Chapter 1: Chemical Reactions and Equations

Comprehensive Study Notes

Introduction to Chemical Reactions

Chemical reactions occur in our daily life constantly. When we observe situations like:

- Milk souring at room temperature
- Iron rusting in humid atmosphere
- Grape fermentation
- Food cooking and digestion
- Respiration process

In all these cases, the nature and identity of initial substances change, indicating **chemical reactions** have taken place.

Signs of Chemical Reactions

A chemical reaction has occurred when we observe:

- **Change in state** (solid to liquid/gas)
- **Change in colour** (green to brown, white to grey)
- **Evolution of gas** (bubbles, fumes)
- **Change in temperature** (heating or cooling)

1.1 Chemical Equations

Word Equations

Chemical reactions can be represented in sentence form, but this is lengthy. A shorter method uses word equations:

Example: Magnesium + Oxygen → Magnesium oxide

Where:

- **Reactants** (left side): Substances that undergo chemical change
- **Products** (right side): New substances formed
- **Arrow** (→): Shows direction of reaction

Chemical Equations Using Formulae

Chemical equations become more concise using chemical formulae:

$Mg + O_2 \rightarrow MgO$

This is called a **skeletal chemical equation** - it shows the correct formulae but may not be balanced.

1.2 Balanced Chemical Equations

Law of Conservation of Mass

- Mass can neither be created nor destroyed in chemical reactions
- Total mass of reactants = Total mass of products
- Number of atoms of each element must be same on both sides

Balancing Steps (Hit-and-Trial Method)

Example: Balancing $Fe + H_2O \rightarrow Fe_3O_4 + H_2$

Step 1: Draw boxes around formulae (don't change what's inside) $[Fe] + [H_2O] \rightarrow [Fe_3O_4] + [H_2]$

Step 2: Count atoms of each element

Element	Reactants	Products
Fe	1	3
H	2	2
O	1	4

Step 3: Balance oxygen first (maximum atoms) $Fe + 4H_2O \rightarrow Fe_3O_4 + H_2$

Step 4: Balance hydrogen $Fe + 4H_2O \rightarrow Fe_3O_4 + 4H_2$

Step 5: Balance iron $3Fe + 4H_2O \rightarrow Fe_3O_4 + 4H_2$

Step 6: Verify final count

Element	Reactants	Products
Fe	3	3
H	8	8
O	4	4

Physical State Symbols

Add state symbols to make equations more informative:

- (s) = solid
- (l) = liquid

- (g) = gas
- (aq) = aqueous solution

Final equation: $3Fe(s) + 4H_2O(g) \rightarrow Fe_3O_4(s) + 4H_2(g)$

Reaction Conditions

Conditions like temperature, pressure, catalyst are written above/below arrow:

$CO(g) + 2H_2(g) \rightarrow CH_3OH(l)$
340 atm

1.3 Types of Chemical Reactions

1.3.1 Combination Reactions

Two or more substances combine to form a single product.

General form: $A + B \rightarrow AB$

Examples:

1. $CaO(s) + H_2O(l) \rightarrow Ca(OH)_2(aq)$ + Heat (Quick lime + Water → Slaked lime)
2. $C(s) + O_2(g) \rightarrow CO_2(g)$ (Burning of coal)
3. $2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$ (Formation of water)

Special Note: Slaked lime [$Ca(OH)_2$] is used for whitewashing. It reacts with CO_2 to form calcium carbonate ($CaCO_3$), giving walls a shiny finish.

1.3.2 Decomposition Reactions

Single substance breaks down into two or more simpler products.

General form: AB → A + B

Types based on energy source:

Thermal Decomposition (Heat)

1. **Ferrous Sulphate Crystals:** $2FeSO_4(s) \rightarrow Fe_2O_3(s) + SO_2(g) + SO_3(g)$ (Green crystals change color, smell of burning sulphur)
2. **Lead Nitrate:** $2Pb(NO_3)_2(s) \rightarrow 2PbO(s) + 4NO_2(g) + O_2(g)$ (Brown fumes of nitrogen dioxide)
3. **Calcium Carbonate:** $CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$ (Used in cement industry)

Photo Decomposition (Light)

1. **Silver Chloride:** $2AgCl(s) \rightarrow 2Ag(s) + Cl_2(g)$ (White to grey, used in photography)
2. **Silver Bromide:** $2AgBr(s) \rightarrow 2Ag(s) + Br_2(g)$ (Used in black and white photography)

Electrolytic Decomposition (Electricity)

Water Electrolysis: $2H_2O(l) \rightarrow 2H_2(g) + O_2(g)$

- H_2 collected at cathode (double volume)
- O_2 collected at anode
- Test: H_2 burns with 'pop' sound, O_2 rekindles glowing splint

1.3.3 Displacement Reactions

More reactive element displaces less reactive element from its compound.

