

Carbon and its Compounds

Comprehensive Study Notes for RBSE Class 10 Science Chapter 4

Exam-Oriented with Key Concepts, Questions, and Solutions

1. BONDING IN CARBON: THE COVALENT BOND

1.1 Why Carbon Forms Covalent Bonds

Carbon has atomic number 6 with electronic configuration: 2, 4

- **Valence electrons:** 4 electrons in outermost shell
- **To attain noble gas configuration:** Needs to gain or lose 4 electrons
- **Problem:** Cannot lose 4 electrons (requires huge energy) or gain 4 electrons (nucleus cannot hold extra electrons)
- **Solution:** Shares valence electrons with other atoms

Key Concept:

The electrons shared belong to the outermost shells of both atoms, allowing both to attain noble gas configuration.

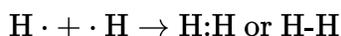
1.2 Definition of Covalent Bond

A covalent bond is formed by the sharing of one or more pairs of electrons between two atoms, allowing both atoms to achieve a stable electron configuration.

1.3 Types of Covalent Bonds

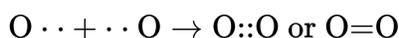
Single Covalent Bond (Single Bond)

- One pair of shared electrons
- Example: H₂, Cl₂, CH₄
- **Hydrogen molecule:**



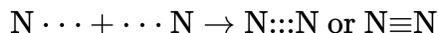
Double Covalent Bond (Double Bond)

- Two pairs of shared electrons
- Example: O₂, C=C in alkenes
- **Oxygen molecule:**



Triple Covalent Bond (Triple Bond)

- Three pairs of shared electrons
- Example: N_2 , $C\equiv C$ in alkynes
- **Nitrogen molecule:**



1.4 Properties of Covalent Compounds

Property	Characteristic
Melting Point	Low
Boiling Point	Low
Electrical Conductivity	Poor (non-conductors)
Intermolecular Forces	Weak van der Waals forces
Solubility	Vary (many soluble in organic solvents)

Reason: Electrons are shared between atoms, no ions are formed, so electrical conductivity is poor.

1.5 Examples of Covalent Compounds

Methane (CH_4):

- Carbon (valency = 4) shares electrons with 4 hydrogen atoms (valency = 1 each)
- Structure: All single bonds
- Formula: CH_4

Electron dot structure:



(with H atoms at each position)

2. ALLOTROPES OF CARBON

2.1 Definition

Allotropes are different forms of the same element that differ in their physical properties but have similar chemical properties.

2.2 Main Allotropes of Carbon

Diamond

- **Structure:** Each carbon atom bonded to 4 other carbon atoms in a rigid 3D tetrahedral structure
- **Bonding:** All single bonds (sp^3 hybridization)
- **Physical Properties:**
 - Hardest natural substance
 - Transparent and colorless
 - High density
 - Poor conductor of electricity
 - High melting point (3823°C)
- **Uses:** Cutting tools, drilling, jewelry, industrial applications
- **Occurrence:** Natural deposits in South Africa, Russia; synthetic diamonds now manufactured

Graphite

- **Structure:** Each carbon atom bonded to 3 other carbon atoms in the same plane forming hexagonal layers
- **Bonding:** One C=C double bond and two C-C single bonds per atom (sp^2 hybridization)
- **Physical Properties:**
 - Soft and slippery
 - Black, opaque, metallic luster
 - Good conductor of electricity (delocalized electrons)
 - Lower density than diamond
 - High melting point (3650°C)
- **Uses:** Pencil leads, lubricants, electrodes, crucibles, brushes in motors
- **Reason for conductivity:** Delocalized π electrons in the layers can move freely

Fullerenes

- **Structure:** Carbon atoms arranged in spherical or ellipsoidal shapes
- **Examples:**
 - C_{60} (Buckminsterfullerene or buckyballs): 60 carbon atoms arranged like a soccer ball
 - C_{70} , C_{84} also known
- **Discovery:** Named after architect Buckminster Fuller (geodesic dome design)
- **Properties:** Cage-like structure with unusual stability
- **Uses:** Research, potential medical applications, semiconductors

2.3 Comparison Table: Diamond vs Graphite

Property	Diamond	Graphite
Bonding	4 single bonds (sp ³)	3 bonds in plane + delocalized electrons
Structure	3D rigid tetrahedral	2D layered hexagonal
Hardness	Very hard	Soft and slippery
Density	Higher	Lower
Electrical Conductivity	Non-conductor	Conductor
Transparency	Transparent	Opaque
Melting Point	3823°C	3650°C
Uses	Jewelry, cutting	Pencils, lubricants

3. VERSATILE NATURE OF CARBON

3.1 Two Key Properties Making Carbon Versatile

Property 1: Catenation

- **Definition:** The ability of carbon atoms to bond with other carbon atoms to form long chains, branched chains, and rings.
- **Uniqueness:** Carbon exhibits catenation to an unparalleled extent.
- **Reasons for strong C-C bonds:**
 - Small size of carbon atom
 - Small size enables nucleus to hold shared electron pairs strongly
 - Carbon-carbon bond is very strong and stable
- **Comparison:** Silicon forms C-Si chains up to 7-8 atoms but these are highly reactive.

Property 2: Tetravalency

- **Definition:** Carbon has a valency of 4 (can form 4 covalent bonds).
- **Significance:** Carbon can bond with:
 - Other carbon atoms (C-C)
 - Hydrogen atoms (C-H)
 - Oxygen atoms (C=O, C-O)
 - Nitrogen atoms (C-N)
 - Halogen atoms (C-F, C-Cl, C-Br)
 - Sulfur atoms (C-S)
 - And other elements

3.2 Result of These Properties

Millions of carbon compounds exist, outnumbering all other elements' compounds combined.

3.3 Why Other Elements Don't Show Catenation Like Carbon

- **Oxygen (O):** Can form at most 2 bonds with itself; not strong enough chains
- **Nitrogen (N):** Can form at most 1 triple bond; not suitable for chain formation
- **Sulfur (S):** Forms weaker S-S bonds compared to C-C
- **Silicon (Si):** Forms Si-Si bonds but these are weaker and reactive; Si-O bonds are preferred

4. SATURATED AND UNSATURATED CARBON COMPOUNDS

4.1 Saturated Hydrocarbons (Alkanes)

Definition

Carbon compounds containing only single bonds between carbon atoms and hydrogen.

