Chemistry Year 1

SECTION

10

CLASSIFICATIONS OF ORGANIC COMPOUNDS

CHEMISTRY OF CARBON COMPOUNDS

Organic Functional groups

INTRODUCTION

You will explore carbon compounds, with a focus on understanding the differences between organic and inorganic compounds. You will also learn about different types of organic compounds and the patterns they follow. Through various activities, you will demonstrate your knowledge and practice classifying organic compounds.

At the end of this section, you will be able to:

- Distinguish between organic and inorganic compounds and classify organic compounds.
- Explain homologous series and state their properties.

Key Ideas

- **Alkanes** are saturated hydrocarbons with only single bonds (e.g., methane, ethane).
- **Alkenes** are unsaturated hydrocarbons with at least one double bond (e.g., ethene).
- **Alkynes** are unsaturated hydrocarbons with at least one triple bond (e.g., ethyne).
- **Aromatic compounds:** are compounds that contain a benzene ring (e.g., benzene, toluene).

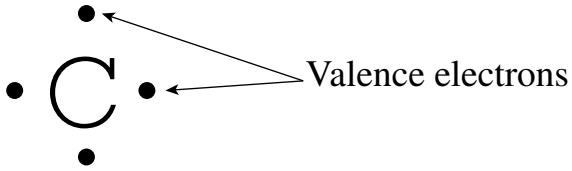
ORGANIC CHEMISTRY

Organic chemistry is a branch of chemistry which studies the structure and properties of carbon compounds, except oxides of carbon, carbonates, carbides and cyanides.

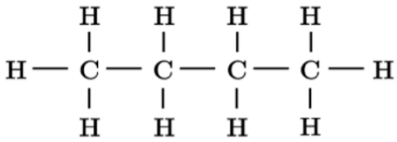
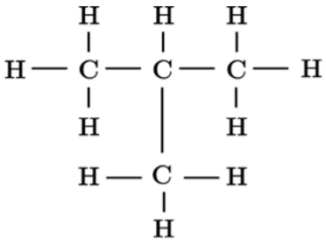
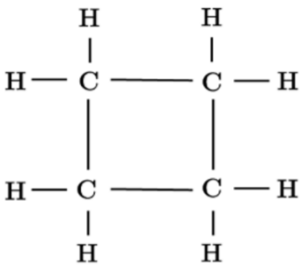
An organic compound is a compound containing carbon atoms covalently bonded to other atoms.

Properties Of Carbon That Make It Possible To Form Many Stable Compounds

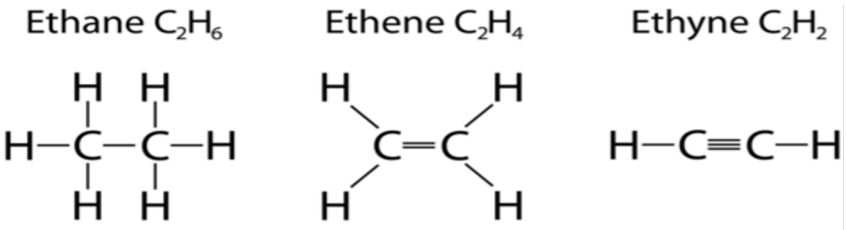
1. Carbon has a valency of four (tetravalent) and can form four covalent bonds.



