

Teacher : Odai ALASSI

1

Use the electronic structure of the carbon atom to understand and explain the diversity of its compounds.(1)

Get it - Text book

574

**Organic compounds** : are the compounds that contain the element carbon.**Inorganic compounds** : are the compounds not containing carbon.

➤ Classify the compounds to organic or inorganic compounds:

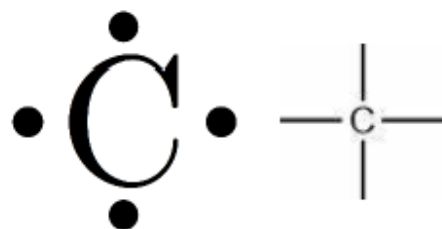
 $C_4H_{10}$ ,  $H_2O$ ,  $FeO$ ,  $CH_3COOH$ ,  $CaS$ ,  $CH_4$ ,  $CO_2$ ,  $CaC_2$ ,  $Na_2CO_3$ ,  $C_5H_{10}$ ,  $C_2H_2$ 

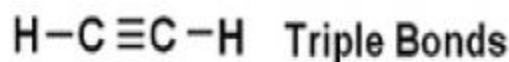
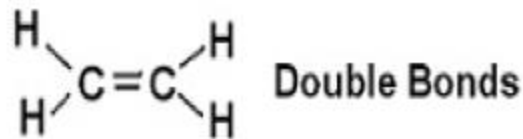
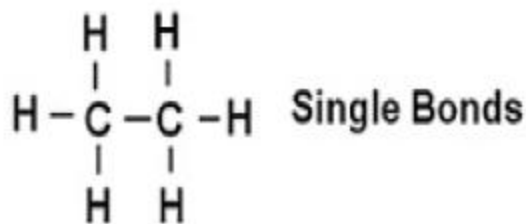
| Organic compounds | Inorganic compounds |
|-------------------|---------------------|
| .....             | .....               |
| .....             | .....               |
| .....             | .....               |
| .....             | .....               |

**Get It?****Explain** why the element carbon can form so many different organic compounds.

➤ Why carbon forms so many different compounds?

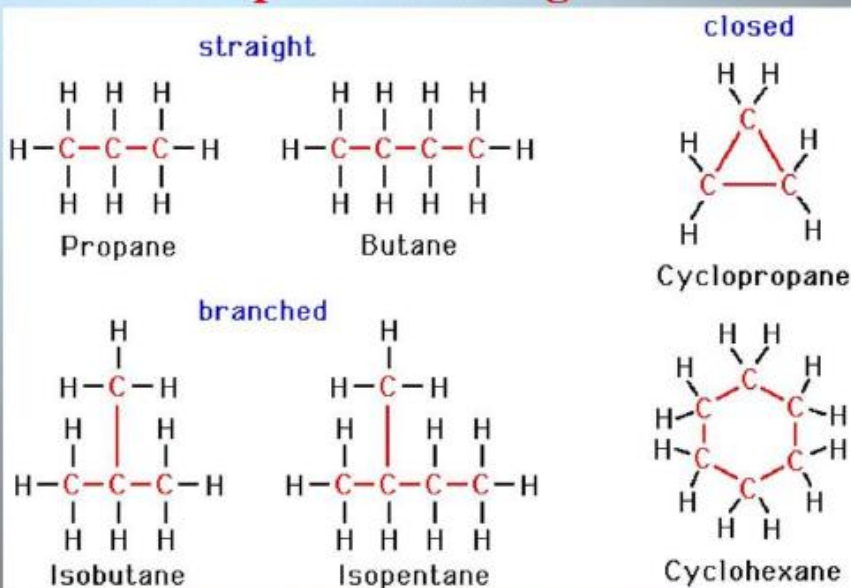
- Carbon atom has 4 electrons in the outer energy level, so it can form 4 covalent bonds with another carbon atom or any other different atoms.
- And it can form single, double, or triple covalent bonds.
- It can form straight chains, branched chains, or cycle chains.





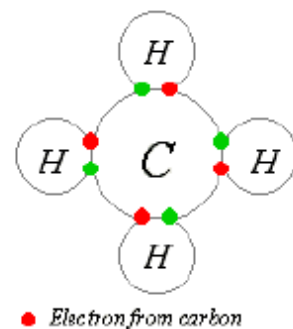
## Carbon bonds: Chains, Branched, Rings

Each line represents a single covalent bond



❖ Covalent bond can be formed when bonding atoms sharing one pair of electrons or more.

- ❖ Carbon can form straight chains, branched, or cycle chains.
- ❖ Short chain can be used as fuel, when long chains can be used to making plastic.



## Practice :

Multiple-Choice Questions (MCQs) :

1- How many electrons does a carbon atom have in its outer energy level?

- A) Two
- B) Three
- C) Four
- D) Five

2- What type of bonds can a carbon atom form with other atoms?

- A) Ionic bonds
- B) Metallic bonds
- C) Covalent bonds
- D) Hydrogen bonds

3- How many covalent bonds can a carbon atom form?

- A) One
- B) Two
- C) Three
- D) Four

4- Which of the following best explains why carbon can form so many different compounds?

- A) It reacts easily with metals only
- B) It can form single, double, and triple bonds
- C) It has a full outer shell of electrons
- D) It is unstable in nature

5- The ability of carbon to form four bonds allows it to:

- A) Combine only with oxygen
- B) Form only small molecules
- C) Create many different types of compounds
- D) Lose electrons easily

6- Covalent bonds are formed when:

- A) Atoms share pairs of electrons
- B) Atoms transfer electrons
- C) Atoms lose neutrons
- D) Atoms absorb energy

7- Which of the following is an example of a compound that carbon can form?

- A) Water ( $\text{H}_2\text{O}$ )
- B) Sodium chloride ( $\text{NaCl}$ )
- C) Methane ( $\text{CH}_4$ )
- D) Iron oxide ( $\text{Fe}_2\text{O}_3$ )

8- Carbon compounds can include:

- A) Simple fuels and complex medicines
- B) Only inorganic substances
- C) Only gases
- D) Only metals

9- What allows carbon to form long chains such as those in plastics?

- A) Its ability to bond with metals
- B) Its four available bonding sites
- C) Its high density
- D) Its low reactivity

10- Which statement best summarizes the diversity of carbon compounds?

- A) Carbon forms limited compounds with only hydrogen
- B) Carbon can bond in many ways, creating a vast range of organic molecules
- C) Carbon forms weak bonds that break easily
- D) Carbon compounds are all gases

| Which statement is <b>NOT true</b> of organic compounds? |                                                |   |                                                |
|----------------------------------------------------------|------------------------------------------------|---|------------------------------------------------|
| A                                                        | Examples include carbon dioxide and carbonates | C | It have an enormous and varied number          |
| B                                                        | Contain carbon element                         | D | The bonds between its atoms are covalent bonds |

|                                                             |                                                                             |                                                                                                                                                                                                                                                                                                                                             |                        |   |                                       |    |                                        |     |                                                |    |                                                                             |
|-------------------------------------------------------------|-----------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------|---|---------------------------------------|----|----------------------------------------|-----|------------------------------------------------|----|-----------------------------------------------------------------------------|
| When carbon atom forms chemical compounds, it is often..... |                                                                             |                                                                                                                                                                                                                                                                                                                                             |                        |   |                                       |    |                                        |     |                                                |    |                                                                             |
|                                                             |                                                                             | <table><tr><td>I</td><td>تفقد 4 إلكترونات<br/>Loses 4 electrons</td></tr><tr><td>II</td><td>تكتسب 4 إلكترونات<br/>Gains 4 electrons</td></tr><tr><td>III</td><td>تكون 4 روابط تساهمية<br/>Forms 4 covalent bonds</td></tr><tr><td>IV</td><td>تكون روابط أحادية وثنائية وثلاثية<br/>Forms single, double, and triple bonds</td></tr></table> |                        | I | تفقد 4 إلكترونات<br>Loses 4 electrons | II | تكتسب 4 إلكترونات<br>Gains 4 electrons | III | تكون 4 روابط تساهمية<br>Forms 4 covalent bonds | IV | تكون روابط أحادية وثنائية وثلاثية<br>Forms single, double, and triple bonds |
| I                                                           | تفقد 4 إلكترونات<br>Loses 4 electrons                                       |                                                                                                                                                                                                                                                                                                                                             |                        |   |                                       |    |                                        |     |                                                |    |                                                                             |
| II                                                          | تكتسب 4 إلكترونات<br>Gains 4 electrons                                      |                                                                                                                                                                                                                                                                                                                                             |                        |   |                                       |    |                                        |     |                                                |    |                                                                             |
| III                                                         | تكون 4 روابط تساهمية<br>Forms 4 covalent bonds                              |                                                                                                                                                                                                                                                                                                                                             |                        |   |                                       |    |                                        |     |                                                |    |                                                                             |
| IV                                                          | تكون روابط أحادية وثنائية وثلاثية<br>Forms single, double, and triple bonds |                                                                                                                                                                                                                                                                                                                                             |                        |   |                                       |    |                                        |     |                                                |    |                                                                             |
| A                                                           | I فقط<br>Only I                                                             | C                                                                                                                                                                                                                                                                                                                                           | III و IV<br>III and IV |   |                                       |    |                                        |     |                                                |    |                                                                             |
| B                                                           | II و IV<br>II and IV                                                        | D                                                                                                                                                                                                                                                                                                                                           | II فقط<br>Only II      |   |                                       |    |                                        |     |                                                |    |                                                                             |

Which of the following is correct regarding to carbon atom?

|   |                                                   |   |                                                                                                 |
|---|---------------------------------------------------|---|-------------------------------------------------------------------------------------------------|
| A | A Carbon atom can form straight chains only       | C | A Carbon atom can form bonds with other carbon atoms only, but not with atoms of other elements |
| B | A Carbon atom can form only single covalent bonds | D | A Carbon atom can form four covalent bonds with atoms of carbon, or with other elements         |

Which of the following is **not** a reason for the ability of carbon to form so many different organic compounds?