General Formula: C_nH_{2n+2}

Characteristics

- **Bonding:** All single bonds
- **Reactivity:** Low reactivity
- **Flame:** Generally give clean, blue flame with complete combustion
- **Oxidation:** Complete oxidation gives CO_2 and H_2O

Examples with Structures

Name	Formula	Structure
Methane	CH_4	H-C-H (with H above and below)
Ethane	C_2H_6	H-C-C-H
Propane	C_3H_8	H-C-C-C-H
Butane	C_4H_{10}	H-C-C-C-C-H

Structural Isomers in Butane:

- **n-Butane:** H-C-C-C-C-H (straight chain)
- **Isobutane (2-methylpropane):** Branched structure with C-C(C)-C arrangement

Both have formula C_4H_{10} but different structures → Structural isomers

4.2 Unsaturated Hydrocarbons

Alkenes (Contain C=C)

Definition: Carbon compounds with one or more double bonds between carbon atoms.

General Formula: C_nH_{2n}

Examples:

- Ethene (C_2H_4): $H_2C=CH_2$
- Propene (C_3H_6): $H_2C=CH-CH_3$
- Butene (C_4H_8): Various isomers possible

Characteristics:

- More reactive than alkanes
- Give yellow sooty flame due to incomplete combustion
- Undergo addition reactions readily

Alkynes (Contain $C\equiv C$)

Definition: Carbon compounds with one or more triple bonds between carbon atoms.

General Formula: C_nH_{2n-2}

Examples:

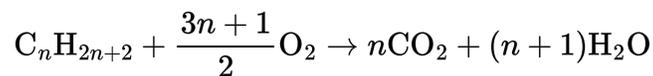
- Ethyne/Acetylene (C_2H_2): $H-C\equiv C-H$
- Propyne (C_3H_4): $H_3C-C\equiv C-H$

Characteristics:

- Most reactive among hydrocarbons
- Used in welding (acetylene-oxygen flame)
- Undergo addition reactions

4.3 Complete Combustion Comparison

Saturated Hydrocarbons:



Unsaturated Hydrocarbons:

- Same products but give yellow sooty flame
 - Indicates carbon (soot) formation from incomplete combustion
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5. STRUCTURAL ISOMERISM

5.1 Definition

Compounds with the same molecular formula but different structural arrangements of atoms.

5.2 Types of Structural Isomerism

Chain Isomerism

- Different arrangements of carbon chain (straight vs. branched)
- Example: n-Butane vs. Isobutane (both C_4H_{10})

Position Isomerism

- Functional group at different positions
- Example: 1-Butene ($H_2C=CH-CH_2-CH_3$) vs. 2-Butene ($CH_3-CH=CH-CH_3$)

Functional Group Isomerism

- Different functional groups
- Example: Ethanol (C_2H_5OH) vs. Dimethyl ether (CH_3-O-CH_3), both C_2H_6O

5.3 Importance in Exam

Students should be able to:

- Draw structures of structural isomers
- Distinguish between isomers
- Calculate number of isomers for given formula

6. CARBON CHAINS: STRAIGHT, BRANCHED, AND RINGS

6.1 Straight Chain Hydrocarbons

- Carbon atoms arranged in a linear sequence
- Examples: Methane, Ethane, Propane, Butane, Pentane, Hexane
- Follow general formulas: C_nH_{2n+2} (alkanes)

6.2 Branched Chain Hydrocarbons

- Carbon atoms with side branches
- Example: 2-methylpropane (isobutane)
- Same molecular formula but different structure than straight chain

6.3 Cyclic/Ring Compounds

Cycloalkanes

- Carbon atoms arranged in rings with only single bonds
- Example: Cyclohexane (C₆H₁₂)
- Formula: C_nH_{2n} (same as alkenes but no double bond)

Aromatic Compounds

- Benzene (C₆H₆) most important aromatic compound
- Hexagonal ring with alternating single and double bonds (resonance)
- Highly stable due to delocalized electron system
- Shows characteristic aroma
- Used in explosives, pharmaceuticals, dyes

Benzene structure: Hexagonal ring with H atoms at each vertex

7. FUNCTIONAL GROUPS

7.1 Definition

Atoms or groups of atoms responsible for characteristic properties of organic compounds, regardless of carbon chain length.

7.2 Common Functional Groups

Functional Group	General Formula	Class	Suffix/Prefix
Alkyl Halide	R-X (X=F, Cl, Br, I)	Haloalkane	-Bromo, -Chloro
Alcohol	R-OH	Alcohol	-ol
Aldehyde	R-CHO	Aldehyde	-al
Ketone	R-CO-R'	Ketone	-one
Carboxylic Acid	R-COOH	Carboxylic Acid	-oic acid
Ester	R-COO-R'	Ester	-oate
Amine	R-NH ₂	Amine	-amine

7.3 Key Functional Groups Details

Alcohol (-OH)

- Contains hydroxyl group bonded to carbon
- Examples: Methanol (CH₃OH), Ethanol (C₂H₅OH), Propanol (C₃H₇OH)
- Characteristics: Polar, soluble in water

Aldehyde (-CHO)

- Contains carbonyl group (C=O) at terminal carbon
- Examples: Methanal (HCHO), Ethanal (CH₃CHO)
- Characteristics: Easily oxidized, pungent odor

Ketone (R-CO-R')

- Contains carbonyl group (C=O) between two carbons
- Example: Propanone (CH₃-CO-CH₃) - acetone
- Characteristics: Less reactive than aldehydes

Carboxylic Acid (-COOH)

- Contains carboxyl group (COOH)
 - Examples: Methanoic acid (HCOOH), Ethanoic acid (CH₃COOH)
 - Characteristics: Weak acids, sour taste
-

8. HOMOLOGOUS SERIES

8.1 Definition

A series of compounds with:

- Same functional group
- Differing by one or more CH₂ units
- Similar chemical properties
- Gradual variation in physical properties

8.2 Characteristics of Homologous Series

1. **Molecular Formula:** Successive members differ by CH₂
 - Example: CH₄, C₂H₆, C₃H₈, C₄H₁₀ (differ by CH₂ each time)
2. **Molecular Mass:** Increases by 14 units (mass of CH₂)
3. **Chemical Properties:** Same functional group → similar reactions
4. **Physical Properties:** Show gradual variation
 - Melting points increase
 - Boiling points increase
 - Density increases
 - Solubility in water decreases
5. **Preparation:** Members can be prepared by similar methods

8.3 Examples of Homologous Series

Alkane Series (C_nH_{2n+2})