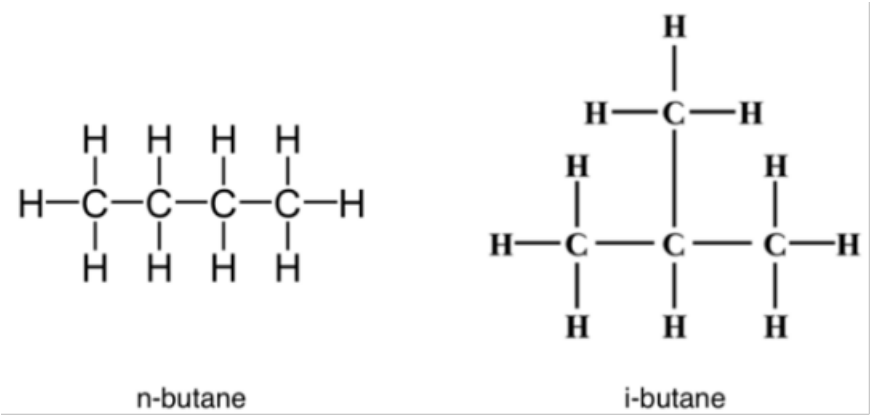
2. Carbon atoms can join to form straight chains, branched chains and ring structures.

straight chain	branched chain	ring
		
butane (C_4H_{10})	isobutane ((C_4H_{10})	cyclobutane (C_4H_8)

3. Carbon can form single, double or triple bonds with itself and other elements



4. Carbon can form isomers (compounds with the same chemical formula but a different structure).



Differences Between Organic And Inorganic Compounds

Table 10.1

Inorganic compounds	Organic compounds
Contain any element except organic carbon.	Must contain a carbon atom.
Are usually ionic compounds and some covalent compounds.	Are usually covalent compounds.
Usually have relatively high melting and boiling points.	Usually have relatively low melting and boiling points.
Often soluble in polar solvents.	Usually soluble in nonpolar solvents.
Usually occurs as solids at room temperature.	Often exist as liquids and gases.

Classes of Organic Compounds

Organic compounds can be classified into:

1. Aliphatic hydrocarbons
2. Alicyclic hydrocarbons
3. Aromatic hydrocarbons
4. Heterocyclic compounds

Hydrocarbons

Hydrocarbons are organic compounds containing only carbon and hydrogen atoms. Hydrocarbons can be saturated or unsaturated. Hydrocarbon names are derived from the number of carbon atoms they contain. A few of the common prefixes are listed below:

Prefix	Number of Carbon atoms	Formula
meth-	1	C
eth-	2	C2
prop-	3	C3
but-	4	C4
pent-	5	C5
hex-	6	C6
hept-	7	C7
oct-	8	C8
non-	9	C9
dec-	10	C10
undec-	11	C11
dodec-	12	C12
tridec-	13	C13
tetradec-	14	C14
pentadec-	15	C15
hexadec-	16	C16
heptadec-	17	C17
octadec-	18	C18
nonadec-	19	C19
eicosan-	20	C20

Saturated hydrocarbons

Have single bonds between two carbon atoms (***C – C***). An example is the alkane family. Specific examples are:

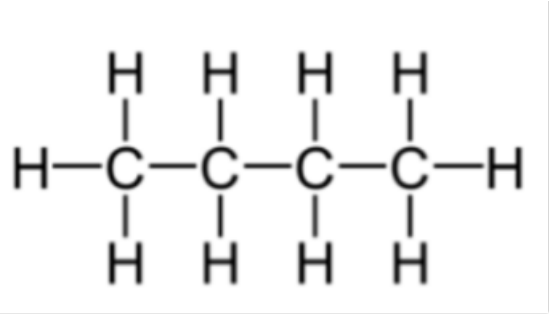


Fig. 10.1: Alkane (butane)

Unsaturated hydrocarbons

Have double or triple bonds between two carbon atoms. Examples are alkenes and alkynes.

Specific examples of alkenes are:

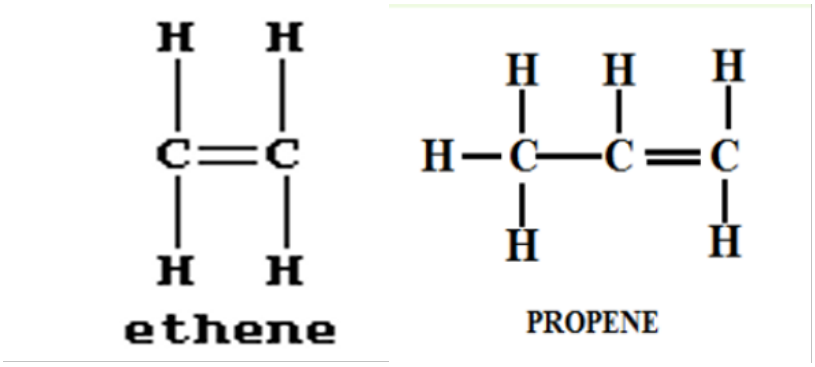


Fig 10.2: Examples of alkenes

Specific examples of alkynes are:

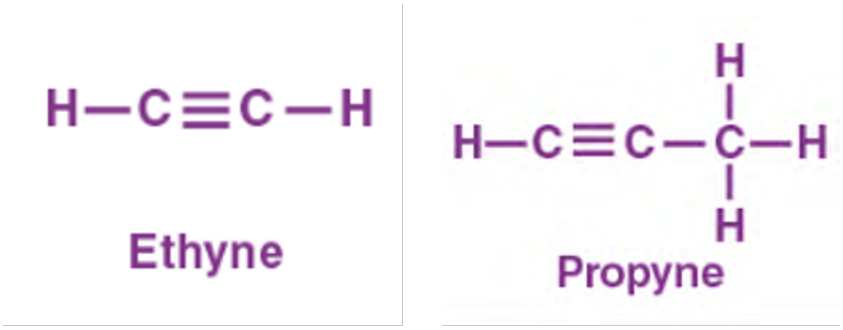


Fig 10.3: Examples of alkynes

Aliphatic hydrocarbons

These are organic compounds containing carbon and hydrogen atoms that are usually linked together in chains via single, double or triple bonds. They can be open straight chains or branched chains. Aliphatic hydrocarbons may be saturated or unsaturated.

Examples are alkanes (which have $C - C$ bonds), alkenes (which have $C = C$ bonds) and alkynes (which have $C \equiv C$ bonds).

Many of the aliphatic compounds are flammable and so they are used as fuels such as butane in LPG and ethylene in welding.

Alicyclic hydrocarbons

These are organic compounds that have closed rings of carbon atoms.

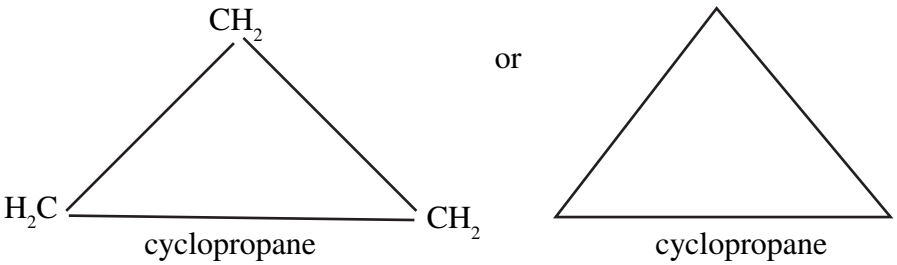


Fig. 10.4: Examples of alicyclic hydrocarbons

Aromatic hydrocarbons

These are organic compounds that have one or more benzene rings in their structure. The different ways of representing the structure of benzene are shown below:

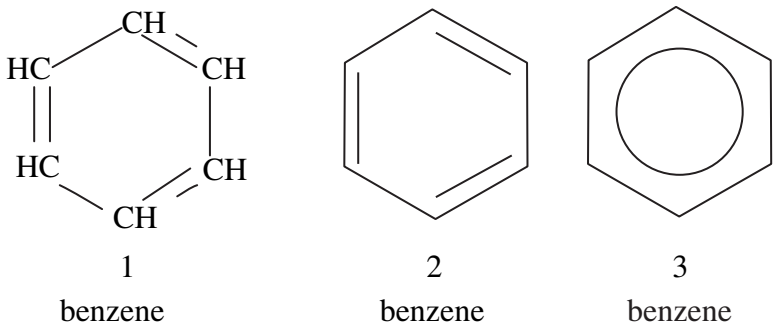


Fig. 10.5: Aromatic hydrocarbon

Heterocyclic compounds

These are organic compounds which are not hydrocarbons. They contain rings of atoms and carbon and hydrogen atoms, including other atoms such as oxygen, nitrogen and sulphur.