|   |                                                                                           |   |                                                                             |
|---|-------------------------------------------------------------------------------------------|---|-----------------------------------------------------------------------------|
| A | Carbon atom has three electrons in the outer energy level                                 | C | Carbon bonding sites allow the formation of single, double and triple bonds |
| B | Each carbon atom can form four covalent bonds with atoms of carbon or with other elements | D | Carbon atoms can form both straight chains, branched chains, and rings too  |

Why carbon can form so many different

organic compounds?

|                                                                                                                                                                 |   |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------|---|
| تحتوي ذرة الكربون على أربعة إلكترونات في مستوى الطاقة الخارجي<br>Carbon atom has four electrons in its outer energy level                                       | 1 |
| تستطيع ذرة الكربون تكوين أربع روابط تساهمية مع ذرات كربون أو عناصر أخرى<br>Carbon atom can form four covalent bonds with atoms of carbon or with other elements | 2 |
| تستطيع ذرة الكربون تكوين روابط تساهمية أحادية وثنائية وثلاثية<br>Carbon atom can form single, double, and triple covalent bonds                                 | 3 |
| تحتوي ذرة الكربون على ثلاثة إلكترونات في مستوى الطاقة الخارجي<br>Carbon atom has three electrons in its outer energy level                                      | 4 |

|   |        |   |            |
|---|--------|---|------------|
| A | 1 only | C | 2, 3 and 4 |
| B | 2 only | D | 1, 2 and 3 |

|   |                                                                      |              |     |
|---|----------------------------------------------------------------------|--------------|-----|
| 2 | Investigate the organic compounds showing their properties and uses. | Hydrocarbons | 575 |
|---|----------------------------------------------------------------------|--------------|-----|

## Hydrocarbons

- Hydrocarbons are made up of **carbon and hydrogen only**.
- Natural methane gas **CH<sub>4</sub>** is one of the main components of the natural gas used at homes
- propane gas **C<sub>3</sub>H<sub>8</sub>** is a fuel for stoves, outdoors grills, and hot air balloons.
- Hydrocarbons produce more than 90% of the energy we use, and hydrocarbons are important for medicine, clothes, and foods.



## Practice :

1- Which compound is the main component of natural gas?

A- Pentane

B- hexane

C- iso-octane

D- methane

2-What is a compound made up of only carbon and hydrogen atoms called?

A) Carbohydrate

B) Hydrocarbon

C) Alcohol

D) Acid

3- Which of the following is a natural gas that is a hydrocarbon?

A) Oxygen

B) Methane

C) Carbon dioxide

D) Ammonia

4- Which hydrocarbon is commonly used as fuel for stoves and hot-air balloons?

A) Propane

B) Butane

C) Ethanol

D) Hydrogen

5- What percentage of the energy that humans use is produced by hydrocarbons?

A) 50 percent

B) 70 percent

C) 90 percent

D) 100 percent

6- Besides being fuels, hydrocarbons are also important in:

A) Metals and minerals

B) Medicines, foods, and clothing

C) Water purification

D) Plant photosynthesis

7- Why can hydrocarbons play so many different roles?

- A) Because they are unstable and easily react
- B) Because their structures can differ in many ways
- C) Because they contain oxygen atoms
- D) Because they are inorganic substances

8- Which of the following statements about hydrocarbons is TRUE?

- A) Hydrocarbons contain oxygen and hydrogen only.
- B) Hydrocarbons produce less than 50% of human energy needs.
- C) Hydrocarbons consist only of carbon and hydrogen atoms.
- D) Hydrocarbons are found only in gases.

9- Which of the following best describes the role of hydrocarbons as fuels?

- A) They store and release large amounts of energy.
- B) They reduce energy efficiency.
- C) They are used only in cold regions.
- D) They cannot burn in air.

10- Propane and methane are examples of:

- A) Acids
- B) Hydrocarbons
- C) Alcohols
- D) Sugars

11- To understand the different uses of hydrocarbons, scientists must:

- A) Study how their structures differ
- B) Measure their boiling points
- C) Observe their color
- D) Burn them in air

- **Hydrocarbon lengths :** The number of carbon atoms in a straight chain hydrocarbon is indicated by the root of its name :
- The length of the carbon chain affects the properties of the compound.
- From graph the boiling point increases with the addition of carbon atoms. The reason that the forces of attraction between molecules increase so it needs more energy to separate molecules.

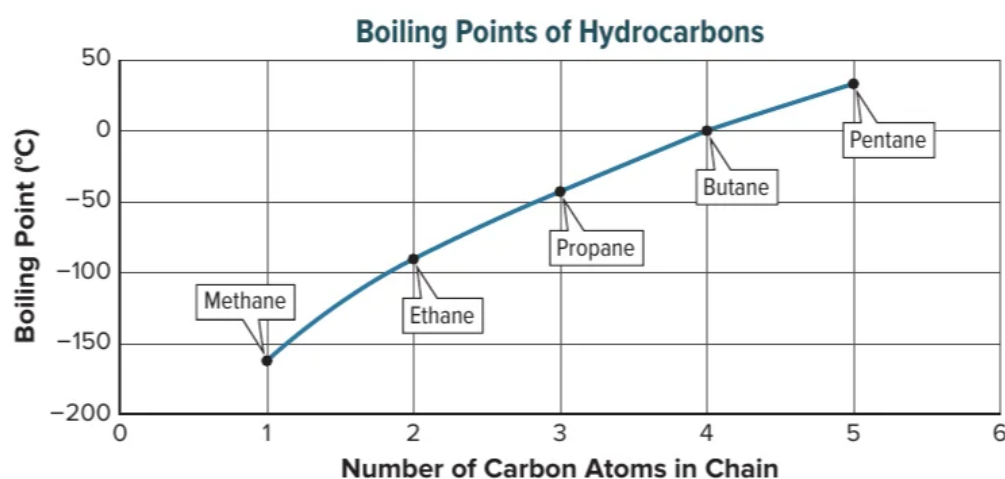


**Figure 3** The root of a hydrocarbon's name indicates how many carbons are in the hydrocarbon. Boiling points of hydrocarbons increase as the number of carbon atoms in the chain increases.

*Predict the approximate boiling point of hexane.*

**Table 1** Roots for Hydrocarbons

| Root  | Number of Carbon Atoms |
|-------|------------------------|
| Meth- | 1                      |
| Eth-  | 2                      |
| Prop- | 3                      |
| But-  | 4                      |
| Pent- | 5                      |
| Hex-  | 6                      |
| Hept- | 7                      |
| Oct-  | 8                      |

2- From the graph, what is the relation between boiling points and the number of carbon atoms in the chain?

.....

.....

3-Which compound has the highest boiling point.?

A- Methane      B- propane      C- ethane      D- butane

4-Which compound has the lowest boiling point.?

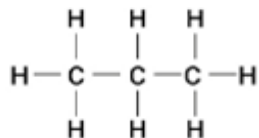
A- Butane      B- pentane      C- hexane      D- methane

5- How many carbon atoms are present in pentane ?

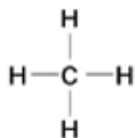
A- 2      B- 4      C- 5      D- 7

Select the correct answer.

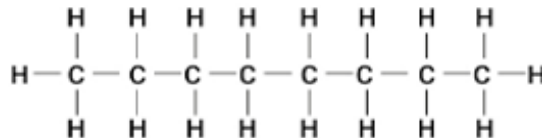
Study the hydrocarbons below. Arrange the hydrocarbons so that their boiling points decrease in order.



(1)



(2)



(3)

☐ 3 < 2 < 1

☐ 2 < 1 < 3

☐ 3 > 1 > 2

☐ 2 > 1 > 3

1- What happens to the boiling point of hydrocarbons as the number of carbon atoms increases?

- A) It decreases
- B) It stays the same
- C) It increases
- D) It fluctuates randomly

2- According to Figure 3, which hydrocarbon has the highest boiling point?

- A) Methane
- B) Propane
- C) Butane
- D) Pentane

3- What does Figure 3 show about the relationship between the number of carbon atoms and boiling point?

- A) Boiling point decreases as carbon atoms increase
- B) Boiling point increases as carbon atoms increase
- C) Boiling point is not affected by the number of carbons
- D) Boiling point depends on hydrogen only

4- The length of the carbon chain affects which property of the hydrocarbon?

- A) Color
- B) Boiling point
- C) Odor
- D) Electrical conductivity

## **Organic compounds:**

They are compounds that contain carbon element except carbon oxides ( $\text{CO}_2$ ,  $\text{CO}$ ), carbonates ( $\text{CO}_3^{2-}$ ) and carbides ( $\text{Al}_4\text{C}_3$ ,  $\text{Be}_2\text{C}$ ,  $\text{CaC}_2$ ) (inorganic compounds).

| Organic compounds<br>( contain Carbon)                                                                                             | Inorganic compounds<br>( not cotain Carbon )                                                     | Inorganic compounds<br>( cotain Carbon) Exceptions                                                                                  |
|------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------|
| $\text{CH}_4$ , $\text{CH}_3\text{COOH}$ , $\text{C}_3\text{H}_8$<br>$\text{N}(\text{CH}_3)_3$ , $\text{CH}_3\text{CH}_2\text{OH}$ | $\text{H}_2\text{O}$ , $\text{NaCl}$ , $\text{MgO}$ ,<br>$\text{Al}_2\text{O}_3$ , $\text{NH}_4$ | $\text{CO}_2$ , $\text{CO}$ , $\text{CaCO}_3$ , $\text{MgCO}_3$<br>$\text{Al}_4\text{C}_3$ , $\text{Be}_2\text{C}$ , $\text{CaC}_2$ |

➤ Of the millions of carbon compounds known today, more than 90% of them are organic compounds.

➤ Why scientists give organic compounds this name?

Because they thought that organic compounds only formed in living organisms' bodies. But in 1830 organic compounds have been prepared in the laboratory.

### **Practice :**

1- What do gasoline, vanilla flavoring, and natural rubber have in common?

- A) They are all inorganic compounds
- B) They are all made of carbon compounds
- C) They contain only hydrogen and oxygen
- D) They are all metals

2- What are most compounds that contain the element carbon called?

