Chapter 2: Acids, Bases and Salts

Comprehensive Study Notes

Introduction

Acids and bases are present in our daily life and determine the sour and bitter tastes of foods. Understanding their properties helps us:

- Choose remedies for acidity (baking soda for stomach problems)
- Understand chemical reactions in cooking and digestion
- Apply knowledge in laboratory and industrial processes

Key Properties:

- **Acids**: Sour taste, turn blue litmus red
- **Bases**: Bitter taste, turn red litmus blue, soapy feel

2.1 Understanding Chemical Properties

2.1.1 Acid-Base Indicators

Natural Indicators

- **Litmus**: Purple dye from lichen (Thallophyta division)
  - Neutral litmus: Purple color
  - In acid: Red color
  - In base: Blue color

- **Other Natural Indicators**:
  - Red cabbage leaves
  - Turmeric (curry stains turn reddish-brown with soap)
  - Hydrangea, Petunia, Geranium petals

Synthetic Indicators

- **Methyl Orange**: Red in acid, yellow in base
- **Phenolphthalein**: Colorless in acid, pink in base

Olfactory Indicators

Substances whose smell changes in acidic/basic media:

- **Onion**: Can be used as olfactory indicator
- **Vanilla and Clove**: Change odor in acid/base solutions

2.1.2 Common Laboratory Acids and Bases

Acids

- Hydrochloric acid (HCl)
- Sulphuric acid (H_2SO_4)
- Nitric acid (HNO_3)
- Acetic acid (CH_3COOH)

Bases

- Sodium hydroxide ($NaOH$)
- Calcium hydroxide [$Ca(OH)_2$]
- Potassium hydroxide (KOH)

- Magnesium hydroxide [$Mg(OH)_2$]
- Ammonium hydroxide (NH_4OH)

2.2 Chemical Reactions of Acids and Bases

2.2.1 Acids with Metals

General Reaction: Acid + Metal → Salt + Hydrogen gas

Examples:

1. **Zinc with Sulphuric Acid:** $Zn(s) + H_2SO_4(aq) \rightarrow ZnSO_4(aq) + H_2(g)$
2. **Zinc with Hydrochloric Acid:** $Zn(s) + 2HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$

Test for Hydrogen Gas:

- Pass through soap solution to form bubbles
- Bring burning candle near bubble
- Hydrogen burns with 'pop' sound

2.2.2 Bases with Metals

Example: $2NaOH(aq) + Zn(s) \rightarrow Na_2ZnO_2(s) + H_2(g)$ (Sodium zincate)

Note: Not all metals react with bases.

2.2.3 Acids with Metal Carbonates and Hydrogencarbonates

General Reactions: Metal carbonate + Acid → Salt + Carbon dioxide + Water Metal hydrogencarbonate + Acid → Salt + Carbon dioxide + Water

Examples:

1. **Sodium Carbonate with HCl:** $Na_2CO_3(s) + 2HCl(aq) \rightarrow 2NaCl(aq) + H_2O(l) + CO_2(g)$
2. **Sodium Hydrogencarbonate with HCl:** $NaHCO_3(s) + HCl(aq) \rightarrow NaCl(aq) + H_2O(l) + CO_2(g)$

Test for Carbon Dioxide:

- Pass through lime water [$Ca(OH)_2$]
- Lime water turns milky due to $CaCO_3$ formation: $Ca(OH)_2(aq) + CO_2(g) \rightarrow CaCO_3(s) + H_2O(l)$

2.2.4 Neutralization Reactions

Definition: Reaction between acid and base to form salt and water.

General Equation: Base + Acid → Salt + Water

Example: $NaOH(aq) + HCl(aq) \rightarrow NaCl(aq) + H_2O(l)$

Observable Changes:

- Phenolphthalein color changes from pink (base) to colorless (neutral)
- Adding base again restores pink color

2.2.5 Metallic Oxides with Acids

General Reaction: Metal oxide + Acid → Salt + Water

Example: $CuO(s) + 2HCl(aq) \rightarrow CuCl_2(aq) + H_2O(l)$ (Black copper oxide becomes blue-green copper chloride solution)

Conclusion: Metallic oxides are basic oxides.

2.2.6 Non-metallic Oxides with Bases

Example: $Ca(OH)_2(aq) + CO_2(g) \rightarrow CaCO_3(s) + H_2O(l)$

Conclusion: Non-metallic oxides are acidic in nature.