Examples are

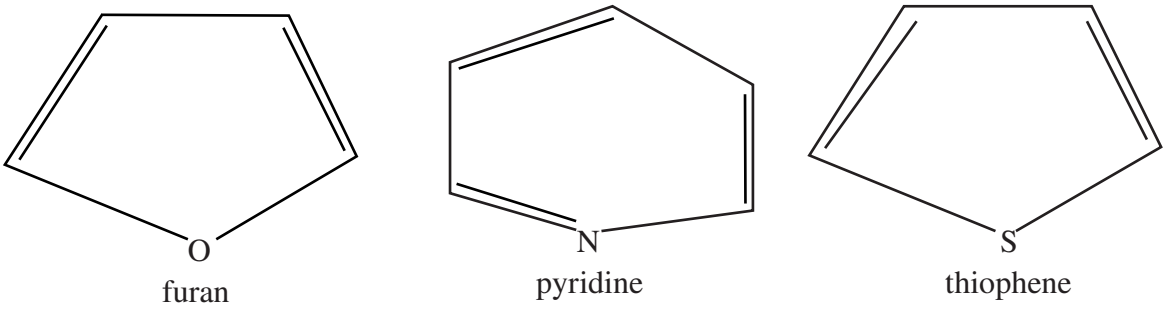


Fig. 10.6: Heterocyclic compounds

Activity 10.1: Understanding Organic Chemistry

Objective: To introduce you to the meaning of organic chemistry.

Form a small group of three or four with your classmates and discuss the following points:

1. The meaning of organic chemistry.
2. Examples of organic compounds (such as methane, ethene, or glucose).
3. The significance of carbon in organic chemistry.
4. The role of organic chemistry in everyday life (e.g., in medicines, plastics, food).
5. Summarise the key points about the meaning of organic chemistry, emphasising the importance of carbon compounds.

Questions

a. What element is most commonly found in organic compounds?

b. Why is carbon so important in organic chemistry?

c. Give two examples of organic compounds and explain why they are considered organic.

d. What types of bonds are most common in organic compounds?

e. What is the difference between a hydrocarbon and an organic compound?

Activity 10.2: Differentiating Between Organic and Inorganic Compounds

Objective: To understand the differences between organic and inorganic compounds.

In your small groups from **Activity 10.1**, discuss the key differences between organic and inorganic compounds under the following points:

Some key points to focus on:

1. Presence of carbon in organic compounds.
2. Organic compounds are often found in living things, while inorganic compounds are typically minerals or non-living substances.
3. Differences in types of bonds (covalent bonds in organic compounds vs. ionic or metallic bonds in inorganic compounds).

Questions

a. Can inorganic compounds contain carbon? If so, give an example.

b. Do organic compounds tend to have higher or lower melting and boiling points than inorganic compounds?

Activity 10.3: Why Carbon Forms Many Compounds

Materials needed: Periodic table, molecular models, access to textbooks or online resources for reference.

1. Brainstorm and list examples of carbon-containing compounds you are familiar with (e.g., sugar, plastics, gasoline, diamonds).
2. What is special about carbon's position in the periodic table?
3. Identify carbon's group and its number of valence electrons.
4. How does carbon bond with other atoms?
5. Use molecular models to build simple molecules (e.g., CH_4, CO_2, and C_2H_6). Visualise carbon's ability to form four covalent bonds.
6. Why do you think carbon can form different types of structures, like chains, rings, and networks?
7. Build different carbon-based structures using the models or diagrams (e.g., a ring structure like benzene, and a network structure like diamond or graphite).