- A) Inorganic compounds
- B) Organic compounds
- C) Ionic compounds
- D) Metallic compounds

3- What are organic compounds mainly composed of?

- A) Hydrogen and nitrogen
- B) Oxygen and sulfur
- C) Carbon and hydrogen
- D) Carbon and sodium

4- Why were organic compounds given their name?

- A) Because they are found only in plants
- B) Because they were once thought to be made only by living organisms
- C) Because they contain oxygen
- D) Because they are found only in minerals

5- Which of the following is **not** an organic compound?

- A) Methane ( $\text{CH}_4$ )
- B) Ethanol ( $\text{C}_2\text{H}_5\text{OH}$ )
- C) Carbon dioxide ( $\text{CO}_2$ )
- D) Glucose ( $\text{C}_6\text{H}_{12}\text{O}_6$ )

6- What type of compounds are carbon dioxide and carbonates classified as?

- A) Organic compounds
- B) Inorganic compounds
- C) Metallic compounds
- D) Biological compounds

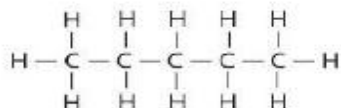
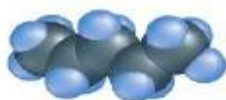
7- Which statement best defines *organic compounds*?

- A) Compounds that contain carbon and are made only by living things
- B) Compounds containing carbon that can be made by living organisms or in laboratories
- C) Compounds containing oxygen and nitrogen
- D) Compounds that form only gases

## Isomers

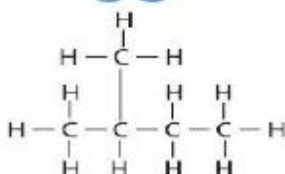
**Isomers:** are compounds that have identical chemical formulas but different molecular structures and shapes.  $C_5H_{12}$

Pentane



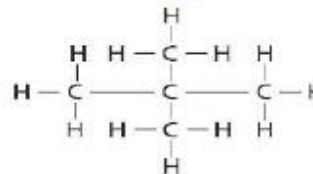
boiling point:  $36^{\circ}C$   
melting point:  $-130^{\circ}C$   
density:  $0.626 \text{ g/cm}^3$

Isopentane



boiling point:  $28^{\circ}C$   
melting point:  $-160^{\circ}C$   
density:  $0.620 \text{ g/cm}^3$

Neopentane



boiling point:  $9.5^{\circ}C$   
melting point:  $-17^{\circ}C$   
density:  $0.614 \text{ g/cm}^3$

- Pentane, isopentane, and neopentane have exactly the same chemical formula ( $C_5H_{12}$ ). However, their carbon atoms are arranged very differently
- In a molecule of pentane, the carbon atoms form a continuous chain. Isopentane has one branch, and neopentane has two branches.

### Practice :

1- What do pentane, isopentane, and neopentane have in common?

- A) They have the same chemical formula but different structures
- B) They have different chemical formulas but the same structure
- C) They are different elements
- D) They contain no carbon atoms

2- What is the chemical formula for pentane, isopentane, and neopentane?

- A)  $C_4H_{10}$
- B)  $C_3H_8$
- C)  $C_5H_{12}$
- D)  $C_6H_{14}$

3- What term is used for compounds that have the same chemical formula but different molecular structures and shapes?

- A) Hydrocarbons
- B) Isomers
- C) Polymers
- D) Catalysts

4- In pentane, how are the carbon atoms arranged?

- A) In a branched chain
- B) In a continuous (straight) chain
- C) In a ring structure
- D) In a double bond structure

5- How many branches does isopentane have?

- A) None
- B) One
- C) Two
- D) Three

6- How many branches does neopentane have?

- A) None
- B) One
- C) Two
- D) Three

7- Which of the following statements best describes isomers?

- A) Compounds with identical structures and formulas
- B) Compounds with identical chemical formulas but different structures
- C) Compounds with different formulas but identical structures
- D) Elements with different numbers of protons

8- The difference between pentane, isopentane, and neopentane is due to:

- A) The number of hydrogen atoms
- B) The type of bonds
- C) The arrangement of carbon atoms
- D) The color of the compounds

9- Which of the following is TRUE about isomers?

- A) They always have different chemical formulas
- B) They contain different elements
- C) They have identical chemical formulas but differ in shape and structure
- D) They have the same structure and shape

6

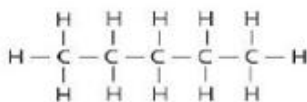
Describe isomers and their properties.

Check Your Progress Question 5

577,579

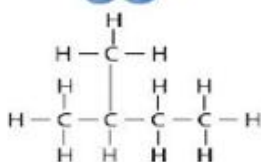
- **Properties of isomers:** the arrangement of carbon atoms in each compound change the shape of the molecule, which affects its physical properties.
- Melting and boiling points lower as the amount of branching in an isomer increases.

Pentane



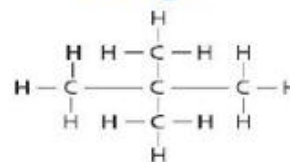
boiling point: 36°C  
melting point: -130°C  
density: 0.626 g/cm<sup>3</sup>

Isopentane



boiling point: 28°C  
melting point: -160°C  
density: 0.620 g/cm<sup>3</sup>

Neopentane



boiling point: 9.5°C  
melting point: -17°C  
density: 0.614 g/cm<sup>3</sup>

5. **Describe** how boiling and melting points generally vary as branching in hydrocarbon isomers increases.

**Practice :**

1- What changes in an isomer cause differences in physical properties?

- A) The color of the molecule
- B) The arrangement of carbon atoms
- C) The number of protons in each atom
- D) The type of elements present

2- The arrangement of carbon atoms in an isomer affects:

- A) Only chemical reactivity
- B) The shape of the molecule and its physical properties
- C) The atomic number
- D) The number of electrons

3- How do melting and boiling points generally change as the amount of branching in an isomer increases?

- A) They increase
- B) They stay the same
- C) They decrease
- D) They change randomly

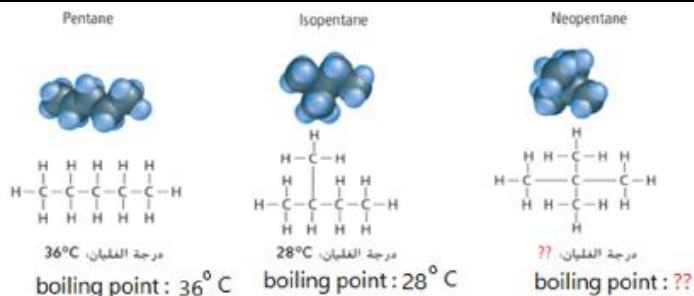
4- As the structure of a hydrocarbon becomes more branched:

- A) Its melting and boiling points increase
- B) Its melting and boiling points decrease
- C) Its chemical formula changes
- D) Its molecular mass increases

5- What property of isomers does branching directly affect?

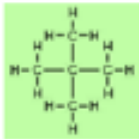
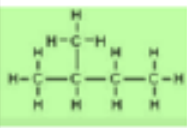
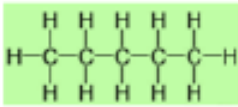
- A) Density only
- B) Boiling and melting points
- C) Color and odor
- D) Chemical formula

Regarding the isomers of the chemical formula  $C_5H_{12}$ , what is the expected boiling point of the Neopentane isomer?



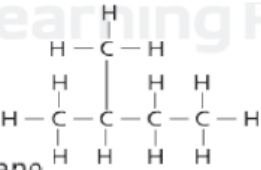
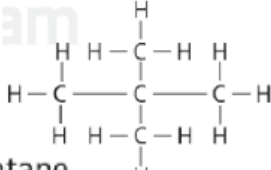
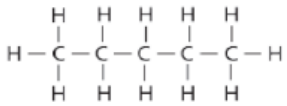
|   |            |   |                           |
|---|------------|---|---------------------------|
| A | Above 36°C | C | Below 36°C and above 28°C |
| B | Below 28°C | D | Equals 28°C               |

Why is the melting point of neopentane higher than the melting point of each of pentane and isopentane?

|                                                                                    |                                                                                    |                                                                                     |
|------------------------------------------------------------------------------------|------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|
|  |  |  |
| Neopentane النيوپنتان                                                              | Isopentane الأيزوبنتان                                                             | Pentane البنتان                                                                     |
| -17 °C درجة الانصهار<br>Melting Point                                              | -160°C درجة الانصهار<br>Melting Point                                              | -130°C درجة الانصهار<br>Melting Point                                               |

|   |                                                |   |                                                             |
|---|------------------------------------------------|---|-------------------------------------------------------------|
| A | Because there are no branches available        | C | Because the increase in the number of carbon atoms          |
| B | Because the decrease in the number of branches | D | Because the symmetry of the molecule and its globular shape |

Which of these statements is true about the following isomers?

| ①                                                                                                   | ②                                                                                                   | ③                                                                                                 |
|-----------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------|
|  <p>Isopentane</p> |  <p>Neopentane</p> |  <p>Pentane</p> |

|   |                                      |   |                                           |
|---|--------------------------------------|---|-------------------------------------------|
| A | pentane has the lowest melting point | C | they have different chemical formulas     |
| B | they are geometric isomers           | D | neopentane has globular (spherical) shape |

## Bonding in hydrocarbons

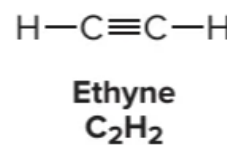
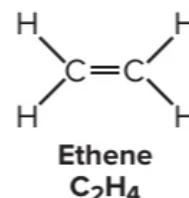
Hydrocarbons can contain single, double, and triple bonds between carbon atoms.

a- **Saturated hydrocarbons**: are hydrocarbons that contain only single covalent bonds between carbon atoms.