Member	Formula	Molar Mass
Methane	CH ₄	16
Ethane	C ₂ H ₆	30
Propane	C ₃ H ₈	44
Butane	C ₄ H ₁₀	58
Pentane	C ₅ H ₁₂	72

Key observation: Each differs by CH₂ (mass difference = 14)

Alkene Series (C_nH_{2n})

- Ethene: C₂H₄
- Propene: C₃H₆
- Butene: C₄H₈

Alcohol Series (C_nH_{2n+1}OH)

- Methanol: CH₃OH
- Ethanol: C₂H₅OH
- Propanol: C₃H₇OH

9. NOMENCLATURE OF CARBON COMPOUNDS

9.1 IUPAC Naming Rules

Step 1: Identify the Carbon Chain Length

Number of Carbons	Prefix
1	Meth-
2	Eth-
3	Prop-
4	But-
5	Pent-
6	Hex-
7	Hept-
8	Oct-

Step 2: Identify the Functional Group

- **Highest priority** determines suffix or prefix
- Use appropriate suffix/prefix from functional group table

Step 3: Identify Saturation

- **Alkane:** Suffix **-ane** (all single bonds)
- **Alkene:** Replace final 'e' with **-ene** (has double bond)
- **Alkyne:** Replace final 'e' with **-yne** (has triple bond)

Step 4: Naming Rules for Functional Groups

Important Rule: If functional group suffix starts with vowel (a, e, i, o, u), drop final 'e' from carbon chain name.

Examples:

- Propane + ol → Propanol (not propanole)
- Propane + one → Propanone (not propaneone)
- Propane + al → Propanal (not propaneal)

9.2 Examples

Alcohols (Suffix: -ol)

- $\text{CH}_3\text{-CH}_2\text{-OH}$ → **Ethanol** (propane → ethan → ethanol)
- $\text{CH}_3\text{-CH(OH)-CH}_3$ → **Propan-2-ol** or **Isopropanol**

Aldehydes (Suffix: -al)

- H-CHO → **Methanal**
- $\text{CH}_3\text{-CHO}$ → **Ethanal**
- $\text{CH}_3\text{-CH}_2\text{-CHO}$ → **Propanal**

Ketones (Suffix: -one)

- $\text{CH}_3\text{-CO-CH}_3$ → **Propanone** (acetone)
- $\text{CH}_3\text{-CO-CH}_2\text{-CH}_3$ → **Butanone**

Carboxylic Acids (Suffix: -oic acid)

- H-COOH → **Methanoic acid** (formic acid)
- $\text{CH}_3\text{-COOH}$ → **Ethanoic acid** (acetic acid)
- $\text{CH}_3\text{-CH}_2\text{-COOH}$ → **Propanoic acid**

Haloalkanes (Prefix: Chloro-, Bromo-)

- $\text{CH}_3\text{-CH}_2\text{-Cl}$ → **Chloroethane**
 - $\text{CH}_3\text{-CHBr-CH}_3$ → **2-Bromopropane**
 - $\text{Cl-CH}_2\text{-CH}_2\text{-CH}_3$ → **1-Chloropropane**
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10. CHEMICAL PROPERTIES OF CARBON COMPOUNDS

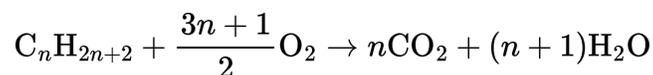
10.1 Combustion

Definition

Burning of carbon compounds in oxygen to produce heat, light, and products (mainly CO₂ and H₂O).

General Equations

Complete Combustion (Sufficient Oxygen):



Examples:

- Methane: $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$
- Ethane: $2C_2H_6 + 7O_2 \rightarrow 4CO_2 + 6H_2O$
- Ethanol: $C_2H_5OH + 3O_2 \rightarrow 2CO_2 + 3H_2O$

Incomplete Combustion (Limited Oxygen):



Products: Carbon monoxide (CO), carbon/soot, and water

Observations

Type of Hydrocarbon	Flame Color	Smoke	Sooty Deposit
Saturated (Alkanes)	Blue (with clean air)	No	No (complete combustion)
Unsaturated (Alkenes)	Yellow	Yes	Yes (carbon/soot)
Limited Air	Yellow/Orange	Yes	Yes

Reasons for Different Flames

- **Blue flame:** Complete combustion, all C converts to CO₂
- **Yellow flame:** Incomplete combustion, some C forms carbon particles
- **Soot/Smoke:** Unburned carbon particles suspended in air

10.2 Oxidation

Definition

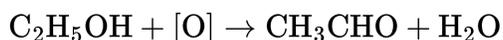
Addition of oxygen or removal of hydrogen from organic compounds.

Types

Mild Oxidation of Alcohols:

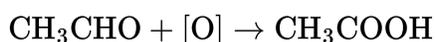
Alcohols can be oxidized to aldehydes or carboxylic acids using oxidizing agents.

Ethanol to Ethanal (Aldehyde):

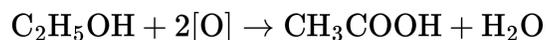


(Using: Hot copper surface, or Acidified $\text{K}_2\text{Cr}_2\text{O}_7$ carefully)

Ethanal to Ethanoic Acid (Carboxylic Acid):



Or directly:



(Using: Alkaline KMnO_4 with heat, or Acidified $\text{K}_2\text{Cr}_2\text{O}_7$ with heat)

Oxidizing Agents

- **Alkaline Potassium Permanganate (KMnO_4):** Purple color
- **Acidified Potassium Dichromate ($\text{K}_2\text{Cr}_2\text{O}_7$):** Orange color

Observation in Experiment:

1. Add oxidizing agent drop by drop
2. Initially, color persists (being used up)
3. When color doesn't disappear → oxidation complete

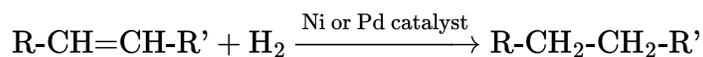
10.3 Addition Reactions

Definition

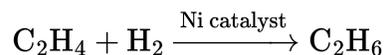
Unsaturated compounds add atoms/groups across double or triple bonds to become saturated.

