

# Summary and Notes for Exam Preparation: Hydrocarbons

## Alkanes and Homologous Series

### Key Concepts:

- Alkanes are hydrocarbons with the general formula  $C_nH_{2n+2}$
- They form a homologous series with similar chemical properties but gradually changing physical properties

### Characteristics of Homologous Series:

- Same general formula ( $C_nH_{2n+2}$ )
- Differ by  $CH_2$  unit between consecutive members
- Similar chemical properties
- Gradual change in physical properties (e.g., boiling point, melting point)

### First 10 Members of Alkane Series:

Name	Formula	Molecular Structure
Methane	$CH_4$	Single C atom with 4 H atoms
Ethane	$C_2H_6$	2 C atoms with 6 H atoms
Propane	$C_3H_8$	3 C atoms chain
Butane	$C_4H_{10}$	4 C atoms chain
Pentane	$C_5H_{12}$	5 C atoms chain

Hexane      C<sub>6</sub>H<sub>14</sub>      6 C atoms chain

Heptane      C<sub>7</sub>H<sub>16</sub>      7 C atoms chain

Octane      C<sub>8</sub>H<sub>18</sub>      8 C atoms chain

Nonane      C<sub>9</sub>H<sub>20</sub>      9 C atoms chain

Decane      C<sub>10</sub>H<sub>22</sub>      10 C atoms chain

### Physical Properties Trends:

1. Boiling Point:
  - Increases with molecular mass
  - Due to stronger van der Waals forces
  - Example: Methane (-161.5°C) < Ethane (-88.6°C) < Propane (-42.1°C)
2. Physical State at Room Temperature:
  - C<sub>1</sub> to C<sub>4</sub>: Gases
  - C<sub>5</sub> to C<sub>17</sub>: Liquids
  - C<sub>18</sub> and above: Solids

## 2. Sources of Alkanes

### Natural Sources:

1. Crude Oil (Petroleum)
  - Primary source
  - Complex mixture of hydrocarbons
  - Formed from ancient marine organisms
2. Natural Gas
  - Mainly methane (85-95%)
  - Small amounts of ethane, propane, butane
3. Coal Bed Methane
  - Trapped in coal seams
  - Extracted during mining

### Industrial Sources:

1. Cracking of Larger Hydrocarbons

- Thermal cracking
- Catalytic cracking Example:  $C_{10}H_{22} \rightarrow C_5H_{12} + C_5H_{10}$  (decane  $\rightarrow$  pentane + pentene)
- 2. Hydrogenation of Alkenes Example:  $C_2H_4 + H_2 \rightarrow C_2H_6$  (ethene + hydrogen  $\rightarrow$  ethane)

### 3. Fractional Distillation of Crude Oil

#### Process Overview:

1. Crude oil is heated to 350-400°C
2. Hydrocarbons vaporize
3. Vapors rise in fractionating column
4. Different fractions condense at different temperatures

#### Column Structure:

- Tall tower with decreasing temperature from bottom to top
- Multiple collection trays at different heights
- Temperature gradient: 400°C (bottom) to 20°C (top)

#### Main Fractions (from top to bottom):

1. Gases (< 20°C)
  - C1 to C4
  - Uses: cooking gas, fuel
2. Petroleum Spirit/Naphtha (20-60°C)
  - C5 to C7
  - Use: petrol/gasoline
3. Kerosene (150-250°C)
  - C10 to C14
  - Use: jet fuel, heating
4. Diesel Oil (250-350°C)
  - C15 to C18
  - Use: diesel engines
5. Lubricating Oil (350-400°C)
  - C19 to C25
  - Use: machinery lubrication
6. Residue (>400°C)
  - C25+
  - Use: bitumen, road surfacing

#### Trends in Fractions:

1. As temperature increases:
  - Carbon chain length increases
  - Viscosity increases

- Volatility decreases
- Color darkens

## 4. Saturated vs Unsaturated Hydrocarbons

### Saturated Hydrocarbons (Alkanes):

1. Characteristics:
  - Single bonds only
  - Maximum number of hydrogen atoms
  - General formula  $C_nH_{2n+2}$
2. Chemical Properties:
  - Less reactive
  - Undergo substitution reactions Example:  $CH_4 + Cl_2 \rightarrow CH_3Cl + HCl$   
(methane + chlorine → chloromethane + hydrogen chloride)