Table 2 Some Saturated Hydrocarbons

| Name               | Methane                                                                                     | Ethane                                                                                                                                             | Propane                                                                                                                                                                                                   | Butane                                                                                                                                                                                                                                                           |
|--------------------|---------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Chemical Formula   | $\text{CH}_4$                                                                               | $\text{C}_2\text{H}_6$                                                                                                                             | $\text{C}_3\text{H}_8$                                                                                                                                                                                    | $\text{C}_4\text{H}_{10}$                                                                                                                                                                                                                                        |
| Structural Formula | $\begin{array}{c} \text{H} \\   \\ \text{H}-\text{C}-\text{H} \\   \\ \text{H} \end{array}$ | $\begin{array}{c} \text{H} \quad \text{H} \\   \quad   \\ \text{H}-\text{C}-\text{C}-\text{H} \\   \quad   \\ \text{H} \quad \text{H} \end{array}$ | $\begin{array}{c} \text{H} \quad \text{H} \quad \text{H} \\   \quad   \quad   \\ \text{H}-\text{C}-\text{C}-\text{C}-\text{H} \\   \quad   \quad   \\ \text{H} \quad \text{H} \quad \text{H} \end{array}$ | $\begin{array}{c} \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \\   \quad   \quad   \quad   \\ \text{H}-\text{C}-\text{C}-\text{C}-\text{C}-\text{H} \\   \quad   \quad   \quad   \\ \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \end{array}$ |

b- **Unsaturated hydrocarbons**: are hydrocarbons that contain at least one double or triple covalent bond between carbon atoms.



4. Explain the term *saturated* in relation to hydrocarbons. What are these compounds saturated with?

### Practice :

1- Hydrocarbons that contain only single bonds between carbon atoms are called:

- A) Unsaturated hydrocarbons
- B) Aromatic hydrocarbons
- C) Saturated hydrocarbons
- D) Cyclic hydrocarbons

2- What does it mean when a hydrocarbon is *saturated*?

- A) It contains oxygen atoms
- B) It holds as many hydrogen atoms as possible
- C) It has double bonds between carbon atoms
- D) It contains few hydrogen atoms

3- Hydrocarbons that contain at least one double or triple bond are called:

- A) Saturated hydrocarbons
- B) Unsaturated hydrocarbons
- C) Aromatic hydrocarbons
- D) Ionic hydrocarbons

4- Which of the following is an example of a saturated hydrocarbon?

- A) Ethene ( $C_2H_4$ )
- B) Ethyne ( $C_2H_2$ )
- C) Ethane ( $C_2H_6$ )
- D) Benzene ( $C_6H_6$ )

5- Which of the following hydrocarbons contains a double bond?

- A) Ethane
- B) Ethene
- C) Ethyne
- D) Methane

6- Which of the following hydrocarbons contains a triple bond?

- A) Ethane
- B) Ethene
- C) Ethyne
- D) Propane

7- Ethene ( $C_2H_4$ ) and ethyne ( $C_2H_2$ ) are examples of:

- A) Saturated hydrocarbons
- B) Unsaturated hydrocarbons
- C) Aromatic hydrocarbons
- D) Inorganic compounds

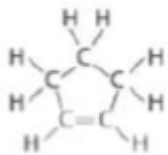
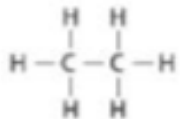
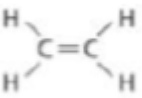
❖ Exercise: write the compound that match the type of bond in the coming table?

Ethane- ethene- ethyne- propyne- pentene- octane- hexene -  $CH_4$ -  $C_2H_2$  -  $C_4H_{10}$  -  $C_3H_4$  -  $C_5H_{10}$

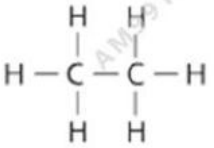
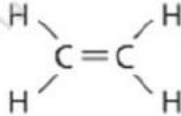
| single covalent bond | double covalent bond | triple covalent bond |
|----------------------|----------------------|----------------------|
|                      |                      |                      |

|                                                                     |          |   |          |
|---------------------------------------------------------------------|----------|---|----------|
| Which of the following formulas represents unsaturated hydrocarbon? |          |   |          |
| A                                                                   | $CH_4$   | C | $C_3H_8$ |
| B                                                                   | $C_2H_6$ | D | $C_2H_4$ |

Which of the following structural formulas represents a saturated hydrocarbon?

|   |                                                                                   |   |                                                                                    |
|---|-----------------------------------------------------------------------------------|---|------------------------------------------------------------------------------------|
| A |  | C |  |
| B |  | D |  |

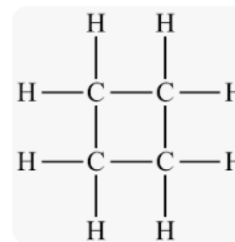
Regarding the compounds in the table below, which is **unsaturated** hydrocarbon?

|                                                                                    |                                                                                    |                                                                                      |
|------------------------------------------------------------------------------------|------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|
|  |  |  |
| <b>3</b>                                                                           | <b>2</b>                                                                           | <b>1</b>                                                                             |

|   |                            |   |                            |
|---|----------------------------|---|----------------------------|
| A | The compound <b>1</b> only | C | The compounds <b>1, 3</b>  |
| B | The compounds <b>2, 3</b>  | D | The compound <b>2</b> only |

**Explain Your Thinking**

6. **Analyze** Cyclobutane is a cyclic, saturated hydrocarbon containing four carbon atoms. Draw its structural formula. Are cyclobutane and butane isomers? Explain.

**Practice :**

1- Cyclobutane is best described as a:

- A) Linear, unsaturated hydrocarbon
- B) Cyclic, saturated hydrocarbon
- C) Branched, unsaturated hydrocarbon
- D) Linear, aromatic hydrocarbon

2- How many carbon atoms does cyclobutane contain?

- A) Two
- B) Three
- C) Four
- D) Five

3- What type of bonds are found between the carbon atoms in cyclobutane?

- A) Single covalent bonds
- B) Double covalent bonds
- C) Triple covalent bonds
- D) Ionic bonds

4- What is the molecular formula of both cyclobutane and butane?

- A)  $C_3H_6$
- B)  $C_4H_8$
- C)  $C_4H_{10}$
- D)  $C_5H_{12}$

6- What is the main structural difference between butane and cyclobutane?

- A) Butane forms a straight chain, while cyclobutane forms a ring
- B) Butane has double bonds, while cyclobutane does not
- C) Cyclobutane contains more hydrogen atoms
- D) Butane contains oxygen atoms

7- What type of hydrocarbon is butane?

- A) Unsaturated and cyclic
- B) Saturated and cyclic
- C) Saturated and straight-chain
- D) Aromatic

8- What is the molecular formula of **butane**?

- A)  $C_4H_8$
- B)  $C_4H_{10}$
- C)  $C_4H_6$
- D)  $C_3H_8$

9- What is the molecular formula of **cyclobutane**?

- A)  $C_4H_{10}$
- B)  $C_4H_8$
- C)  $C_4H_6$
- D)  $C_3H_8$

10- Are **cyclobutane** and **butane** isomers?

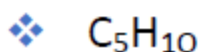
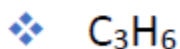
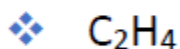
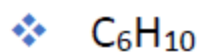
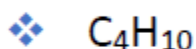
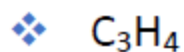
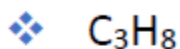
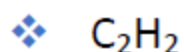
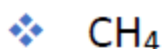
- A) Yes, because they have the same molecular formula.
- B) No, because they have different molecular formulas.
- C) Yes, because they both contain four carbon atoms.
- D) No, because they both are cyclic compounds.

Table 1 Roots for Hydrocarbons

| Root  | Number of Carbon Atoms |
|-------|------------------------|
| Meth– | 1                      |
| Eth–  | 2                      |
| Prop– | 3                      |
| But–  | 4                      |
| Pent– | 5                      |
| Hex–  | 6                      |
| Hept– | 7                      |
| Oct–  | 8                      |

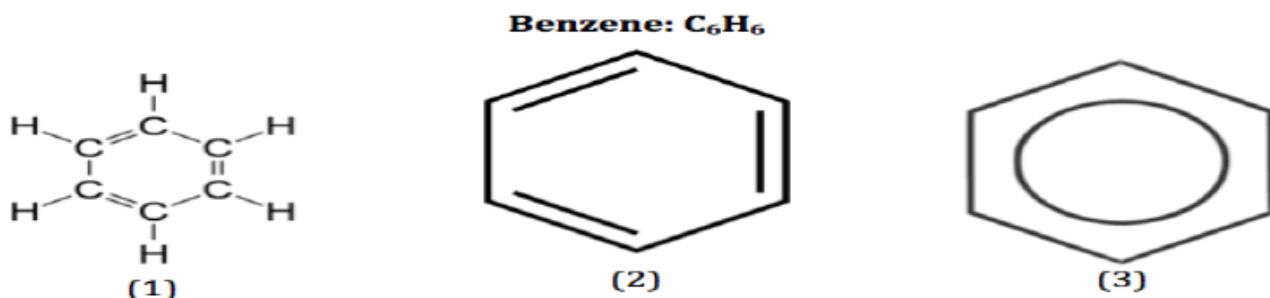
|                    | Alkane                                                                                  | Alkene                                                                                                         | Alkyne                                              |
|--------------------|-----------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------|-----------------------------------------------------|
| General formula    | $C_nH_{2n+2}$<br>n = number of carbon atoms                                             | $C_nH_{2n}$                                                                                                    | $C_nH_{2n-2}$                                       |
| type               | single                                                                                  | double                                                                                                         | triple                                              |
| show               | $C-C$                                                                                   | $C=C$                                                                                                          | $C\equiv C$                                         |
| Name end with      | ane                                                                                     | ene                                                                                                            | yne                                                 |
| example            | Ethane $C_2H_6$                                                                         | Ethene $C_2H_4$                                                                                                | Ethyne $C_2H_2$                                     |
| Structural formula | $  \begin{array}{c}  H & H \\    &   \\  H-C & -C-H \\    &   \\  H & H  \end{array}  $ | $  \begin{array}{c}  H & & H \\  & \diagdown & / \\  & C = C & \\  & / & \diagdown \\  H & & H  \end{array}  $ | $  \begin{array}{c}  H-C \equiv C-H  \end{array}  $ |

❖ Write in structural formula then name the compound :



**Benzene:** is a cyclic hydrocarbon with carbon atoms that are joined with alternating single and double bonds ( $C_6H_6$ ).