Compare and discuss your findings with a classmate.

Extended Activity Questions

1. What are organic compounds?
2. State four reasons why carbon forms many stable compounds.
3. Distinguish between alicyclic hydrocarbons and aromatic hydrocarbons.
4. What is meant by the term aromatic hydrocarbon?
5. In a tabular form, state the differences between organic compounds and inorganic compounds.
6. Describe the general differences in chemical bonding between organic and inorganic compounds.
7. Compare and contrast the physical and chemical properties of organic and inorganic compounds.

HOMOLOGOUS SERIES

Homologous series is a group of compounds having the same general molecular formula and similar chemical properties. The tables below show examples of the homologous series for alkanes and alkenes.

Table 10.2: Molecular formula of Alkanes

Number of carbon atoms (n)	Molecular formula, (C_nH_{2n+2})
1	CH_4
2	C_2H_6
3	C_3H_8
4	C_4H_{10}
5	C_5H_{12}

Table 10.3: Molecular formula of Alkenes

Number of carbon atoms (n)	Molecular formula, (C_nH_{2n+2})
2	C_2H_4
3	C_3H_6
4	C_4H_8
5	C_5H_{10}

Note that the alkenes cannot have a compound with a single atom of carbon, this is because the alkenes are defined as having a single carbon-to-carbon double bond.

Properties of a Homologous Series

1. They have a general molecular formula.
2. They have a general method of preparation.
3. They exhibit similar chemical properties.
4. They have the same functional group.
5. They exhibit a gradual change in physical properties along the series.

How to Represent Organic Compounds

Organic compounds are represented by using their molecular formula, condensed formula or structural formula.

The tables below show examples of alkanes and alkenes

Table 10.4: Structural formula of Alkanes

Number of carbon atoms (n)	Molecular formula, (C_nH_{2n+2})	Structural formula
1	CH_4	CH_4
2	C_2H_6	CH_3CH_3
3	C_3H_8	$CH_3CH_2CH_3$
4	C_4H_{10}	$CH_3CH_2CH_2CH_3$
5	C_5H_{12}	$CH_3CH_2CH_2CH_2CH_3$

Table 10.5: Structural formula of Alkenes

Number of carbon atoms (n)	Molecular formula, (C_nH_{2n})	Structural formula
2	C_2H_4	$CH_2=CH_2$
3	C_3H_6	$CH_3CH=CH_2$
4*	C_4H_8	$CH_3CH_2CH=CH_2$
5*	C_5H_{10}	$CH_3CH_2CH_2CH=CH_2$
6*	C_6H_{12}	$CH_3CH_2CH_2CH_2CH=CH_2$

***Note here that the double bond could in fact be in different positions along the chain, this will give a subtle difference in properties and change the reactions it will undergo.**

Activity 10.4: Writing the Homologous Series for Alkanes and Alkenes

Materials needed: Periodic table, molecular model kits, access to textbooks or online resources (for reference).

1. What are the general formulae for alkanes and alkenes?
2. Give a few examples of alkanes (e.g., methane, ethane, propane) and alkenes (e.g., ethene, propene, but-1-ene, but-2-ene).
3. Using molecular model kits, build molecular structures of the first three or four alkanes and alkenes (methane, ethane, ethene, etc.).
4. Write down the first five members of the homologous series for alkanes and alkenes. For each compound, they should write molecular formula and Structural formula.

Activity 10.5: Discussing the Properties of Homologous Series

1. With a classmate, discuss how physical properties such as states of matter, boiling points, and solubility change as you go up the homologous series.
2. Predict the trend in boiling points and physical states as they move up the series.
3. Discuss how **chemical properties** change as you move up the series?

   Do compounds become more or less reactive?

Activity 10.6

1. What are organic compounds?
2. State four reasons why carbon forms many stable compounds.
3. Distinguish between alicyclic hydrocarbons and aromatic hydrocarbons.
4. Explain the term homologous series.
5. State three properties of a homologous series.
6. The following compound is a member of the alkane homologous series: CH_3CH_3

   Draw the structures of the next three members of the series that follow the compound.