Hydrogenation of Unsaturated Compounds

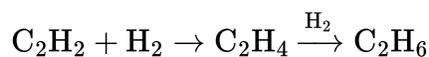
Alkene + H_2 :



Example - Ethene to Ethane:



Example - Ethyne to Ethene to Ethane:

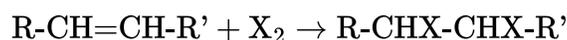


Industrial Application: Vegetable Oil Hydrogenation

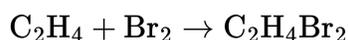
- **Vegetable oils:** Long unsaturated carbon chains (liquid at room temp)
- **Animal fats:** Long saturated carbon chains (solid at room temp)
- **Purpose:** Convert liquid oils to semi-solid fats for margarine, shortening
- **Catalyst:** Nickel (Ni)
- **Process:** Oil + H₂ with Ni catalyst heated → Solid fat
- **Health aspect:** Saturated fats considered less healthy; unsaturated fats preferred

Addition with Halogens (Cl₂, Br₂)

Alkene + Halogen:



Example - Ethene + Bromine:



(1,2-dibromoethane)

Brown bromine solution decolorizes → Test for unsaturation

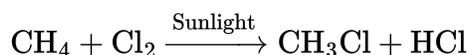
10.4 Substitution Reactions

Definition

One atom or group is replaced by another atom or group in a molecule.

Halogenation of Alkanes

Mechanism: Free radical substitution in presence of sunlight (UV light)

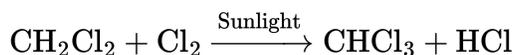


(Chloromethane)

Further substitution possible:



(Dichloromethane)



(Chloroform)



(Carbon tetrachloride)

Key Characteristics

- Requires sunlight (UV radiation)
 - Saturated hydrocarbons undergo substitution (unlike addition)
 - Multiple products formed with higher homologues
 - Slow reaction compared to addition of unsaturated compounds
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11. IMPORTANT CARBON COMPOUNDS

11.1 ETHANOL (C₂H₅OH)

Structure

H-C-C-OH with hydrogens:

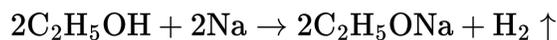


Physical Properties

- **Appearance:** Colorless, volatile liquid
- **Odor:** Pleasant, characteristic
- **Melting point:** 156 K (-117°C)
- **Boiling point:** 351 K (78°C)
- **Solubility:** Completely miscible with water in all proportions
- **Density:** 0.79 g/cm³

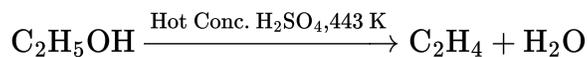
Chemical Properties

1. Reaction with Sodium:



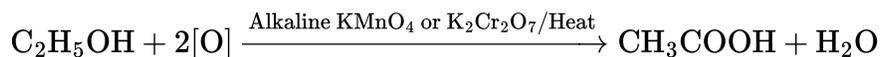
- Sodium ethoxide formed
- Hydrogen gas evolved (can test with burning splint → "pop" sound)
- Vigorous reaction (exothermic)

2. Dehydration to Ethene:



- Concentrated H₂SO₄ acts as dehydrating agent
- Temperature: 443 K (170°C)
- Ethene gas is evolved (colorless, pungent)

3. Oxidation to Ethanoic Acid:



Uses

- Solvent in medicines (tincture iodine, cough syrups, tonics)
- Fuel (cleaner burning, used in some countries as petrol additive)
- Laboratory reagent
- Industrial chemical
- Beverage (alcoholic drinks) - but medically harmful in excess

Health Aspects

- **Small quantities:** Causes intoxication (depresses nervous system)
- **Large quantities:** Affects vital organs, can be lethal
- **Long-term consumption:** Liver damage, brain damage, various health issues
- **Methanol danger:** Extremely toxic - blindness, death even in small amounts
- **Industrial ethanol:** Often made "denatured" (poisoned with methanol and colored) to prevent drinking

Mechanism of alcohol toxicity:

- Depresses central nervous system
- Slows metabolic processes
- Impairs judgment, coordination, timing
- High concentrations → stupor, coma, death

11.2 ETHANOIC ACID / ACETIC ACID (CH₃COOH)

Structure



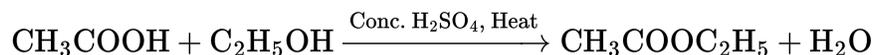
Carboxylic acid functional group (-COOH) bonded to methyl group.

Physical Properties

- **Appearance:** Colorless liquid or white crystalline solid
- **Odor:** Pungent, sour
- **Melting point:** 290 K (17°C) → Often freezes in winter → Called "glacial acetic acid"
- **Boiling point:** 391 K (118°C)
- **Solubility:** Completely miscible with water
- **Strength:** Weak acid (partial ionization unlike HCl)

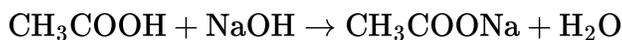
Chemical Properties

1. Reaction with Alcohol - Esterification:



- Produces: Ethyl ethanoate (sweet-smelling ester)
- Catalyst: Concentrated H₂SO₄
- Condition: Heating
- Products: Ester + Water
- Reversible reaction (equilibrium)

2. Reaction with Sodium Hydroxide (Base):



(Sodium ethanoate/sodium acetate)

3. Reaction with Sodium Carbonate:



- CO_2 gas evolved (colorless, odorless)
- Test: Pass through lime-water \rightarrow White precipitate of CaCO_3

4. Reaction with Sodium Bicarbonate:



- Vigorous fizzing
- CO_2 gas evolved

Uses

- **Vinegar:** 5-8% acetic acid solution in water (food preservative, food flavoring)
- **Solvent:** Industrial processes
- **Disinfectant:** Mild antibacterial properties
- **Esterification:** Production of esters (perfumes, flavorings)
- **pH adjustment:** In various industrial processes

Distinguishing Ethanol from Ethanoic Acid

Property	Ethanol	Ethanoic Acid
Odor	Pleasant, sweet	Pungent, vinegar-like
Litmus Paper	No change	Red (acidic)
pH	~7 (neutral)	<7 (acidic)
Na Reaction	Vigorous, H_2 evolved	Vigorous, H_2 evolved
Na_2CO_3	No gas	Effervescence (CO_2)
Universal Indicator	No color change	Orange/Yellow (acidic)

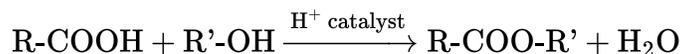
Best test: Add sodium carbonate solution:

- Ethanol: No effervescence
- Ethanoic acid: Vigorous fizzing with CO_2 evolution

12. ESTERS AND ESTERIFICATION

12.1 Definition of Esters

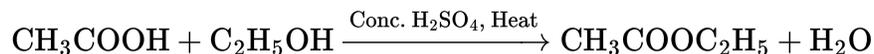
Organic compounds formed by reaction of a carboxylic acid and an alcohol in presence of an acid catalyst.