- The electrons in the double bonds are shared by all the six carbon atoms in the ring.
- The equal sharing of electrons is represented by the benzene symbol: a circle in a hexagon.



### Practice :

1- What is the molecular formula of **benzene**?

- A)  $C_4H_8$
- B)  $C_6H_6$
- C)  $C_5H_{12}$
- D)  $C_6H_{12}$

2- Benzene is classified as an example of a(n):

- A) Aliphatic hydrocarbon
- B) Aromatic hydrocarbon
- C) Saturated hydrocarbon
- D) Unsaturated aliphatic compound

3- What type of bonds are found between the carbon atoms in benzene?

- A) Only single bonds
- B) Only double bonds
- C) Alternating single and double bonds
- D) Triple bonds only

4- How many carbon atoms are present in one molecule of benzene?

- A) 4
- B) 5
- C) 6
- D) 8

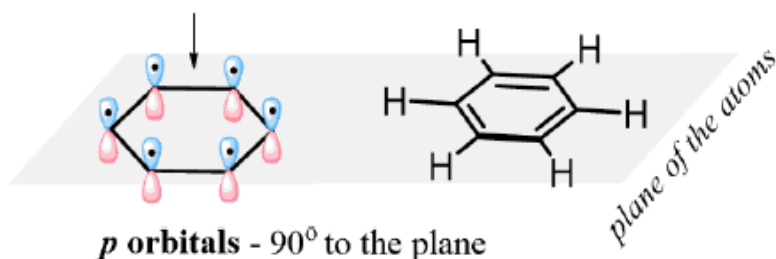
5- How many hydrogen atoms are in a molecule of benzene?

- A) 4
- B) 6
- C) 8
- D) 10

6- Which of the following correctly describes benzene's structure?

- A) A straight-chain hydrocarbon
- B) A branched hydrocarbon
- C) A cyclic hydrocarbon
- D) A single-bonded alkane

➤ **Benzene is very stable** because all carbon atoms share the electrons of the double bonds in the ring. And the carbon atoms are bonded in a rigid flat structure.



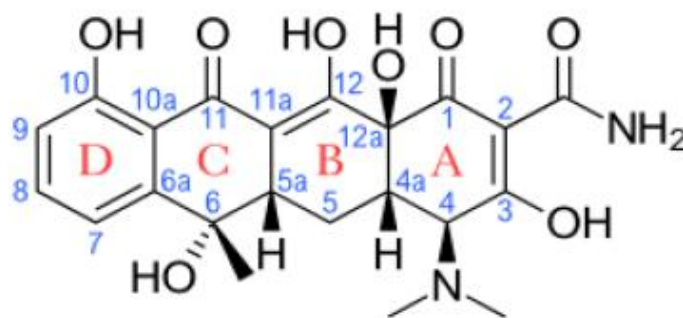
### Fused rings:

Benzene ring can fuse together, like in naphthalene molecule. **Naphthalene** is used in mothball, which have a distinct odor.

**Tetracycline antibiotics** are based on fused ring system containing four fused rings.



Naphthalene



### Practice :

1- Why is **benzene** very stable?

- A) Because it has single bonds only
- B) Because all carbon atoms share the electrons of the double bonds in the ring
- C) Because it has no hydrogen atoms
- D) Because its bonds are weak

2- What is the shape or structure of the benzene molecule?

- A) A linear chain
- B) A bent structure
- C) A rigid, flat ring
- D) A branched chain

3- What is **naphthalene**?

- A) A single benzene ring
- B) Two benzene rings fused together
- C) A straight-chain alkane
- D) A triple-bonded alkyne

4- What is **naphthalene** commonly used for?

- A) In perfumes
- B) In mothballs due to its distinct odor
- C) As a cooking fuel
- D) In fertilizers

5- What are **fused rings**?

- A) Rings that contain single bonds only
- B) Two or more benzene rings that share common carbon atoms
- C) Separate rings that do not touch
- D) Rings that contain oxygen atoms

6- The **delocalization of electrons** in benzene leads to:

- A) Instability of the molecule
- B) Increased chemical reactivity
- C) High stability of the molecule
- D) Breaking of bonds easily

Which of the following statements is **NOT true** of benzene molecule?

|   |                                     |   |                                                                   |
|---|-------------------------------------|---|-------------------------------------------------------------------|
| A | Its symbol is a circle in a hexagon | C | Have the chemical formula $C_3H_6$                                |
| B | Very stable cyclic hydrocarbon      | D | Carbon atoms are joined with alternating single and double bonds. |

## Replacing Hydrogen

- Chemists often change hydrocarbons into other compounds having different physical and chemical properties.
- They may include a double or triple bond or add different atoms or groups of atoms to a hydrocarbon.
- A substituted hydrocarbon** has one or more of its hydrogen atoms replaced by atoms, or groups of atoms, of other elements.
- functional groups** :The groups of atoms used in the substitution.
- Depending on what properties are needed, chemists decide what functional groups to add.
- Examples of substituted hydrocarbons

|                      | Functional group                                                                                        | General formula    |
|----------------------|---------------------------------------------------------------------------------------------------------|--------------------|
| <b>Alcohols</b>      | OH Hydroxide group                                                                                      | R-OH               |
| <b>Organic acids</b> | $\text{COOH} \quad \begin{array}{c} \text{O} \\ \parallel \\ \text{—C—OH} \end{array}$ Carboxylic group | R-COOH             |
| <b>Esters</b>        | O- CO- Ester group<br>$\begin{array}{c} \text{O} \\ \parallel \\ \text{—C—O—} \end{array}$              | R-OCO -R'          |
| <b>Amines</b>        | NH <sub>2</sub> Amine group                                                                             | R -NH <sub>2</sub> |
| <b>Thiols</b>        | SH thiole group                                                                                         | R-SH               |
| <b>Halocarbons</b>   | X ( Cl-F-Br-I)                                                                                          | R-X                |

## Explain Your Thinking

12. **Explain** Chloroethane (C<sub>2</sub>H<sub>5</sub>Cl) can be used as a spray-on anesthetic for localized injuries. How does chloroethane fit the definition of a substituted hydrocarbon? Diagram its structure.

Practice :

1- What is a **substituted hydrocarbon**?

- A) A hydrocarbon that has lost all its hydrogen atoms
- B) A hydrocarbon in which one or more hydrogen atoms are replaced by other atoms or groups of atoms
- C) A hydrocarbon that contains only single bonds
- D) A hydrocarbon that has no carbon atoms

2- What do chemists often do to change hydrocarbons into other compounds?

- A) Remove all hydrogen atoms
- B) Add atoms or groups of atoms to replace hydrogen
- C) Decrease the number of carbon atoms
- D) Increase the molecular weight only

3- The groups of atoms that replace hydrogen in substituted hydrocarbons are called:

- A) Isomers
- B) Bonds
- C) Functional groups
- D) Catalysts

4- Which of the following is an example of a substituted hydrocarbon?

- A) Methane ( $\text{CH}_4$ )
- B) Ethane ( $\text{C}_2\text{H}_6$ )
- C) Chloroethane ( $\text{C}_2\text{H}_5\text{Cl}$ )
- D) Propane ( $\text{C}_3\text{H}_8$ )

5- How does **chloroethane ( $\text{C}_2\text{H}_5\text{Cl}$ )** fit the definition of a substituted hydrocarbon?

- A) A chlorine atom replaces one hydrogen atom
- B) A hydrogen atom replaces one chlorine atom
- C) It contains only carbon and hydrogen atoms
- D) It has a double bond between carbons

#### Summary:

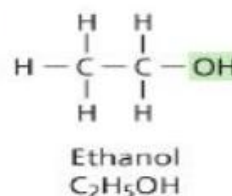
- **Parent hydrocarbon:** Ethane ( $\text{C}_2\text{H}_6$ )
- **Substitution:** One H  $\rightarrow$  replaced by Cl
- **New compound:** Chloroethane ( $\text{C}_2\text{H}_5\text{Cl}$ )
- **Type:** Substituted hydrocarbon (haloalkane)
- **Use:** Local anesthetic spray for minor injuries

## Substituting Oxygen Groups

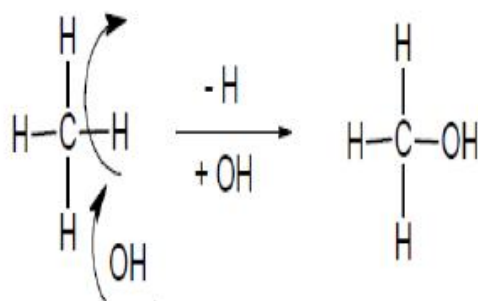
- Oxygen is found in the air, in water, and in many substituted hydrocarbons.
  - Oxygen can form single and double bonds with carbon and single bonds with hydrogen.
  - As a result, there are many compounds containing just carbon, hydrogen, and oxygen.
- These compounds include alcohols, organic acids, and esters.

## Alcohols

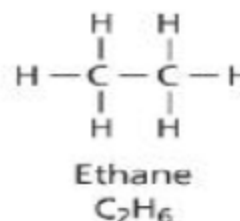
- Rubbing alcohol, used for rubbing aching muscles, is a substituted hydrocarbon.
- An **alcohol** is formed when  $\text{-OH}$  groups replace one or more hydrogen atoms in a hydrocarbon.
- Alcohols often serve as solvents and disinfectants and can be used as pieces to assemble larger molecules.
- **Figure 10** shows ethanol, an alcohol produced by the fermentation of sugar in grains and in fruit.



Most ethanol ( $\text{C}_2\text{H}_5\text{OH}$ ) is obtained from corn.



Substituting  $\text{-OH}$  forms an alcohol

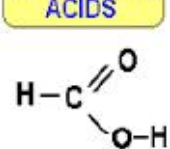


## Organic acids

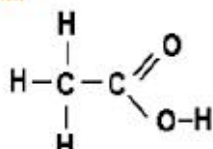
- Organic acids form when a carboxyl group ( $-\text{COOH}$ ) is substituted for one of the hydrogen atoms in a hydrocarbon.
- Ethanoic acid, also known as acetic acid, is an organic acid found in vinegar. As shown in **Figure 10**, the structures of ethanol and ethanoic acid are similar.
  - You know some other organic acids, like citric acid found in citrus fruits, such as oranges and lemons, and lactic acid found in sour milk.