REVIEW QUESTIONS

Review Questions 10.1

1. Which of the following is an example of an organic compound?
   - **A.** Water (H_2O)
   - **B.** Carbon dioxide (CO_2)
   - **C.** Glucose ($C_6H_{12}O_6$)
   - **D.** Ammonia (NH_3)
2. How are organic compounds classified based on their structure?
3. What are the main types of hydrocarbons, and how are they classified?
4. Why is it important to classify organic compounds?
5. Why are homologous series important in organic chemistry?
6. Why do boiling and melting points increase along a homologous series?
7. What is the difference between alkanes, alkenes, and alkynes?
8. Why are hydrocarbons important?
9. What is the primary difference between organic and inorganic compounds?
10. What types of bonds are typically found in organic compounds compared to inorganic compounds?
11. Can organic compounds only be found in living organisms?

ANSWERS TO REVIEW QUESTIONS

Answers To Review Questions 10.1

1. C. Glucose ($C_6H_{12}O_6$)

2. Organic compounds can be classified into:

- Acyclic (Open-chain): Straight or branched carbon chains, e.g., propane (C_3H_8).
- Cyclic (Closed-chain): Carbon atoms arranged in rings, further divided into:
  - Alicyclic: Non-aromatic rings, e.g., cyclohexane.
  - Aromatic: Conjugated ring systems, e.g., benzene (C_6H_6).

3. Hydrocarbons are classified into:

- Alkanes: Saturated, single bonds, e.g., methane (CH_4).
- Alkenes: Unsaturated, contain double bonds, e.g., ethene (C_2H_4).
- Alkynes: Unsaturated, contain triple bonds, e.g., ethyne (C_2H_2).

4. Classifying organic compounds helps in understanding their chemical properties, reactivity, and applications, making it easier to predict their behaviour in various chemical reactions.

5. Homologous series help in systematically organising and studying organic compounds. They make it easier to predict the properties and reactions of compounds based on their structural similarities.

6. As the molecular mass increases, intermolecular forces (like Van der Waals forces) become stronger, requiring more energy to break these forces. This results in higher boiling and melting points.

7. **Alkanes**: Saturated hydrocarbons with only single C-C bonds, making them less reactive.

Alkenes: Unsaturated hydrocarbons with at least one C=C double bond, making them more reactive in addition reactions.

Alkynes: Unsaturated hydrocarbons with at least one C≡C triple bond, which makes them even more reactive than alkenes.

8. Hydrocarbons are a fundamental energy source (e.g., natural gas, petroleum) and serve as raw materials for many chemical products, including plastics, fuels, and pharmaceuticals.

9. The primary difference is that organic compounds primarily contain carbon and hydrogen atoms, often with other elements, and are mainly based on carbon-hydrogen bonds. In contrast, inorganic compounds may or may not contain carbon, and they include salts, metals, and minerals.

10. Organic compounds mostly consist of covalent bonds (sharing of electrons), while inorganic compounds may have both ionic bonds (transfer of electrons) and covalent bonds.

11. **Answer:** No, while organic compounds were initially believed to come only from living organisms, they can now be synthesised in the lab. Organic chemistry deals with a wide range of carbon-based compounds, whether from biological or synthetic sources.

EXTENDED READING

Click on the links below and watch videos on the types of hydrocarbons.

- https://www.youtube.com/watch?v=z5hQ8iZZ8dU&t=32
- https://www.youtube.com/watch?v=z5hQ8iZZ8dU&t=58
- https://www.youtube.com/watch?v=z5hQ8iZZ8dU&t=76
- https://study.com/academy/lesson/video/organic-molecules-alkanes-alkenes-aromatic-hydrocarbons-and-isomers.html

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ACKNOWLEDGEMENTS

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