### Unsaturated Hydrocarbons:

1. Alkenes ( $C_nH_{2n}$ ):
  - Contains C=C double bond
  - More reactive than alkanes
  - Undergo addition reactions Example:  $C_2H_4 + Br_2 \rightarrow C_2H_4Br_2$   
(ethene + bromine → dibromoethane)
2. Alkynes ( $C_nH_{2n-2}$ ):
  - Contains C≡C triple bond
  - Very reactive
  - Multiple addition reactions possible

### Testing for Saturation:

1. Bromine Water Test:
  - Saturated: Remains brown/orange
  - Unsaturated: Decolorizes from brown to colorless
2. Potassium Permanganate Test:
  - Saturated: Remains purple
  - Unsaturated: Decolorizes from purple to colorless

## Exam Preparation Tips:

1. Practice drawing structural formulas
2. Memorize the first 10 alkanes and their formulas
3. Understand trends in physical properties
4. Know the different fractions from fractional distillation and their uses
5. Practice writing balanced equations for reactions
6. Remember tests for saturation/unsaturation

## Example Exam Questions:

Question: "Draw the structural formula for butane and show its combustion reaction." Answer: Structural formula:  $\text{CH}_3\text{-CH}_2\text{-CH}_2\text{-CH}_3$

Combustion:  $\text{C}_4\text{H}_{10} + 6.5\text{O}_2 \rightarrow 4\text{CO}_2 + 5\text{H}_2\text{O}$

Question: "Explain why pentane has a higher boiling point than ethane."

Answer: Pentane ( $\text{C}_5\text{H}_{12}$ ) has more carbon atoms than ethane ( $\text{C}_2\text{H}_6$ ), resulting in stronger van der Waals forces between molecules. This requires more energy to overcome, leading to a higher boiling point.

Question: "Name the process that converts longer chain hydrocarbons into shorter ones." Answer: Cracking (either thermal or catalytic).

Example:  $\text{C}_{10}\text{H}_{22} \rightarrow \text{C}_6\text{H}_{14} + \text{C}_4\text{H}_8$

## Reactions of Alkanes

### Key Characteristics:

- Alkanes are generally unreactive due to strong C-C and C-H bonds
- Require high temperatures or UV light for reactions
- Main reaction types: combustion and substitution

### Types of Reactions:

1. Combustion (complete and incomplete)
2. Free radical substitution
3. Cracking (thermal and catalytic)

## 2. Combustion of Alkanes

### Complete Combustion:

- Requires excess oxygen
- Products:  $\text{CO}_2$  and  $\text{H}_2\text{O}$
- General equation:  $\text{C}_n\text{H}_{2n+2} + (3n+1)/2 \text{O}_2 \rightarrow n\text{CO}_2 + (n+1)\text{H}_2\text{O}$

### Examples:

1. Methane:  $\text{CH}_4 + 2\text{O}_2 \rightarrow \text{CO}_2 + 2\text{H}_2\text{O}$
2. Ethane:  $\text{C}_2\text{H}_6 + 3.5\text{O}_2 \rightarrow 2\text{CO}_2 + 3\text{H}_2\text{O}$
3. Propane:  $\text{C}_3\text{H}_8 + 5\text{O}_2 \rightarrow 3\text{CO}_2 + 4\text{H}_2\text{O}$

### Incomplete Combustion:

- Limited oxygen supply
- Products:  $\text{CO}$ ,  $\text{C}$  (soot), and/or  $\text{H}_2\text{O}$
- Example:  $2\text{CH}_4 + 3\text{O}_2 \rightarrow 2\text{CO} + 4\text{H}_2\text{O}$