(Carboxylic acid) + (Alcohol) → (Ester) + (Water)

12.2 Esterification Reaction

Example: Formation of Ethyl Ethanoate



Conditions Required

1. **Catalyst:** Concentrated H_2SO_4 (absorbs water, shifts equilibrium)
2. **Heat:** Warm in water bath (usually $50\text{-}70^\circ\text{C}$)
3. **Time:** Several minutes of heating

Observations in Lab

- Characteristic fruity/pleasant smell develops
- Oily droplets visible
- Mixture becomes warm (exothermic)

12.3 Properties of Esters

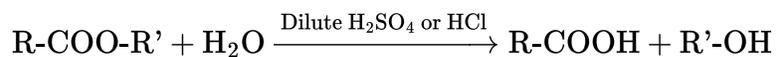
- **Appearance:** Colorless liquids or solids
- **Odor:** Sweet, fruity, pleasant (characteristic)
- **Solubility:** Generally insoluble in water (unlike acids/alcohols)
- **Boiling point:** Lower than corresponding acids and alcohols
- **Flammability:** Flammable
- **Reactivity:** Undergo hydrolysis (reverse of esterification)

12.4 Uses of Esters

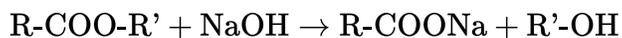
- **Perfumes:** Natural and synthetic fragrances
- **Flavorings:** Fruit flavors in candies, ice cream, drinks
- **Solvents:** Industrial applications
- **Plasticizers:** In polymers
- **Oils and fats:** Triglycerides are esters of glycerol and fatty acids

12.5 Hydrolysis of Esters (Reverse Reaction)

Acid Hydrolysis



Alkaline Hydrolysis (Saponification)



Important Note: This reaction is irreversible (unlike acid hydrolysis).

Product: Sodium salt of carboxylic acid (salt) + Alcohol

13. SOAPS AND DETERGENTS

13.1 Soaps

Definition

Sodium or potassium salts of long-chain fatty acids (long-chain carboxylic acids).

Structure of Soap



(Example: Sodium stearate)

Key Structural Feature

Soap molecules are **amphipathic** (dual nature):

Part	Nature	Property
Long hydrocarbon chain ($C_{17}H_{35}$)	Hydrophobic	Repels water, attracts oil/grease
Ionic head (-COONa or -COOK)	Hydrophilic	Attracted to water, repels oil

Mechanism of Soap Action

1. Micelle Formation in Water:

When soap dissolves in water:

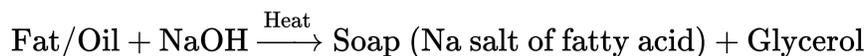
- Hydrophobic tails cluster together (away from water)
- Hydrophilic heads face outward (toward water)
- Forms spherical structure = **Micelle**

2. Cleaning Mechanism:

- Oil/grease molecules are hydrophobic
- Soap micelles surround oil droplets
- Hydrophobic tails interact with oil
- Hydrophilic heads interact with water
- Forms stable **emulsion** in water
- Oil can then be rinsed away

Chemical Reaction

Formation of soap from fat (triglyceride) and alkali:



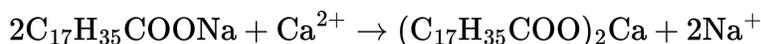
(Triglyceride) + (Sodium hydroxide) → (Soap) + (Glycerol)

Problem with Soap in Hard Water

Hard Water Composition:

- Contains Ca^{2+} and Mg^{2+} ions
- From dissolved calcium and magnesium salts

Reaction of Soap with Hard Water:



Products:

- Insoluble calcium salt (white curdy precipitate)
- Sodium salt remains in solution

Consequences:

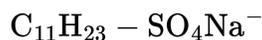
- White scum formation
- Soap wasted (forms precipitate)
- Less foam production
- Requires more soap for cleaning

13.2 Detergents

Definition

Synthetic cleaning agents, generally sodium salts of sulphonic acids or ammonium salts with halides.

General Structure



Or: Long hydrocarbon chain + Ionic head group

Advantages over Soap

Property	Soap	Detergent
Hard Water	Forms precipitate ✗	No precipitate ✓
Efficiency	Reduced in hard water	Works equally well
Cleaning	Good	Excellent
Cost	Cheaper	More expensive
Biodegradability	Easily biodegradable	Some persist in environment
pH Range	Works best in neutral	Works in acidic/alkaline

Mechanism of Detergent Action

Same as soap:

- Forms micelles
- Hydrophobic tails interact with oil
- Hydrophilic heads interact with water
- Creates emulsion

Key Difference from Soap

The ionic end of detergent does NOT form insoluble salts with Ca^{2+} and Mg^{2+} ions.

- Therefore, detergent works effectively in hard water
- No scum formation
- No wasting of detergent

Uses of Detergents

- **Shampoos:** Hair washing
- **Laundry detergents:** Clothes washing
- **Dish soap:** Dishwashing
- **Industrial cleaners:** Degreasing

Environmental Concern

- Early detergents were non-biodegradable
 - Accumulated in environment
 - Modern detergents are "biodegradable" (breakdown by bacteria)
 - Still some persistence issues
-

14. FOSSIL FUELS

14.1 Definition and Importance

Fossil fuels are energy sources formed from remains of dead organisms (plants and animals) that lived millions of years ago.

Importance:

- Primary source of energy for civilization
- Raw materials for chemicals and polymers
- Non-renewable resources (on human timescale)

14.2 Coal

Formation

- Remains of trees, ferns, plants that lived 300+ million years ago
- Buried under layers of earth/rock by earthquakes, volcanoes
- Subjected to:
 - High pressure
 - High temperature (geothermal)
 - Microbial decay
- Gradually converted to coal over geological time

Composition

- Carbon (60-90%)
- Hydrogen, Oxygen, Nitrogen, Sulfur
- Ash (mineral impurities)

Properties

- Black, solid at room temperature
- Hard, brittle
- Low thermal conductivity
- Good fuel (releases large energy on burning)

Types of Coal (By rank)

Type	Carbon %	Heat Value	Age
Lignite	60-75%	Lowest	Youngest
Bituminous	75-85%	High	-
Anthracite	85-95%	Highest	Oldest

Environmental Issues

- Sulfur impurities → SO₂ pollution
- Nitrogen impurities → NO_x pollution
- CO₂ emissions → Climate change