2.3 What Makes Acids and Bases Special?

2.3.1 Ion Formation in Solution

Acids in Water

- **Hydrogen Ion Production:** All acids produce $H^+(aq)$ ions in water
- **Hydronium Ion Formation:** $H^+ + H_2O \rightarrow H_3O^+$

Examples:

- $HCl + H_2O \rightarrow H_3O^+ + Cl^-$
- $H_2SO_4 + H_2O \rightarrow H_3O^+ + HSO_4^-$

Bases in Water

- **Hydroxide Ion Production:** Bases produce $OH^-(aq)$ ions in water

Examples:

- $NaOH(s) \rightarrow Na^+(aq) + OH^-(aq)$
- $Ca(OH)_2(s) \rightarrow Ca^{2+}(aq) + 2OH^-(aq)$

2.3.2 Electrical Conductivity

Key Findings:

- **Acids conduct electricity** due to H^+ and anion formation
- **Bases conduct electricity** due to metal cation and OH^- formation
- **Glucose and alcohol don't conduct** because they don't form ions
- **Dry HCl gas is non-acidic** - requires water for ion formation

2.3.3 Neutralization at Ion Level

$H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$

This explains why acids and bases neutralize each other.

2.4 Measuring Acid-Base Strength: pH Scale

2.4.1 pH Scale Concept

Definition: pH scale measures hydrogen ion concentration in solution

- **Range:** 0 to 14
- **pH 7:** Neutral (pure water)
- **pH < 7:** Acidic (lower pH = stronger acid)
- **pH > 7:** Basic/Alkaline (higher pH = stronger base)

2.4.2 Universal Indicator

Mixture of several indicators showing different colors at different pH values:

- **Red/Orange:** Strong acid (pH 0-3)
- **Yellow:** Weak acid (pH 4-6)
- **Green:** Neutral (pH 7)
- **Blue:** Weak base (pH 8-10)
- **Purple:** Strong base (pH 11-14)

2.4.3 Strong vs Weak Acids and Bases

Strong Acids: Produce more H^+ ions (HCl, H_2SO_4, HNO_3) **Weak Acids:** Produce fewer H^+ ions (CH_3COOH, citric acid) **Strong Bases:** Produce more OH^- ions (NaOH, KOH) **Weak Bases:** Produce fewer OH^- ions (NH_4OH)

2.5 Importance of pH in Daily Life

2.5.1 Biological Systems

Human Body pH

- **Normal range:** 7.0 to 7.8
- **Stomach pH:** ~1.5-2.0 (due to HCl production)
- **During indigestion:** Excess acid causes pain
- **Treatment:** Antacids ($Mg(OH)_2$ - Milk of Magnesia)

Tooth Decay

- **Critical pH:** Below 5.5
- **Cause:** Bacteria produce acids from sugar/food particles
- **Prevention:** Brushing with basic toothpaste neutralizes acid
- **Tooth enamel:** Calcium hydroxyapatite (hardest body substance)

2.5.2 Agricultural pH

Soil pH Requirements:

- Most plants need specific pH ranges for healthy growth
- **Testing:** Mix soil with water, filter, test filtrate with pH paper
- **Treatment:** Acidic soil treated with lime [$Ca(OH)_2$] or limestone ($CaCO_3$)

2.5.3 Environmental pH

Acid Rain

- **Definition:** Rain water with $pH < 5.6$
- **Cause:** Air pollution (SO_2, NO_2 forming acids)
- **Effects:** Damages aquatic life, buildings, vegetation

Natural Defense Mechanisms

- **Bee sting:** Injects acid - treat with baking soda (base)
- **Nettle sting:** Methanoic acid - treat with dock plant leaves (basic)

2.6 Salts and Their Properties

2.6.1 Classification of Salts

Based on pH:

1. **Neutral Salts (pH = 7):** From strong acid + strong base
   - Example: $NaCl$ (from HCl + $NaOH$)
2. **Acidic Salts (pH < 7):** From strong acid + weak base
   - Example: NH_4Cl (from HCl + NH_4OH)
3. **Basic Salts (pH > 7):** From weak acid + strong base
   - Example: CH_3COONa (from CH_3COOH + $NaOH$)

Based on Common Ions:

- **Chloride family:** $NaCl$, KCl, $MgCl_2$
- **Sulphate family:** Na_2SO_4, $CuSO_4$, $ZnSO_4$

- **Sodium family:** $NaCl$, Na_2SO_4, $NaNO_3$

2.6.2 Water of Crystallization

Definition: Fixed number of water molecules in one formula unit of salt

Examples:

1. **Copper Sulphate:** $CuSO_4.5H_2O$
   - Blue crystals become white on heating (water loss)
   - Regain blue color when water added
2. **Washing Soda:** $Na_2CO_3.10H_2O$
   - Contains 10 water molecules per formula unit
3. **Gypsum:** $CaSO_4.2H_2O$
   - Contains 2 water molecules per formula unit

2.7 Chemicals from Common Salt (NaCl)

2.7.1 Sodium Hydroxide (Chlor-alkali Process)

Electrolysis of Brine: $2NaCl(aq) + 2H_2O(l) \rightarrow 2NaOH(aq) + Cl_2(g) + H_2(g)$