## Applications of Combustion:

1. Domestic Uses:
  - Cooking (natural gas stoves)
  - Heating (gas furnaces)
  - Hot water systems
2. Industrial Applications:
  - Power generation
  - Industrial furnaces
  - Manufacturing processes
3. Transportation:
  - Internal combustion engines
  - Jet engines
  - Rocket fuel

## 3. Pollution from Hydrocarbon Fuels

### Major Pollutants:

1. Carbon Dioxide (CO<sub>2</sub>):
  - Greenhouse gas
  - Contributes to global warming
  - Source: Complete combustion
2. Carbon Monoxide (CO):
  - Toxic gas
  - Binds to hemoglobin
  - Source: Incomplete combustion
3. Sulfur Dioxide (SO<sub>2</sub>):
  - Acid rain formation
  - Respiratory irritant
  - Source: Sulfur impurities in fuel
4. Nitrogen Oxides (NO<sub>x</sub>):
  - Photochemical smog
  - Acid rain formation
  - Source: High-temperature combustion
5. Particulate Matter:
  - Respiratory problems
  - Reduced visibility
  - Source: Incomplete combustion

### Environmental Effects:

1. Global Warming:
  - Increased average temperatures
  - Sea level rise
  - Climate change
2. Acid Rain:

- Building damage
- Soil acidification
- Aquatic ecosystem damage

## 4. Catalytic Converters

### Function:

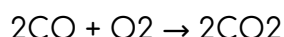
- Converts harmful exhaust gases into less harmful substances
- Operates at high temperatures (300-600°C)
- Contains precious metal catalysts (Pt, Pd, Rh)

### Structure:

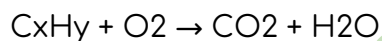
1. Ceramic honeycomb structure
2. Washcoat (Al<sub>2</sub>O<sub>3</sub>)
3. Catalyst particles

### Chemical Processes:

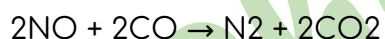
1. Oxidation of CO:



2. Oxidation of unburned hydrocarbons:



### Reduction of NO<sub>x</sub>:



3.  $2\text{NO} + 2\text{H}_2 \rightarrow \text{N}_2 + 2\text{H}_2\text{O}$

### Applications:

1. Automotive vehicles
2. Industrial emissions control
3. Power plant emissions

## 5. Substitution Reactions of Alkanes

### Overview:

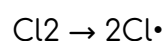
- Replacement of H atoms with halogen atoms

- Requires UV light or high temperature
- Follows free radical mechanism

## Free Radical Mechanism:

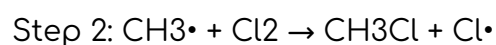
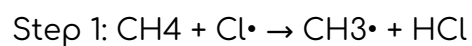
### 1. Initiation:

- UV light breaks halogen molecule
- Forms halogen radicals



### 2. Propagation:

- Two-step chain reaction
- Creates new radicals



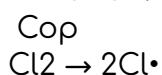
### 3. Termination:

- Radicals combine
- Chain reaction ends

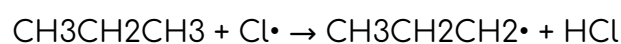


## Example with Propane:

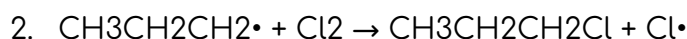
### 1. Initiation:



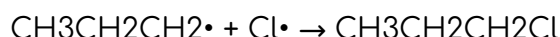
### Propagation:







3. Termination:



## 6. Practice Problems

### Problem 1:

Write balanced equations for the complete combustion of: a) Butane ( $\text{C}_4\text{H}_{10}$ ) b) Pentane ( $\text{C}_5\text{H}_{12}$ )

Solution: a)  $\text{C}_4\text{H}_{10} + 6.5\text{O}_2 \rightarrow 4\text{CO}_2 + 5\text{H}_2\text{O}$  b)  $\text{C}_5\text{H}_{12} + 8\text{O}_2 \rightarrow 5\text{CO}_2 + 6\text{H}_2\text{O}$

### Problem 2:

For the chlorination of methane: a) Write the initiation step b) Write both propagation steps c) Write three possible termination steps

