- (b) Ca
- (c) Na
- (d) Al

Q15. You are given the following chemical reaction:



This reaction represents:

- (a) Combination reaction as well as double displacement reaction
- (b) Redox reaction as well as displacement reaction
- (c) Double displacement reaction as well as redox reaction
- (d) Decomposition reaction as well as displacement reaction



## ANSWERS

<b>Q1. (a)</b>	<b>Q2. (b)</b>	<b>Q3. (b)</b>	<b>Q4. (a)</b>	<b>Q5. (c)</b>
<b>Q6. (b)</b>	<b>Q7. (d)</b>	<b>Q8. (a)</b>	<b>Q9. (b)</b>	<b>Q10. (b)</b>
<b>Q11. (b)</b>	<b>Q12. (a)</b>	<b>Q13. (b)</b>	<b>Q14. (b)</b>	<b>Q15. (b)</b>

### Assignment:

Q1. What happens chemically when quicklime is added to water filled in a bucket?

Answer. Quicklime reacts with water to form slaked lime and produces lot of heat and hissing sound.

Q2. On what basis is a chemical equation balanced?

Answer. A chemical reaction is balanced on the basis of law of conservation of mass.

Q3. What change in colour is observed when white silver chloride is left exposed to sunlight?

State the type of chemical reaction in this change.

Answer. Silver chloride becomes grey. It is a photochemical decomposition reaction.

Q4. A solution of potassium chloride when mixed with silver nitrate solution, an insoluble white substance is formed. Write the chemical reaction involved and also mention the type of the chemical reaction?

Answer.  $\text{KCl (aq)} + \text{AgNO}_3 \text{ (aq)} \longrightarrow \text{AgCl (s)} + \text{KNO}_3 \text{ (aq)}$

It is a double displacement reaction. It is also a precipitation reaction as AgCl is a white precipitate.

Q5. Translate the following statement into chemical equation and then balance it Barium Chloride reacts with Aluminium sulphate to give Aluminium Chloride and a precipitate of Barium Sulphate. State the two types in which this reaction can be classified.

Answer.  $3\text{BaCl}_2 \text{ (aq)} + \text{Al}_2 \text{ (SO}_4)_3 \text{ (aq)} \longrightarrow 3\text{BaSO}_4 \text{ (s)} + 2\text{AlCl}_3 \text{ (aq)}$

It can be classified as double displacement as well as precipitation reaction.

Q6. Why decomposition reactions are called the opposite of combination reactions? Write equations for these reactions.

Answer. In decomposition reaction, a compound is broken down into simpler compounds or elements, e.g.  $\text{CuCO}_3 \text{ (s)} \longrightarrow \text{CuO (s)} + \text{CO}_2 \text{ (g)}$

Combination reaction is a reaction in which two or more elements or compounds combine to form a new compound, e.g.  $\text{N}_2 \text{ (g)} + \text{H}_2 \text{ (g)} \longrightarrow 2\text{NH}_3 \text{ (g)}$

Thus, decomposition and combination reactions are opposite to each other.

Q7. What is redox reaction? Identify the substance oxidized and the substance reduced in the following reactions.

(i)  $2\text{PbO} + \text{C} \longrightarrow 2\text{Pb} + \text{CO}_2$

(ii)  $\text{MnO}_2 + 4\text{HCl} \longrightarrow \text{MnCl}_2 + 2\text{H}_2\text{O} + \text{Cl}_2$

Answer. Those reactions in which oxidation and reduction takes place simultaneously are called redox reactions.

(i) PbO is getting reduced and C is getting oxidized.

(ii) MnO<sub>2</sub> is getting reduced and HCl is getting oxidized.

**Q8.** Using a suitable chemical equation, justify that some chemical reactions are determined by:

(i) change in colour, (ii) change in temperature.

Answer. (i)  $\text{Pb (NO}_3)_2 \text{ (aq)} + 2\text{KI} \longrightarrow \text{PbI}_2 + 2\text{KNO}_3 \text{ (aq)}$

Colourless

Yellow ppt.

(ii)  $\text{CaO (s)} + \text{H}_2\text{O (l)} \longrightarrow \text{Ca (OH)}_2 + \text{heat}$



Q9. Write balanced equations for the following mentioning the type of reaction involved.

(i) Aluminium + Bromine  $\longrightarrow$  Aluminium bromide

(ii) Calcium carbonate  $\longrightarrow$  Calcium oxide + Carbon dioxide

(iii) Silver chloride  $\longrightarrow$  Silver + Chlorine

Answer. (i)  $2\text{Al (s)} + 3\text{Br}_2\text{(g)} \longrightarrow 2\text{AlBr}_3\text{(s)}$

(ii)  $\text{CaCO}_3\text{(s)} \longrightarrow \text{CaO} + \text{CO}_2$

(iii)  $2\text{AgCl (s)} \longrightarrow 2\text{Ag (s)} + \text{Cl}_2\text{(g)}$

Q10. (a) Why is respiration considered as an exothermic reaction?

(b) Define the terms oxidation and reduction.

(c) Identify the substance that is oxidized and reduced in the following reaction.

$\text{CuO (s)} + \text{Zn (s)} \longrightarrow \text{Cu (s)} + \text{ZnO (s)}$

Answer. (a) It is because heat is evolved during respiration.

(b) Oxidation is a process in which  $\text{O}_2$  is added or  $\text{H}_2$  is removed or loss of electrons takes place.

Reduction is a process in which  $\text{H}_2$  is added or  $\text{O}_2$  is removed or gain of electrons take place.

(c) Zn is getting oxidized, CuO is getting reduced.



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