### CARBOXYLIC ACIDS

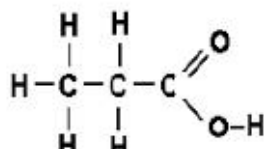
© Doc Brown



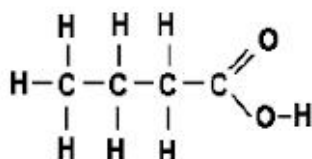
methanoic acid



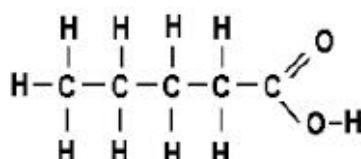
ethanoic acid



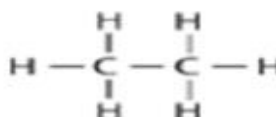
propanoic acid



butanoic acid



pentanoic acid



Ethane  
 $\text{C}_2\text{H}_6$



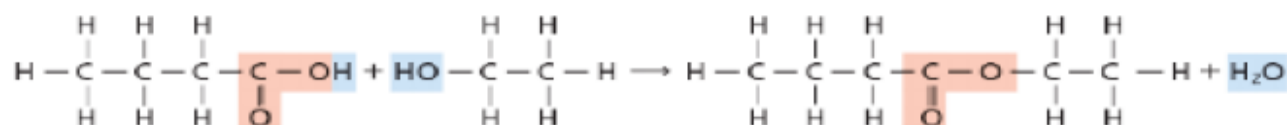
Ethanoic acid  
 $\text{CH}_3\text{COOH}$

Ethanoic acid ( $\text{CH}_3\text{COOH}$ ) is found in vinegar.

Substituting  $-\text{COOH}$  forms an organic acid

## Esters

- Recall that mixing an acid and a base will yield water and a salt.
- In a similar way, alcohols and organic acids combine to form water and an ester.
- An **ester** is a substituted hydrocarbon with a  $-\text{COOC}-$  group.
- Figure 11** shows the reaction of butyric acid and ethyl alcohol to produce water and the ester ethyl butyrate, which is a component in pineapple flavor.



Butyric acid

Ethyl alcohol

Ethyl butyrate

Water

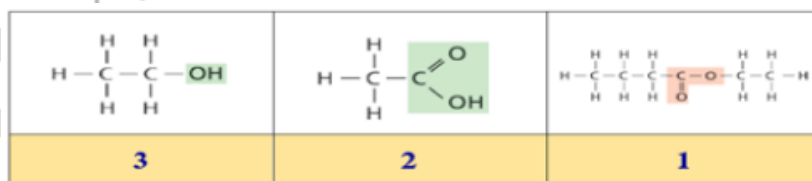
8. **Classify** each of the following as a hydrocarbon or a substituted hydrocarbon: ethyne, tetrachloroethene, ethanol, benzene, propane, and acetic acid.

| Compound          | Formula    | Classification          |
|-------------------|------------|-------------------------|
| Ethyne            | $C_2H_2$   | Hydrocarbon             |
| Tetrachloroethene | $C_2Cl_4$  | Substituted hydrocarbon |
| Ethanol           | $C_2H_5OH$ | Substituted hydrocarbon |
| Benzene           | $C_6H_6$   | Hydrocarbon             |
| Propane           | $C_3H_8$   | Hydrocarbon             |
| Acetic acid       | $CH_3COOH$ | Substituted hydrocarbon |

### Practice :

Regarding the substituted hydrocarbons in the table

below, which of the following is correct?

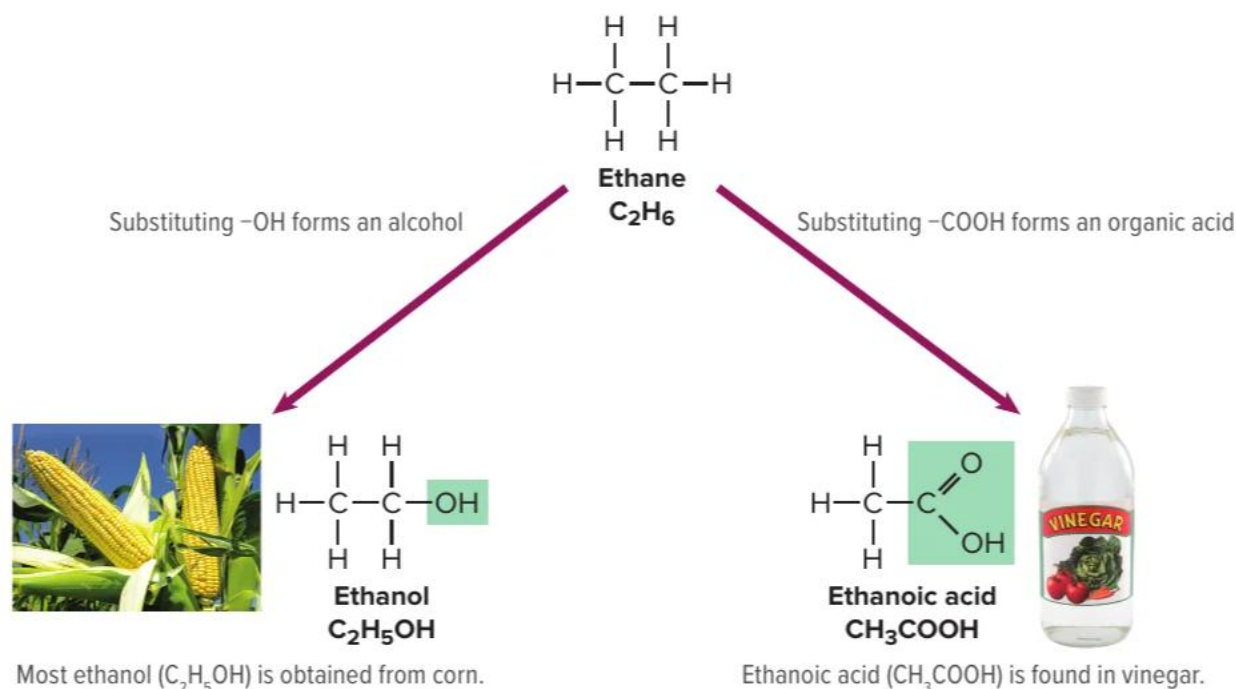


| 3               | 2               | 1               |   |
|-----------------|-----------------|-----------------|---|
| إستر<br>Ester   | حمض<br>Acid     | كحول<br>Alcohol | A |
| كحول<br>Alcohol | حمض<br>Acid     | إستر<br>Ester   | B |
| حمض<br>Acid     | إستر<br>Ester   | كحول<br>Alcohol | C |
| إستر<br>Ester   | كحول<br>Alcohol | حمض<br>Acid     | D |

|   |   |   |   |
|---|---|---|---|
| A | A | C | C |
| B | B | D | D |

What results if  $\text{-COOH}$  group replaces one or more hydrogen atoms in a hydrocarbon?

- a. organic acid
- b. alcohol
- c. ester
- d. amine



## Organic acids

Organic acids form when a carboxyl group ( $-\text{COOH}$ ) is substituted for one of the hydrogen atoms in a hydrocarbon. Ethanoic acid, also known as acetic acid, is an organic acid found in vinegar. As shown in **Figure 10**, the structures of ethanol and ethanoic acid are similar. You know some other organic acids, too—citric acid found in citrus fruits, such as oranges and lemons, and lactic acid found in sour milk.



### Get It?

**Explain** why organic acids are considered substituted hydrocarbons.

### Practice :

1- What functional group is found in **organic acids**?

- A) Hydroxyl group ( $-\text{OH}$ )
- B) Carboxyl group ( $-\text{COOH}$ )
- C) Amino group ( $-\text{NH}_2$ )
- D) Carbonyl group ( $\text{C}=\text{O}$ )

2- What happens when a carboxyl group ( $\text{-COOH}$ ) replaces a hydrogen atom in a hydrocarbon?

- A) The compound becomes a hydrocarbon gas.
- B) The compound becomes an **organic acid**.
- C) The compound becomes an alcohol.
- D) The compound becomes an ester.

3- Why are **organic acids** considered **substituted hydrocarbons**?

- A) They contain only carbon and hydrogen atoms.
- B) A hydrogen atom in the hydrocarbon is replaced by a carboxyl group ( $\text{-COOH}$ ).
- C) They contain triple bonds between carbon atoms.
- D) They have no functional groups.

4- What is another name for **ethanoic acid**?

- A) Methanol
- B) Acetic acid
- C) Propanoic acid
- D) Citric acid

5- In what common household item is **acetic acid** found?

- A) Soap
- B) Vinegar
- C) Detergent
- D) Perfume

6- Which of the following is an **organic acid**?

- A) Ethanol ( $\text{C}_2\text{H}_5\text{OH}$ )
- B) Ethanoic acid ( $\text{CH}_3\text{COOH}$ )
- C) Methane ( $\text{CH}_4$ )
- D) Benzene ( $\text{C}_6\text{H}_6$ )

7- Which of the following is **NOT** an organic acid?

- A) Citric acid
- B) Lactic acid
- C) Methane
- D) Acetic acid

8- What type of organic compounds are found in **citrus fruits** such as oranges and lemons?

- A) Alcohols
- B) Organic acids
- C) Esters
- D) Hydrocarbons

Odai Alassi

10. **Explain** why chemists might want to prepare substituted hydrocarbons. Give two examples of possible substitutions.

Answer : to create compounds with **different chemical and physical properties** that can be useful for specific purposes .

**Examples of possible substitutions:**

**1. Chloroethane ( $C_2H_5Cl$ ):**

Formed when a **hydrogen atom** in ethane ( $C_2H_6$ ) is **replaced by chlorine (Cl)**.

→ Used as a **local anesthetic**.

**2. Ethanol ( $C_2H_5OH$ ):**

Formed when a **hydrogen atom** in ethane ( $C_2H_6$ ) is **replaced by a hydroxyl group ( $-OH$ )**.