Solution: a) Initiation:  $\text{Cl}_2 \rightarrow 2\text{Cl}\cdot$  b) Propagation:

- $\text{CH}_4 + \text{Cl}\cdot \rightarrow \text{CH}_3\cdot + \text{HCl}$
- $\text{CH}_3\cdot + \text{Cl}_2 \rightarrow \text{CH}_3\text{Cl} + \text{Cl}\cdot$  c) Termination:
- $\text{Cl}\cdot + \text{Cl}\cdot \rightarrow \text{Cl}_2$
- $\text{CH}_3\cdot + \text{Cl}\cdot \rightarrow \text{CH}_3\text{Cl}$
- $\text{CH}_3\cdot + \text{CH}_3\cdot \rightarrow \text{C}_2\text{H}_6$

### Problem 3:

Explain why the following equation represents incomplete combustion:  $2\text{C}_3\text{H}_8 + 7\text{O}_2 \rightarrow 4\text{CO} + 2\text{CO}_2 + 8\text{H}_2\text{O}$

Solution:

- This is incomplete combustion because:
  1. CO is produced instead of  $\text{CO}_2$  for some carbon atoms
  2. Insufficient oxygen was available for complete oxidation
  3. Complete combustion would require  $10\text{O}_2$  and produce only  $\text{CO}_2$

### Problem 4:

Calculate the volume of oxygen needed for complete combustion of  $50\text{cm}^3$  of propane.

Solution:



Ratio of  $C_3H_8:O_2 = 1:5$

Therefore,  $50\text{cm}^3$  of propane needs  $250\text{cm}^3$  of oxygen

## The Alkenes

### Characteristics:

- General formula:  $C_nH_{2n}$
- Contains C=C double bond
- Unsaturated hydrocarbons
- More reactive than alkanes

### First Six Members:

Name	Formula	Structure
Ethene	$C_2H_4$	$CH_2=CH_2$
Propene	$C_3H_6$	$CH_3-CH=CH_2$
Butene	$C_4H_8$	$CH_3-CH_2-CH=CH_2$
Pentene	$C_5H_{10}$	$CH_3-(CH_2)_2-CH=CH_2$
Hexene	$C_6H_{12}$	$CH_3-(CH_2)_3-CH=CH_2$

### Physical Properties:

- Lower boiling points than equivalent alkanes
- Slightly polar due to electron density in double bond
- Generally insoluble in water

## 2. Oil Refineries and Cracking

### Oil Refinery Process:

1. Fractional Distillation
2. Cracking

### 3. Treatment processes

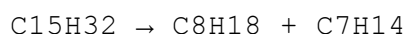
#### Cracking Methods:

#### 1. Catalytic Cracking:

- Temperature: 450-500°C
- Pressure: Moderate
- Catalyst: Zeolites
- Produces more branched alkanes and alkenes

Process:

Long-chain alkane → shorter-chain alkane + alkene



Advantages:

- Lower temperature than thermal cracking
- Better yield of useful products
- More selective process

#### 2. Thermal Cracking:

- Temperature: 700-900°C
- No catalyst
- Produces mixture of alkanes and alkenes

Example:



Decane → hexane + but-1-ene

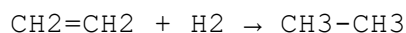
#### Catalytic Cracker Components:

1. Reactor vessel
2. Regenerator
3. Fractionating column
4. Catalyst recycling system

### 3. Addition Reactions of Alkenes

#### 1. Addition of Hydrogen (Hydrogenation):

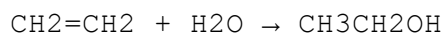
- Conditions: Ni/Pt/Pd catalyst, 150°C
- Products: Alkanes



Ethene → Ethane

## 2. Addition of Steam (Hydration):

- Conditions: H<sub>3</sub>PO<sub>4</sub> catalyst, 300°C, 60 atm
- Products: Alcohols



Ethene → Ethanol

## 3. Addition of Hydrogen Halides:

- Room temperature
- Products: Haloalkanes



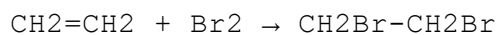
Propene → 2-bromopropane

Markovnikov's Rule:

- H attaches to C with more H atoms
- X attaches to C with fewer H atoms

## 4. Addition of Halogens:

- Room temperature
- Products: Dihalogenoalkanes



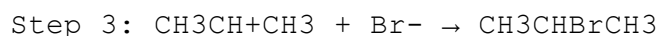
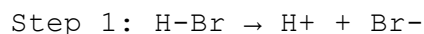
Ethene → 1,2-dibromoethane

## 4. Electrophilic Addition Mechanism

Steps:

1. Formation of electrophile
2. Attack by  $\pi$  electrons
3. Formation of carbocation
4. Attack by nucleophile

Example with HBr:



## 5. Oxidation of Alkenes

### 1. Cold Oxidation (Mild):

- Reagent: Cold  $\text{KMnO}_4$  or  $\text{K}_2\text{Cr}_2\text{O}_7$
- Products: Diols



### 2. Hot Oxidation (Vigorous):

- Reagent: Hot  $\text{KMnO}_4$
- Products: Carboxylic acids



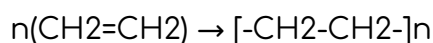
## 6. Addition Polymerization

Process:

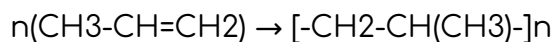
- Involves unsaturated monomers
- Double bonds break
- Monomers join to form long chains

Examples:

1. Polyethene from ethene:



2. Polypropene from propene:



### Types of Polyethene:

1. HDPE (High Density):
  - Linear chains
  - Higher density
  - Stronger
2. LDPE (Low Density):
  - Branched chains
  - Lower density
  - More flexible

## 7. Environmental Considerations

### Disposal Methods:

1. Landfill:
  - Non-biodegradable
  - Long-term environmental impact
  - Space issues
2. Incineration:
  - Produces energy
  - Potential toxic emissions
  - Requires proper filtering
3. Recycling:
  - Mechanical recycling
  - Chemical recycling
  - Energy recovery

### Environmental Issues:

1. Plastic Pollution
2. Microplastic contamination
3. Marine ecosystem damage
4. Greenhouse gas emissions

## 8. Exam Preparation

### Tackling Polymer Questions:

## 1. Identifying Repeat Units:

- Look for the double bond in monomer
- Break the double bond
- Connect monomers

Example:

Monomer:  $\text{CH}_2=\text{CH}-\text{Cl}$

Repeat unit:  $[-\text{CH}_2-\text{CHCl}-]$

## 2. Identifying Monomers:

- Look for repeating pattern
- Add double bond
- Check valencies

Example:

Polymer:  $[-\text{CH}_2-\text{CH}(\text{CH}_3)-]$

Monomer:  $\text{CH}_2=\text{CH}-\text{CH}_3$

### Practice Problems:

1. Draw the structure of the polymer formed from: a)  $\text{CH}_2=\text{CHCl}$  b)  $\text{CH}_2=\text{C}(\text{CH}_3)_2$

Solution: a)  $[-\text{CH}_2-\text{CHCl}-]_n$  b)  $[-\text{CH}_2-\text{C}(\text{CH}_3)_2-]_n$

2. Identify the monomer used to make:  $[-\text{CH}_2-\text{CH}(\text{C}_6\text{H}_5)-]_n$

Solution:  $\text{CH}_2=\text{CH}-\text{C}_6\text{H}_5$  (styrene)

3. For the reaction between propene and HBr: a) Draw the mechanism b) Name the product c) Explain why this product forms

### Key Points to Remember:

1. Always show all bonds clearly
2. Use curly arrows correctly in mechanisms
3. Apply Markovnikov's Rule
4. Remember polymerization conditions
5. Consider environmental impacts

## Common Exam Questions:

1. Drawing mechanisms
2. Identifying products
3. Naming monomers/polymers
4. Environmental discussions
5. Industrial applications

## Writing Tips:

- Use precise chemical terminology
  - Show working clearly
  - Include relevant equations
  - Explain mechanisms step by step
  - Link structure to properties
- 

Chemcrack.in