General form: A + BC → AC + B

Examples:

1. $Fe(s) + CuSO_4(aq) \rightarrow FeSO_4(aq) + Cu(s)$

- Iron nail becomes brownish
- Blue copper sulphate solution fades
- Copper deposited on iron

2. $Zn(s) + CuSO_4(aq) \rightarrow ZnSO_4(aq) + Cu(s)$
3. $Pb(s) + CuCl_2(aq) \rightarrow PbCl_2(aq) + Cu(s)$

Reactivity order: Zn > Pb > Fe > Cu

1.3.4 Double Displacement Reactions

Exchange of ions between two compounds.

General form: $AB + CD \rightarrow AD + CB$

Example: $Na_2SO_4(aq) + BaCl_2(aq) \rightarrow BaSO_4(s) + 2NaCl(aq)$

- White precipitate of $BaSO_4$ forms
- Called **precipitation reaction** when insoluble product forms
- Ion exchange: SO_4^{2-} with Cl^- and Na^+ with Ba^{2+}

1.4 Oxidation and Reduction

Definitions

Oxidation:

- Gain of oxygen
- Loss of hydrogen

Reduction:

- Loss of oxygen
- Gain of hydrogen

Examples

Oxidation Example:

$2Cu + O_2 \rightarrow 2CuO$
(Copper gains oxygen - gets oxidized)

Reduction Example:

$CuO + H_2 \rightarrow Cu + H_2O$

- CuO loses oxygen (reduced)
- H_2 gains oxygen (oxidized)

Redox Reactions

Reactions where both oxidation and reduction occur simultaneously.

Examples:

1. $ZnO + C \rightarrow Zn + CO$
    - C is oxidized (gains oxygen)
    - ZnO is reduced (loses oxygen)
2. $MnO_2 + 4HCl \rightarrow MnCl_2 + 2H_2O + Cl_2$
    - HCl is oxidized to Cl_2
    - MnO_2 is reduced to $MnCl_2$

1.5 Energy Changes in Reactions

Exothermic Reactions

Reactions that release heat energy.

Examples:

1. **Respiration:** $C_6H_{12}O_6(aq) + 6O_2(aq) \rightarrow 6CO_2(aq) + 6H_2O(l)$ + Energy
2. **Burning of natural gas:** $CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$
3. **Formation of slaked lime:** $CaO(s) + H_2O(l) \rightarrow Ca(OH)_2(aq)$ + Heat

Endothermic Reactions

Reactions that absorb heat energy.

Examples:

1. **Decomposition reactions requiring heat:**
   - $CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$
   - $2FeSO_4(s) \rightarrow Fe_2O_3(s) + SO_2(g) + SO_3(g)$
2. **Electrolysis reactions**
3. **Photolysis reactions**

1.6 Effects of Oxidation in Daily Life

1.6.1 Corrosion

Definition: Attack of metals by substances like moisture, acids, etc.

Examples:

- **Rusting of iron:** Iron gets reddish-brown coating

- **Tarnishing of silver:** Black coating forms
- **Corrosion of copper:** Green coating appears

Economic Impact: Enormous money spent annually replacing corroded iron structures (bridges, ships, buildings).

1.6.2 Rancidity

Definition: Oxidation of fats and oils causing change in smell and taste.

Prevention Methods:

- Adding antioxidants to food
- Storing in airtight containers
- Flushing with nitrogen gas (chips packets)
- Refrigeration

Summary of Reaction Types

Reaction Type	General Form	Example	Key Feature
Combination	$A + B \rightarrow AB$	$2H_2 + O_2 \rightarrow 2H_2O$	Two or more → One
Decomposition	$AB \rightarrow A + B$	$2H_2O \rightarrow 2H_2 + O_2$	One → Two or more
Displacement	$A + BC \rightarrow AC + B$	$Zn + CuSO_4 \rightarrow ZnSO_4 + Cu$	More reactive displaces less
Double Displacement	$AB + CD \rightarrow AD + CB$	$AgNO_3 + NaCl \rightarrow AgCl + NaNO_3$	Ion exchange

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Important Formulas and Equations

Key Balanced Equations:

1. **Photosynthesis:** $6CO_2(aq) + 12H_2O(l) \rightarrow C_6H_{12}O_6(aq) + 6O_2(aq) + 6H_2O(l)$
2. **Methanol formation:** $CO(g) + 2H_2(g) \rightarrow CH_3OH(l)$
3. **Whitewashing reaction:** $Ca(OH)_2(aq) + CO_2(g) \rightarrow CaCO_3(s) + H_2O(l)$

Practice Questions and Answers

Q1. What is a balanced chemical equation? Why should chemical equations be balanced?