Products and Uses:

- **Chlorine:** Bleaching, water purification, PVC manufacture
- **Hydrogen:** Fuel, ammonia production, margarine manufacture
- **Sodium Hydroxide:** Soap, paper, textile industry

2.7.2 Bleaching Powder $Ca(ClO)_2$

Preparation: $Ca(OH)_2 + Cl_2 \rightarrow Ca(ClO)_2 + H_2O$ (Dry slaked lime + Chlorine gas)

Uses:

- Bleaching cotton, linen, wood pulp
- Oxidizing agent in chemical industries
- Disinfecting drinking water

2.7.3 Baking Soda ($NaHCO_3$)

Preparation: $NaCl + H_2O + CO_2 + NH_3 \rightarrow NH_4Cl + NaHCO_3$

Properties:

- Mild, non-corrosive basic salt
- $pH > 7$ (can neutralize acids)

Thermal Decomposition: $2NaHCO_3 \rightarrow Na_2CO_3 + H_2O + CO_2$ (Heat releases CO_2 making food soft and spongy)

Uses:

1. **Baking Powder:** $NaHCO_3$ + tartaric acid
   - Releases CO_2 when heated/mixed with water
   - Makes bread/cake soft and spongy
2. **Antacid:** Neutralizes excess stomach acid
3. **Fire Extinguisher:** Soda-acid type
   - $NaHCO_3 + H_2SO_4 \rightarrow Na_2SO_4 + H_2O + CO_2$
   - CO_2 cuts off oxygen supply to fire

2.7.4 Washing Soda ($Na_2CO_3.10H_2O$)

Preparation: $Na_2CO_3 + 10H_2O \rightarrow Na_2CO_3.10H_2O$ (Recrystallization of heated baking soda)

Uses:

- Glass, soap, and paper industries
- Manufacturing sodium compounds (borax)
- Domestic cleaning agent
- Removing permanent hardness of water

2.7.5 Plaster of Paris

Preparation from Gypsum: $CaSO_4.2H_2O \rightarrow CaSO_4.\frac{1}{2}H_2O + 1\frac{1}{2}H_2O$ (Gypsum heated at 373K → Plaster of Paris)

Setting Reaction: $CaSO_4.\frac{1}{2}H_2O + 1\frac{1}{2}H_2O \rightarrow CaSO_4.2H_2O$ (Plaster of Paris + Water → Hard gypsum)

Uses:

- Medical plaster for fractured bones
- Making toys and decorative materials
- Smoothening surfaces

2.8 Natural Occurrence of Acids

Common Natural Acids

Natural Source	Acid Present
Vinegar	Acetic acid
Citrus fruits (Orange, Lemon)	Citric acid
Tamarind	Tartaric acid
Tomato	Oxalic acid
Sour milk (Curd)	Lactic acid

Natural Source	Acid Present
Ant sting	Methanoic acid
Nettle sting	Methanoic acid

2.9 Important Reaction Patterns

Acid Reactions Summary

1. **Acid + Metal → Salt + Hydrogen**
2. **Acid + Metal carbonate → Salt + Water + CO_2**
3. **Acid + Metal oxide → Salt + Water**
4. **Acid + Base → Salt + Water (Neutralization)**

Base Reactions Summary

1. **Base + Metal → Salt + Hydrogen** (limited metals)
2. **Base + Non-metal oxide → Salt + Water**
3. **Base + Acid → Salt + Water (Neutralization)**

2.10 Safety and Dilution

Dilution Process

- **Always add acid to water, never water to acid**
- **Reason:** Mixing is highly exothermic
- **Risk:** Heat generated can cause splashing and burns
- **Proper method:** Add acid slowly with constant stirring

Laboratory Safety

- Handle concentrated acids/bases with care
- Look for warning signs on containers
- Use proper ventilation
- Wear protective equipment

2.11 pH Applications in Different Fields

Industrial Applications

- **Water treatment:** pH control for purification
- **Food industry:** Preservation and taste control
- **Agriculture:** Soil pH management for crop growth
- **Medicine:** Drug formulation and body pH maintenance

Environmental Monitoring

- **Water bodies:** pH indicates pollution levels
- **Soil testing:** Determines fertilizer requirements
- **Air quality:** Acid rain monitoring

Practice Questions and Answers

Q1. Explain why HCl, H_2SO_4 show acidic character in aqueous solutions while glucose and alcohol do not.

Answer: HCl and H_2SO_4 ionize in water to produce H^+ ions (H_3O^+), which are responsible for acidic properties. Glucose and alcohol do not ionize in water to produce H^+ ions, hence they don't show acidic character despite containing hydrogen atoms.