→ Used in **fuels, disinfectants, and beverages**.

**Practice :**

1- Why do chemists prepare **substituted hydrocarbons**?

- A) To increase the number of hydrogen atoms
- B) To create compounds with different physical and chemical properties
- C) To make hydrocarbons lighter in mass
- D) To remove all carbon atoms

2- Which of the following is an example of a substituted hydrocarbon used as a **local anesthetic**?

- A) Ethanol ( $C_2H_5OH$ )
- B) Methane ( $CH_4$ )
- C) Chloroethane ( $C_2H_5Cl$ )
- D) Propane ( $C_3H_8$ )

3- Which of the following is **not** a substituted hydrocarbon?

- A) Methane ( $\text{CH}_4$ )
- B) Ethanol ( $\text{C}_2\text{H}_5\text{OH}$ )
- C) Chloroethane ( $\text{C}_2\text{H}_5\text{Cl}$ )
- D) Acetic acid ( $\text{CH}_3\text{COOH}$ )

**11. Identify** possible uses for each of the following types of substituted hydrocarbons: alcohols, esters, and halocarbons.

| Name          | Functional group   | General formula  | Example                              | Naming                  | uses                             |
|---------------|--------------------|------------------|--------------------------------------|-------------------------|----------------------------------|
| Alcohol       | Hydroxyl<br>-OH    | R-OH             | $\text{C}_2\text{H}_5\text{OH}$      | Ethan <b>ol</b>         | Fuel , solvent ,<br>disinfectant |
| Organic acids | Carboxyl<br>-COOH  | R-COOH           | $\text{CH}_3\text{COOH}$             | Ethan <b>oic acid</b>   | In milk , and fruit              |
| Esters        | -COO-              | R-COO-R          | $\text{CH}_3\text{COOC}_2\text{H}_5$ | Ethyl ethan <b>oate</b> | Fruits                           |
| Thiols        | -SH                | R-SH             | $\text{C}_3\text{H}_7\text{SH}$      | Propan <b>ethiol</b>    | In garlic                        |
| Halocarbons   | -X<br>X: F,Cl,Br,I | R-X              | $\text{CH}_3\text{Br}$               | <b>Bromomethane</b>     | pesticide                        |
| Amines        | -NH <sub>2</sub>   | RNH <sub>2</sub> | $\text{C}_2\text{H}_5\text{NH}_2$    | Ethyl <b>amine</b>      | plastic                          |

## Bonding in hydrocarbons

Hydrocarbons can contain single, double, and triple bonds between carbon atoms. An easy way to know what type of bond that a hydrocarbon has is to look at the last three letters of the compound's name. The ending *-ane* indicates a single bond only, the ending *-ene* indicates a double bond, and *-yne* indicates a triple bond.

### Practice :

1- What type of bonds can hydrocarbons contain?

- A) Only single bonds
- B) Only double bonds
- C) Only triple bonds
- D) Single, double, and triple bonds

2- What does the **ending “-ane”** in a hydrocarbon's name indicate?

- A) It has a double bond
- B) It has a triple bond
- C) It has single bonds only
- D) It has no carbon atoms

3- Which of the following hydrocarbons contains a **double bond**?

- A) Ethane
- B) Ethene
- C) Ethyne
- D) Methane

4- Which of the following endings shows that a hydrocarbon contains a **triple bond**?

- A) -ane
- B) -ene
- C) -yne
- D) -one

5- Which hydrocarbon contains **only single bonds** between its carbon atoms?

- A) Propane
- B) Propene
- C) Propyne
- D) Ethyne

6-The hydrocarbon **ethyne** ( $\text{C}_2\text{H}_2$ ) contains what type of bond between its carbon atoms?

- A) Single bond
- B) Double bond
- C) Triple bond
- D) Ionic bond

7- What does the ending “**-ene**” in a hydrocarbon’s name indicate?

- A) A single bond
- B) A double bond
- C) A triple bond
- D) No bond

8- Which of the following hydrocarbons is **unsaturated**?

- A) Methane ( $\text{CH}_4$ )
- B) Ethane ( $\text{C}_2\text{H}_6$ )
- C) Ethene ( $\text{C}_2\text{H}_4$ )
- D) Propane ( $\text{C}_3\text{H}_8$ )

9- The difference between **ethane**, **ethene**, and **ethyne** lies in:

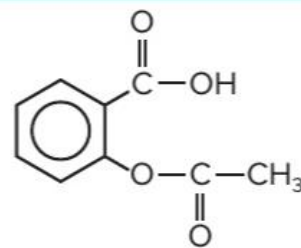
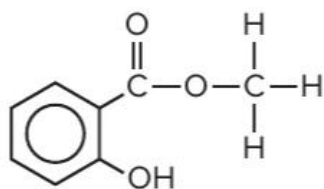
- A) The number of oxygen atoms
- B) The type of bonds between carbon atoms
- C) The position of hydrogen atoms
- D) The presence of nitrogen

## Aromatic Compounds

Recall that benzene is very stable and makes a good building block for compounds. All compounds that contain a benzene structure are **aromatic compounds**. Benzene's hydrogen atoms can be replaced with various functional groups to make many different aromatic compounds.

### Aromatic compounds and smell

Aromatic compounds are so named because most of them have a distinctive smell. They contribute to the smell of cloves, cinnamon, and vanilla. Some aromatic compounds produce pleasant odors or tastes. For example, methyl salicylate, shown in **Figure 15**, produces a fresh wintergreen fragrance. Other aromatic compounds have less pleasant flavors and smells. Aspirin, also shown in **Figure 15**, is a sour-tasting aromatic compound. The different flavors are due to the different functional groups.



Methyl salicylate gives gum and mints a wintergreen flavor.

Acetyl salicylic acid, commonly called aspirin, is a pain reliever.

**Figure 15** Aromatic compounds contain a benzene ring and often have strong scents and flavors.

- 1- Why are aromatic compounds called "aromatic"?
  - A) Because they are made from aroma oils
  - B) Because most of them have distinctive smells
  - C) Because they have no odor
  - D) Because they contain only single bonds
- 2- What do aromatic compounds often contain in their structure?
  - A) A chain of single carbon bonds
  - B) A benzene ring
  - C) A carboxyl group only
  - D) A hydroxyl group only

3-What type of smell do most aromatic compounds produce?

- A) Metallic smell
- B) Distinctive or pleasant smell
- C) No smell
- D) Acidic odor only

4- Which aromatic compound gives **gum and mints** a **wintergreen flavor**?

- A) Aspirin (acetyl salicylic acid)
- B) Methyl salicylate
- C) Benzene
- D) Ethanol

5- Which aromatic compound is used as a **pain reliever**?

- A) Methyl salicylate
- B) Acetyl salicylic acid (aspirin)
- C) Benzene
- D) Propanol

6- Which of the following is **true** about aromatic compounds?

- A) They never have a smell
- B) They always taste sour
- C) They often have pleasant odors or flavors
- D) They are non-organic substances

7- What gives **aspirin** its **sour taste**?

- A) The carbon ring
- B) The acetyl and carboxyl functional groups
- C) The chlorine atoms
- D) The oxygen atom only

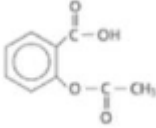
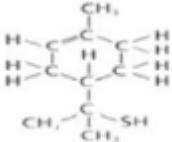
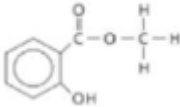
8- Aromatic compounds contribute to the smell of all the following **except**:

- A) Cloves
- B) Cinnamon
- C) Vanilla
- D) Oxygen

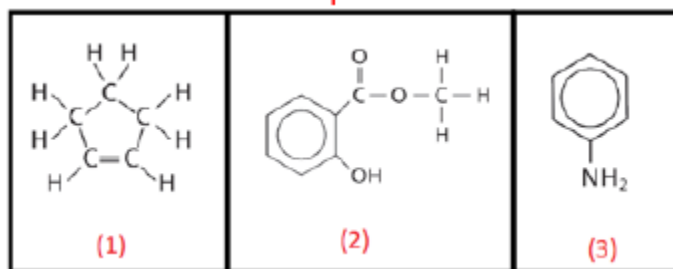
Which of the following correctly describes aromatic compounds?

|   |                                                                                                             |   |                                                                   |
|---|-------------------------------------------------------------------------------------------------------------|---|-------------------------------------------------------------------|
| A | Forms when a carboxyl group( $-\text{COOH}$ ) is substituted for one of the hydrogen atoms in a hydrocarbon | C | All contain ( $-\text{OH}$ ) group                                |
| B | Forms when amine group( $-\text{NH}_2$ ) replaces a hydrogen atom in a hydrocarbon                          | D | Contain benzene structure and most of them have distinctive smell |

Which of the following is **Not** an aromatic compound?

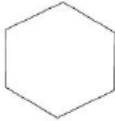
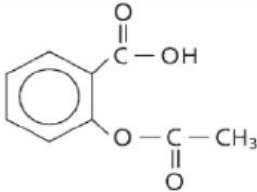
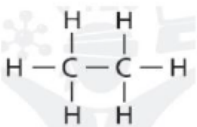
|   |                                                                                    |   |                                                                                      |
|---|------------------------------------------------------------------------------------|---|--------------------------------------------------------------------------------------|
| A |   | C |    |
| B |  | D |  |

Which of the following is an aromatic compound?