14.3 Petroleum (Crude Oil)

Formation

- Remains of tiny marine plants (algae) and animals (zooplankton)
- Lived millions of years ago in ancient seas
- When died, settled on sea floor
- Covered by silt/mud
- Bacteria decomposed organic matter under:
 - High pressure
 - High temperature
 - Anaerobic conditions (no oxygen)
- Converted to crude oil (hydrocarbons)
- Silt compressed into rock layers → Oil trapped in porous rock

Composition

- Complex mixture of hydrocarbons
- Mainly alkanes (C₁ to C₃₀₊)
- Small amounts of sulfur, nitrogen, oxygen compounds

Properties

- Viscous liquid
- Dark brown to black color
- Flammable
- Insoluble in water, soluble in organic solvents

Fractional Distillation

Crude oil separated into fractions by boiling point:

Fraction	Boiling Range	Molecules	Uses
Petroleum Gas	<40°C	C ₁ -C ₄	Fuel, LPG
Petrol/Gasoline	40-200°C	C ₅ -C ₁₀	Car fuel
Kerosene	150-300°C	C ₁₀ -C ₁₆	Aircraft fuel, heating
Diesel	250-350°C	C ₁₆ -C ₂₀	Diesel engines
Fuel Oil	>350°C	C ₂₀ ⁺	Ship fuel, heating
Bitumen	Residue	Very long chains	Road construction

Environmental Issues

- CO₂ emissions → Global warming
- Oil spills → Marine ecosystem damage
- Extraction → Habitat destruction
- Non-renewable resource

14.4 Natural Gas

Composition

- Primarily methane (CH₄)
- Also ethane (C₂H₆), propane (C₃H₈)
- Found with petroleum deposits

Properties

- Colorless, odorless gas
- Lighter than air
- Highly flammable
- Cleanest burning fossil fuel (produces only CO₂ and H₂O)

Uses

- Domestic heating
- Cooking fuel
- Compressed Natural Gas (CNG) for vehicles
- Industrial processes
- Power generation

Advantages

- Cleaner than coal or petroleum
 - Efficient
 - Easily transported via pipelines
-

15. COMBUSTION AND ENERGY

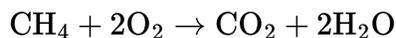
15.1 Complete Combustion

All hydrocarbons burn in excess oxygen to give CO₂ and H₂O with release of heat and light.

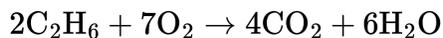


Examples

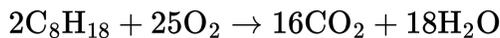
Methane:



Ethane:



Octane (in petrol):



15.2 Incomplete Combustion

With limited oxygen supply:



Products: Carbon monoxide (toxic), carbon (soot), water

Why it occurs:

- Insufficient oxygen for complete combustion
- Temperature too low
- Blocked air holes in burner/stove

15.3 Flame Types

Flame Type	Conditions	Color	Products	Emissions
Blue flame	Complete combustion, clean air	Blue	CO ₂ + H ₂ O	Clean
Yellow flame	Incomplete combustion, more soot	Yellow	CO + C + H ₂ O	Smoky
Luminous flame	Carbon particles glow from heat	Yellow-orange	Mixture	Sooty

15.4 Why Substances Burn

Flame burning requires:

1. **Heat:** Ignition temperature reached
2. **Fuel:** Hydrocarbon or other combustible substance
3. **Oxygen:** From air or supplied

Glowing (without flame):

- Charcoal, coal glow red in angithi
- No flame produced
- Gaseous substances produce flames (glowing particles in gas)
- Solid/liquid combustion may or may not produce flame

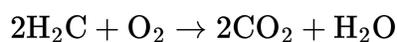
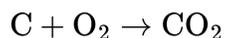
Luminous flame characteristic:

- Caused by incandescent carbon particles
- Each element produces characteristic color when heated
- Copper → Green/Blue flame
- Sodium → Yellow flame
- Carbon → Yellow/orange (soot particles)

16. CARBON DIOXIDE: COMBUSTION PRODUCT AND TEST

16.1 Formation

Carbon compounds burn in oxygen to produce CO₂:



16.2 Test for Carbon Dioxide

Reagent: Freshly prepared lime-water [$\text{Ca}(\text{OH})_2$]

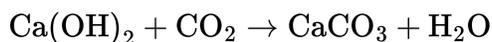
Procedure:

1. Pass gas through lime-water
2. Observe change

Result if CO_2 present:

- Lime-water turns **white/milky** (turbid)
- White precipitate forms

Chemical reaction:



(Colorless) + (Colorless) → (White precipitate) + (Water)

Further observation:

- If excess CO_2 passed: White precipitate dissolves
- Becomes clear again (forms soluble calcium bicarbonate)



(White) → (Soluble, colorless)

17. EXAM-IMPORTANT QUESTIONS AND ANSWERS

Question 1: Difference Between Ethanol and Ethanoic Acid

Question: How would you distinguish experimentally between an alcohol and a carboxylic acid?

Answer:

Test	Ethanol	Ethanoic Acid
Litmus Paper	No change (neutral)	Red litmus remains red; Blue litmus turns red
Universal Indicator	Green/Yellow (pH~7)	Orange/Red (pH<7)
Sodium Carbonate/NaHCO₃	No effervescence	Vigorous fizzing, CO ₂ gas produced
Odor	Pleasant, sweet	Pungent, vinegar-like
pH Measurement	~7	<7 (acidic)

Best test: Add sodium carbonate solution

- Ethanol: No gas evolution
- Ethanoic acid: Effervescence (CO₂ bubbles)

Equation for acid:



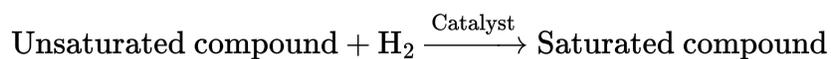
Question 2: Hydrogenation of Unsaturated Compounds

Question: What is hydrogenation? What is its industrial application?

Answer:

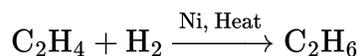
Definition: Hydrogenation is the addition of hydrogen gas to unsaturated compounds (containing C=C or C≡C) in presence of a catalyst to form saturated compounds.