Answer: A balanced chemical equation has equal number of atoms of each element on both sides. Equations must be balanced to follow the law of conservation of mass - atoms can neither be created nor destroyed in chemical reactions.

Q2. Distinguish between oxidation and reduction with examples.

Answer: Oxidation: Gain of oxygen or loss of hydrogen

- Example: $2Cu + O_2 \rightarrow 2CuO$ (copper gains oxygen)

Reduction: Loss of oxygen or gain of hydrogen

- Example: $CuO + H_2 \rightarrow Cu + H_2O$ (copper oxide loses oxygen)

Q3. What happens when iron nails are placed in copper sulphate solution?

Answer: Iron displaces copper from copper sulphate solution: $Fe(s) + CuSO_4(aq) \rightarrow FeSO_4(aq) + Cu(s)$

- Iron nail becomes brownish (copper coating)
- Blue color of solution fades
- This is a displacement reaction

Q4. Explain the difference between combination and decomposition reactions.

Answer: Combination: Two or more reactants form single product (A + B → AB) Example: $CaO + H_2O \rightarrow Ca(OH)_2$

Decomposition: Single reactant breaks into multiple products (AB → A + B) Example: $2FeSO_4 \rightarrow Fe_2O_3 + SO_2 + SO_3$

These are opposite reactions.

Q5. Why are food items containing fats and oils flushed with nitrogen?

Answer: Nitrogen is an inert gas that prevents oxidation of fats and oils, which causes rancidity. Rancidity changes the smell and taste of food. By removing oxygen and replacing it with nitrogen, oxidation is prevented and food stays fresh longer.

Key Diagrams and Processes

Balancing Chemical Equations Flowchart:

```
Start with skeletal equation
↓
Count atoms of each element
↓
Identify unbalanced elements
↓
Add coefficients (smallest whole numbers)
↓
Recount atoms
↓
Balanced? → Yes: Add physical states → Complete equation
```

↓ No
Adjust coefficients and repeat

Electrolysis of Water Setup:

Battery (6V)
|
Carbon electrodes in water + dilute H_2SO_4
|
H_2 gas (cathode) + O_2 gas (anode)
Volume ratio = 2:1

Displacement Reaction Mechanism:

More reactive metal + Less reactive metal compound
→ More reactive metal compound + Less reactive metal

Example: $Fe + CuSO_4 \rightarrow FeSO_4 + Cu$
(Iron displaces copper)

Important Notes and Tips

For Balancing Equations:

1. Never change chemical formulae while balancing
2. Use smallest whole number coefficients
3. Start with compound having maximum atoms
4. Balance one element at a time
5. Check final atom count

For Identifying Reaction Types:

1. **Count reactants and products** to identify combination/decomposition
2. **Look for element displacement** for displacement reactions
3. **Check for ion exchange** for double displacement
4. **Observe energy changes** for exothermic/endothermic classification

Laboratory Safety:

- Handle acids with care
- Use safety glasses when burning substances
- Teacher supervision required for certain activities
- Keep burning materials away from eyes

Real-Life Applications

Industrial Applications:

- **Cement industry:** Uses thermal decomposition of limestone
- **Photography:** Uses photo decomposition of silver compounds
- **Metallurgy:** Uses displacement reactions for metal extraction

Daily Life Applications:

- **Cooking:** Combination reactions create new flavors
- **Food preservation:** Preventing oxidation reactions
- **Cleaning:** Using chemical reactions to remove stains
- **Medicine:** Many drugs work through specific chemical reactions

Chapter Summary

Chemical reactions involve breaking and making of bonds between atoms. They can be represented using word equations or chemical equations with formulae. All chemical equations must be balanced according to the law of conservation of mass.

The main types of reactions are:

- **Combination** (synthesis)
- **Decomposition** (analysis)
- **Displacement** (single replacement)
- **Double displacement** (double replacement)

Reactions can be classified by energy changes as exothermic (release heat) or endothermic (absorb heat). Oxidation-reduction reactions involve transfer of oxygen or hydrogen.

Understanding chemical reactions helps us comprehend processes in industry, environment, and our own bodies. The ability to write and balance chemical equations is fundamental to studying chemistry.

Study Tips:

- Practice balancing equations daily
- Memorize common chemical formulae
- Understand reaction types through examples
- Connect reactions to real-life processes
- Focus on identifying oxidation and reduction

Source: NCERT Science Textbook Notes compiled for comprehensive exam preparation