Q2. Why does dry HCl gas not change the color of dry litmus paper?

Answer: Dry HCl gas does not produce hydrogen ions (H^+) in the absence of water. Acidic properties are shown only when H^+ ions are present in solution. Therefore, dry HCl gas cannot change the color of dry litmus paper.

Q3. What happens when sodium hydrogencarbonate is heated? Write the equation.

Answer: When sodium hydrogencarbonate (baking soda) is heated, it decomposes to form sodium carbonate, water, and carbon dioxide: $2NaHCO_3(s) \rightarrow Na_2CO_3(s) + H_2O(l) + CO_2(g)$ The CO_2 gas released makes baked goods soft and spongy.

Q4. A farmer finds his field soil is acidic. Which substance would you recommend to neutralize the soil and why?

Answer: I would recommend quick lime [CaO], slaked lime [$Ca(OH)_2$], or chalk [$CaCO_3$]. These are basic substances that can neutralize the acidic soil by reacting with acids present in soil. The reaction increases soil pH to optimal levels (6.5-7.5) required for healthy plant growth.

Q5. Explain the difference between strong and weak acids with examples.

Answer: Strong Acids: Completely ionize in water producing more H^+ ions. Examples: HCl, H_2SO_4, HNO_3 **Weak Acids:** Partially ionize in water producing fewer H^+ ions. Examples: CH_3COOH (acetic acid), citric acid The strength determines the pH value - stronger acids have lower pH values.

2.12 Important Formulas and Equations

Key Chemical Equations:

1. **Chlor-alkali process:** $2NaCl(aq) + 2H_2O(l) \rightarrow 2NaOH(aq) + Cl_2(g) + H_2(g)$
2. **Bleaching powder formation:** $Ca(OH)_2 + Cl_2 \rightarrow Ca(ClO)_2 + H_2O$
3. **Baking soda preparation:** $NaCl + H_2O + CO_2 + NH_3 \rightarrow NH_4Cl + NaHCO_3$
4. **Plaster of Paris:** $CaSO_4.2H_2O \rightarrow CaSO_4.\frac{1}{2}H_2O + 1\frac{1}{2}H_2O$

pH Relationships:

- **$[H^+]$ increases → pH decreases (more acidic)**
- **$[OH^-]$ increases → pH increases (more basic)**
- **At pH 7:** $[H^+] = [OH^-]$ (neutral)

2.13 Memory Aids and Tips

Indicator Color Memory:

- **Litmus:** "Red Acid, Blue Base"
- **Phenolphthalein:** "Pink in Base, Clear in Acid"
- **Methyl Orange:** "Red in Acid, Yellow in Base"

pH Scale Memory:

- **0-6:** Acidic (lower = stronger acid)
- **7:** Neutral (pure water)
- **8-14:** Basic (higher = stronger base)

Safety Rules:

- **"Acid to Water"** - never reverse
- **Test gases carefully** - hydrogen pops, CO_2 extinguishes flame

- **Handle with care** - acids and bases can cause burns

2.14 Real-Life Applications

Household Uses:

- **Vinegar (acetic acid):** Food preservation, cleaning
- **Baking soda:** Cooking, antacid, cleaning, fire extinguisher
- **Washing soda:** Cleaning, water softening
- **Lime water:** Testing CO_2, whitewashing

Industrial Uses:

- **Sulphuric acid:** Battery acid, fertilizer production
- **Sodium hydroxide:** Soap making, paper industry
- **Hydrochloric acid:** Metal cleaning, pH control

Medical Uses:

- **Antacids:** Stomach acid neutralization
- **Plaster of Paris:** Bone fracture treatment
- **pH monitoring:** Blood, urine analysis

Chapter Summary

Acids and bases are fundamental chemical substances that play crucial roles in our daily lives. Acids produce H^+ ions in water and have sour taste, while bases produce OH^- ions and have bitter taste. The pH scale quantifies their strength from 0-14.

Chemical reactions of acids and bases follow predictable patterns, producing salts and other useful compounds. Common salt ($NaCl$) serves as raw material for many important chemicals including sodium hydroxide, bleaching powder, baking soda, and washing soda.

Understanding acid-base chemistry helps explain biological processes, environmental phenomena, and industrial applications. Proper handling and safety measures are essential when working with these substances.

The concept of neutralization explains how acids and bases cancel each other's effects, forming salts and water. This principle is applied in medicine (antacids), agriculture (soil treatment), and industry (waste neutralization).

Study Strategy:

- Practice identifying acid-base reactions
- Memorize pH values of common substances
- Understand the connection between ion concentration and pH
- Focus on practical applications in daily life
- Learn safety protocols for handling acids and bases

Source: NCERT Science Textbook
Comprehensive notes for effective exam preparation