General reaction:



Catalyst used: Nickel (Ni), Palladium (Pd), or Platinum (Pt)

Example - Ethene to Ethane:



Industrial Application: Vegetable Oil Hydrogenation

Process:

- Vegetable oils contain long unsaturated fatty acid chains
- Oil + H₂ with Ni catalyst at high temperature and pressure

- Produces semi-solid fats (margarines, shortenings)

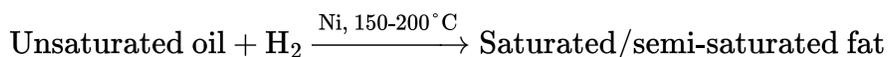
Advantages:

- Increases shelf life (more stable, resists rancidity)
- Changes consistency (liquid → semi-solid)
- Preserves food better

Health consideration:

- Some unsaturated fats are healthier than fully saturated fats
- Excessive hydrogenation creates "trans fats" (unhealthy)
- Modern practice: Balance between preservation and health

Overall reaction with natural oils:



Question 3: Testing for Saturation and Unsaturation

Question: Give a test that can be used to differentiate between saturated and unsaturated hydrocarbons.

Answer:

Test 1: Bromine Water (Most Common)

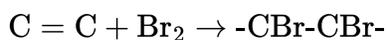
Procedure:

1. Take sample of hydrocarbon in test tube
2. Add bromine water (orange-brown color)
3. Shake well and observe

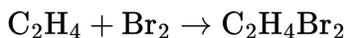
Results:

Hydrocarb on Type	Observation	Reason
Saturated	No decolorization, remains orange-brown	No C=C, no addition reaction with Br ₂
Unsaturate d	Brown color fades, becomes colorless	C=C reacts with Br ₂ , forms colorless dibromide

Chemical reaction (unsaturated):



Example:



(Ethene) (Brown) → (Colorless)

Test 2: Alkaline KMnO_4 Solution

Procedure:

1. Add dilute alkaline KMnO_4 to hydrocarbon sample
2. Shake and observe

Results:

- **Saturated:** Purple color persists (no reaction)
- **Unsaturated:** Purple color disappears, becomes colorless (oxidized)

Why: Unsaturated compounds are easily oxidized by KMnO_4 .

Test 3: Flame Test

Observations:

- **Saturated hydrocarbons:** Blue flame, no smoke
- **Unsaturated hydrocarbons:** Yellow sooty flame with smoke

Why: Incomplete combustion produces carbon (soot) in unsaturated compounds.

Question 4: Formation of Coal and Petroleum

Question: Explain how coal and petroleum were formed.

Answer:

Coal Formation:

Source: Remains of ancient vegetation (trees, ferns, plants) that lived 300-400 million years ago in vast swamps.

Process:

1. When plants died, they fell into swamps (anaerobic environment)
2. Covered by sediment, soil, and mud
3. Layers of earth and rock accumulated above (from earthquakes, upheavals)
4. Heat and pressure increased with depth
5. Bacteria decomposed organic matter over millions of years
6. Gradually transformed into coal

Conditions: High temperature, high pressure, no oxygen, time (millions of years)

Result: Black solid fuel containing 60-90% carbon

Petroleum Formation:

Source: Remains of tiny marine organisms - algae (phytoplankton) and zooplankton that lived in ancient seas 300+ million years ago.

Process:

1. When organisms died, they sank to sea floor
2. Covered by silt and mud (sediment)

3. Silt compressed into rock layers over time
4. Heat and pressure increased with depth
5. Bacteria decomposed organic matter (anaerobic conditions - important)
6. Transformed into crude oil (mixture of hydrocarbons)
7. Oil seeped into porous rocks, trapped like water in sponge

Conditions: High temperature, high pressure, no oxygen (anaerobic), time, bacterial action

Result: Viscous liquid of hydrocarbons (complex mixture of C_nH_{2m} compounds)

Why called "Fossil Fuels"?

- Formed from fossilized remains of living organisms
- Represent accumulated energy from ancient sunlight
- Non-renewable on human timescale (take millions of years to form)

Question 5: Mechanism of Soap Action

Question: Explain the mechanism of the cleaning action of soaps.

Answer:

Structure of Soap:

Soap is sodium or potassium salt of long-chain carboxylic acid.

Example: Sodium stearate: $C_{17}H_{35}-COONa$

Key Feature: Amphipathic molecule (two different regions):

- **Long hydrocarbon tail** ($C_{17}H_{35}$): Hydrophobic (water-repelling, grease-loving)
- **Ionic head** ($-COO^-Na^+$): Hydrophilic (water-loving, grease-repelling)

Mechanism of Cleaning:

Step 1: Micelle Formation in Water

When soap is dissolved in water:

- Soap molecules orient themselves at water surface and in bulk water
- Hydrophobic tails (water-repelling) cluster together in the interior
- Hydrophilic heads (water-loving) face outward toward water
- Forms spherical structure = **Micelle**

Structure:

(Head)

↓

O-Na O-Na O-Na

↑ ↑ ↑

[Aqueous environment]

↓ ↓ ↓

****Step 2: Trapping Oily Dirt****

- Oily dirt (hydrophobic) is insoluble in water
- Soap micelles surround the oil droplet
- Hydrophobic tails (also hydrophobic) penetrate into oil droplet
- Forms stable association: Oil droplet in micelle center

****Step 3: Emulsion Formation****

- Multiple micelles surround separate oil droplets
- Hydrophilic heads face water, repel each other (ion-ion repulsion)
- Prevents micelles from aggregating together
- Forms stable ****emulsion**** (oil suspended in water)

****Step 4: Rinsing Away****

- Emulsified oil droplets easily rinsed away with water
- Water can now contact oily surface (due to micelle coating)

****Overall Effect:****

Soap acts as a "bridge" between water and oil, allowing water to wet oily surface

Question 6: Why Soaps Don't Work Well in Hard Water

****Question:**** Explain the formation of scum when hard water is treated with

****Answer:****

****Hard Water Composition:****

Hard water contains dissolved salts of calcium and magnesium:

- Calcium ions (Ca^{2+})
- Magnesium ions (Mg^{2+})

Causes:

- Calcium carbonate/bicarbonate from limestone
- Magnesium salts from mineral deposits

Reaction of Soap with Hard Water:

Soap in hard water undergoes precipitation reaction:



(Soluble sodium salt) + (Ca²⁺ ions) → (Insoluble calcium salt) + (Na⁺)



Product: Insoluble calcium stearate/magnesium stearate

Observations:

1. **White curdy precipitate** forms (scum)

- Settles as sticky residue
- Deposits on clothes, bathtub

2. **Reduced cleaning power**

- Soap converted to insoluble salt
- Less free soap available for cleaning
- Requires more soap than in soft water

3. **Poor lather formation**

- Less foam produced
- Micelles cannot form effectively

Solutions:

1. **Use more soap** - Compensates for loss to precipitation

2. **Soften water first** - Remove Ca²⁺ and Mg²⁺ using ion exchange

3. **Use detergents** - Ionic head doesn't form precipitate with Ca²⁺/Mg²⁺

- Detergent = $\text{R-SO}_4^- \text{Na}^+$ (sulphonic acid salt)
- Calcium and magnesium sulphonates are slightly soluble → Don't form visible precipitate
- Works effectively in hard water

Question 7: Esterification and Saponification

Question: Write equations for esterification and saponification reactions. [10 marks]

Answer:

Esterification (Forward Reaction):

Formation of ester from carboxylic acid and alcohol:



Specific Example:



(Ethanoic acid) + (Ethanol) → (Ethyl ethanoate) + (Water)

Conditions:

- Catalyst: Concentrated H_2SO_4
- Heat: $50-70^\circ\text{C}$ (water bath heating)
- Reversible equilibrium reaction

Saponification (Reverse Reaction):

Hydrolysis of ester using alkali (base):



(Ester) + (Alkali) → (Sodium salt/Soap) + (Alcohol)

Specific Example:



(Ethyl ethanoate) + (NaOH) → (Sodium ethanoate/Salt) + (Ethanol)

****In soap making from fats:****

$\text{Fat/Oil} + \text{NaOH} \xrightarrow{\text{Heat}} \text{Soap (Na salt of fat)}$

****Relationship:****

- ****Esterification:**** Synthesis of ester (Reversible)
- ****Saponification:**** Breaking of ester with alkali (Irreversible)
- ****Reverse reactions:**** Acid hydrolysis reverses esterification; alkaline hydrolysis reverses saponification

****Differences:****

Property	Acid Hydrolysis	Saponification
Conditions	Dilute H ₂ SO ₄ , heat	NaOH, heat
Products	Carboxylic acid + Alcohol	Salt + Alcohol
Reversibility	Reversible	Irreversible
Purpose	Lab synthesis	Industrial soap production

18. KEY FORMULAE AND EQUATIONS SUMMARY

Combustion Reactions

- $\text{CH}_4 + 2\text{O}_2 \rightarrow \text{CO}_2 + 2\text{H}_2\text{O}$
- $2\text{C}_2\text{H}_6 + 7\text{O}_2 \rightarrow 4\text{CO}_2 + 6\text{H}_2\text{O}$
- $\text{C}_2\text{H}_5\text{OH} + 3\text{O}_2 \rightarrow 2\text{CO}_2 + 3\text{H}_2\text{O}$

Oxidation Reactions

- $\text{C}_2\text{H}_5\text{OH} + 2[\text{O}] \rightarrow \text{C}_2\text{H}_3\text{COOH}$
- $\text{C}_2\text{H}_5\text{CHO} + [\text{O}] \rightarrow \text{C}_2\text{H}_3\text{COOH}$

Dehydration

- $\text{C}_2\text{H}_5\text{OH} \xrightarrow{\text{Hot Conc. H}_2\text{SO}_4} \text{C}_2\text{H}_4 + \text{H}_2\text{O}$

Addition Reactions

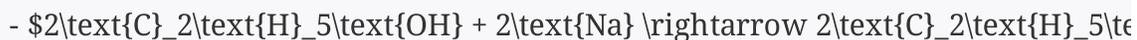
- $\text{C}_2\text{H}_4 + \text{H}_2 \xrightarrow{\text{Ni}} \text{C}_2\text{H}_6$



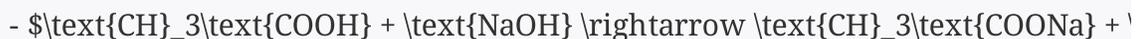
Substitution Reactions



Ethanol Reactions



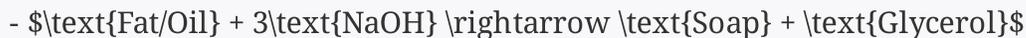
Ethanoic Acid Reactions



Esterification



Saponification



19. EXAM TIPS AND IMPORTANT POINTS

High-Priority Topics for Exam

- Covalent Bonding:** Electronic configuration explanation, examples of H_2
- Allotropes of Carbon:** Properties comparison, structure differences, uses
- Nomenclature:** IUPAC naming with functional groups, suffix/prefix rules
- Homologous Series:** Definition, characteristics, examples (alkanes, alkenes)
- Saturated vs Unsaturated:** Definition, examples, flame test differences
- Combustion:** Complete vs incomplete, balanced equations, flame colors

7. **Ethanol:**

- Properties and uses
- Reactions: Na reaction, dehydration, oxidation
- Health effects

8. **Ethanoic Acid:**

- Weak acid properties
- Reactions: Bases, carbonates, esters
- Distinction from ethanol (sodium carbonate test)

9. **Esterification & Saponification:** Equations, conditions, mechanism

10. **Soaps and Detergents:**

- Structure, micelle formation
- Hard water problem
- Comparison of soaps vs detergents

11. **Fossil Fuels:** Formation of coal and petroleum, non-renewable

12. **Chemical Reactions:** Addition, substitution, oxidation mechanisms

Exam Strategy

Short Answer Questions (2-3 marks):

- Test the gas produced
- Distinguish between two compounds
- Name the compound
- Balanced equation for reaction

Medium Answer Questions (3-5 marks):

- Mechanism of cleaning action
- Formation of coal/petroleum
- Comparison with properties table
- Series of reactions

Long Answer Questions (5+ marks):

- Detailed explanation with diagrams
- Multiple reactions showing versatility

- Environmental aspects
- Industrial applications

Common Student Mistakes to Avoid

1. **Nomenclature:** Forgetting to drop 'e' when suffix starts with vowel (prop)
2. **Combustion:** Incorrectly balancing equations, forgetting to balance H and
3. **Tests:** Confusing what happens - bromine decolorizes with unsaturated
4. **Distinctions:** Ethanol vs acid: Don't just say "ethanol is alcohol" - use sod
5. **Soap:** Confusing micelle interior (hydrophobic tails) with exterior (hydr
6. **Reactions:** Confusing esterification (produces water) with saponification

Document Complete

Total Chapters Covered: 19 comprehensive sections with exam-focused con

Key Features:

- Clear definitions and concepts
- Detailed examples and structures
- Balanced chemical equations
- Comparison tables
- Exam-important questions with answers
- LaTeX mathematical equations
- Professional structure for PDF export

Suitable for: RBSE Class 10 Science examination preparation