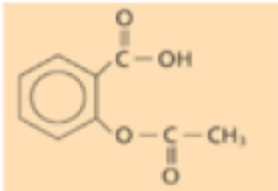
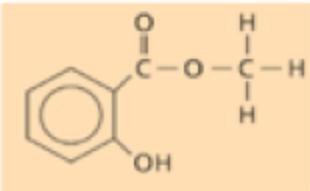
|   |            |   |           |
|---|------------|---|-----------|
| A | 1, 2 and 3 | C | 2, 3 only |
| B | 2 only     | D | 1, 2 only |

Which of the following compounds are aromatic compounds?

| ①                                                                                 | ②                                                                                 | ③                                                                                   |
|-----------------------------------------------------------------------------------|-----------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|
|  |  |  |

|   |            |   |           |
|---|------------|---|-----------|
| A | 1, 2 and 3 | C | 2, 3 only |
| B | 2 only     | D | 1, 2 only |

Regarding the two compounds in the table below,  
which of the following is **incorrect**?

|                                                                                    |                                                                                     |
|------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|
|  |  |
| <b>1</b>                                                                           | <b>2</b>                                                                            |

|   |                                                                                     |   |                                                                                      |
|---|-------------------------------------------------------------------------------------|---|--------------------------------------------------------------------------------------|
| A | Benzene is chemically stable and makes a good building block for aromatic compounds | C | The compound <b>2</b> gives mints their wintergreen flavor                           |
| B | The compound <b>1</b> is used as a pain reliever                                    | D | Benzene is chemically unstable and makes a bad building block for aromatic compounds |

## Halocarbons

A substituted hydrocarbon with a halogen, such as chlorine or bromine, in place of a hydrogen atom is called a halocarbon. For example, when four chlorine atoms replace four hydrogen atoms in ethene, the result is tetrachloroethene (teh truh klor uh eh THEEN), a solvent used in dry cleaning. Adding four fluorine atoms to ethene makes a compound that is a starting material for making nonstick coatings on cookware, as shown in **Figure 14**.



**Tetrafluoroethene**

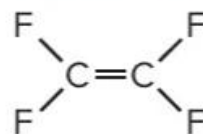


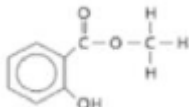
**Figure 14** Tetrafluoroethene is a halocarbon used to make nonstick coatings on pans.

What substituted hydrocarbon is used in industry to make non-stick coatings on pans?



|   |                 |   |                   |
|---|-----------------|---|-------------------|
| A | Ethyl butanoate | C | Tetrafluoroethene |
| B | Aniline         | D | Thiol             |

Which of the following structural formulas represents halocarbons?

|   |                                                                                   |   |                                                                                    |
|---|-----------------------------------------------------------------------------------|---|------------------------------------------------------------------------------------|
| A |  | C |  |
| B |  | D |  |

## Polymer properties

The properties of polymers depend mostly on which monomers are used to make them. The amount of branching and the shape of the polymer also greatly affect its properties. Because of this diversity, polymers can be made light and flexible or strong enough to make plastic pipes, boats, and even some auto bodies. Other polymers can be spun into threads for use in clothing, suitcases, and backpacks.

### Polymer properties

➤ The properties of polymers depend mostly on :

- 1- which monomers are used to make them.
- 2- The amount of branching .
- 3- the shape of the polymer.

Because of this diversity:

- polymers can be made light and flexible .
- strong enough to make plastic pipes, boats, and even some auto bodies.
- Other polymers can be spun into threads for use in clothing, suitcases, and backpacks.

Practice :

1- What do the properties of polymers depend on the most?

- A) The color of the polymer
- B) The type of monomers used to make them
- C) The temperature during production
- D) The amount of oxygen in the air

2- Which factor also greatly affects the properties of polymers?

- A) The amount of branching and the shape of the polymer
- B) The number of colors added
- C) The temperature of water
- D) The type of gas used

3- Why can polymers have such a wide range of properties?

- A) Because they are made from metals
- B) Because of the diversity of monomers and structures
- C) Because all polymers are the same
- D) Because they contain oxygen

4- Which of the following products can be made from **strong polymers**?

- A) Plastic pipes and auto bodies
- B) Water bottles only
- C) Food containers
- D) Cotton fabrics

5- Polymers that are **light and flexible** can be used to make:

- A) Wooden furniture
- B) Glass windows
- C) Rubber bands and plastic wraps
- D) Metal tools

6- Which of the following can be made by **spinning polymers into threads**?

- A) Auto tires
- B) Clothing, suitcases, and backpacks
- C) Glass bottles
- D) Wooden desks

7- Which statement best describes **polymers**?

- A) They are simple molecules that exist alone.
- B) They are large molecules made of repeating smaller units called monomers.
- C) They are metals that conduct electricity.
- D) They are always brittle and weak.

1- What are the small units that make up polymers called?

A- monomers

C- plastics

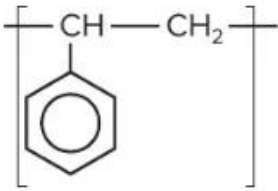
B- isomers

D- carbohydrates

## Hydrocarbon polymers

Some polymers are made entirely of carbon and hydrogen, as shown in **Table 3**. When ethene combines with itself repeatedly, it forms the common polymer polyethylene (pah lee EH thuh leen). Polyethylene is used widely in shopping bags and plastic bottles, as shown in **Table 3**. Another common polymer, polypropylene (pah lee PRO puh leen), is made of propene monomers and has many uses.

Table 3 Hydrocarbon Polymers

| Polymer       | Monomer                                                                             | Uses                                                                                                                                                                                                                            |
|---------------|-------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Polyethylene  | $\left[ \text{CH}_2 - \text{CH}_2 \right]$                                          |  <ul style="list-style-type: none"> <li>• plastic bags</li> <li>• plastic bottles</li> </ul>                                                  |
| Polypropylene | $\left[ \text{CH}_2 - \underset{\text{CH}_3}{\text{CH}} \right]$                    |  <ul style="list-style-type: none"> <li>• glues</li> <li>• carpets</li> <li>• high-performance outdoor clothing</li> </ul>                   |
| Polystyrene   |  |  <ul style="list-style-type: none"> <li>• foam packing</li> <li>• disposable food containers</li> <li>• computer monitor casings</li> </ul> |

|                                                                   |              |   |                    |
|-------------------------------------------------------------------|--------------|---|--------------------|
| What polymer is used widely in shopping bags and plastic bottles? |              |   |                    |
| A                                                                 | Polystyrene  | C | Polyvinyl chloride |
| B                                                                 | Polyethylene | D | Polypropylene      |

|                                                                                                                                                         |              |   |                    |
|---------------------------------------------------------------------------------------------------------------------------------------------------------|--------------|---|--------------------|
| What polymer is used in foam packing and disposable food containers?  |              |   |                    |
| A                                                                                                                                                       | Polystyrene  | C | Polyvinyl chloride |
| B                                                                                                                                                       | Polyethylene | D | Polypropylene      |

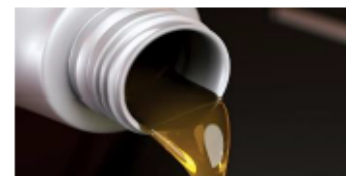
|                                                                                            |               |   |                    |
|--------------------------------------------------------------------------------------------|---------------|---|--------------------|
| What polymer is formed of ethene monomers with chlorine substituted for one hydrogen atom? |               |   |                    |
| A                                                                                          | Polypropylene | C | Polyester          |
| B                                                                                          | Polyurethane  | D | Polyvinyl chloride |

What polymer is formed by combining an organic acid containing two carboxyl groups  $\text{-COOH}$  with an alcohol containing two hydroxyl groups  $\text{-OH}$ ?

|   |                    |   |               |
|---|--------------------|---|---------------|
| A | Polyvinyl chloride | C | Polyurethane  |
| B | Polyester          | D | Polypropylene |

## What is petroleum?

- **Petroleum**: a mixture of hydrocarbons and small amounts of other substances found deep within Earth.
- Because it is formed from the remains of fossilized material, it is a fossil fuel.
- The liquid part of petroleum is called crude oil. Crude oil is dark, flammable, and foul-smelling.
- **Crude oil** is a mixture of thousands of organic compounds.
- To make items such as combs, specific compounds are refined from this mixture and then processed into consumer products.



### Practice :

1- What is **petroleum**?

- A) A single pure chemical substance
- B) A mixture of hydrocarbons and other substances found deep within Earth
- C) A metal ore found underground
- D) A type of mineral water

2- Why is petroleum considered a **fossil fuel**?

- A) Because it comes from living plants
- B) Because it is formed from the remains of fossilized material
- C) Because it contains fossils inside it
- D) Because it is found near fossils

3- What is the **liquid part** of petroleum called?

- A) Diesel
- B) Natural gas
- C) Crude oil
- D) Coal

4- Which statement best describes **crude oil**?

- A) It is colorless and odorless
- B) It is dark, flammable, and has a strong odor
- C) It is a solid fossil material
- D) It contains no hydrocarbons

5- What type of compounds does **crude oil** contain?

- A) A mixture of thousands of organic compounds
- B) Only one type of hydrocarbon
- C) Only water and minerals
- D) Only inorganic compounds

6- Which of the following items can be made from petroleum compounds?

- A) Plastic combs and clothing fibers
- B) Sand and rocks
- C) Ice and salt
- D) Wood and paper

7- Petroleum is found:

- A) Floating on the surface of rivers
- B) Deep within Earth
- C) Inside volcanoes only
- D) In the atmosphere

## Processing Crude Oil :

- The first step is to extract the crude oil from its underground source.
- Once the crude oil is obtained, chemists and engineers separate the crude oil into fractions containing compounds with similar boiling points.
- **fractional distillation** is The separation process that takes place in oil refineries.
- **fractional distillation depends on** difference in boiling points of hydrocarbon compounds.



Figure 16 To obtain crude oil, large wells must be drilled deep into Earth.

## 16. Describe the process of fractional distillation.

### The tower :

- ❖ **fractionating towers** : is big, metal towers that, can rise as high as 35 m and be 18 m wide.
- ❖ Inside the tower is a series of metal plates arranged like the floors of a building.
- ❖ These plates have small holes through which vapors can pass. On the outside is a maze of scaffolding and pipes at various levels.

### Separating organic compounds :

- ✚ The tower separates crude oil into fractions containing compounds having a range of boiling points.
- ✚ Within a fraction, boiling points may range more than  $100^{\circ}\text{C}$ .
- ✚ At the base of the tower, the crude oil is heated to more than  $350^{\circ}\text{C}$ .
- ✚ At this temperature, most hydrocarbons in the mixture become vapor and start to rise.
- ✚ A few compounds, such as those in asphalt, remain as liquids and are drained from the bottom of the tower.

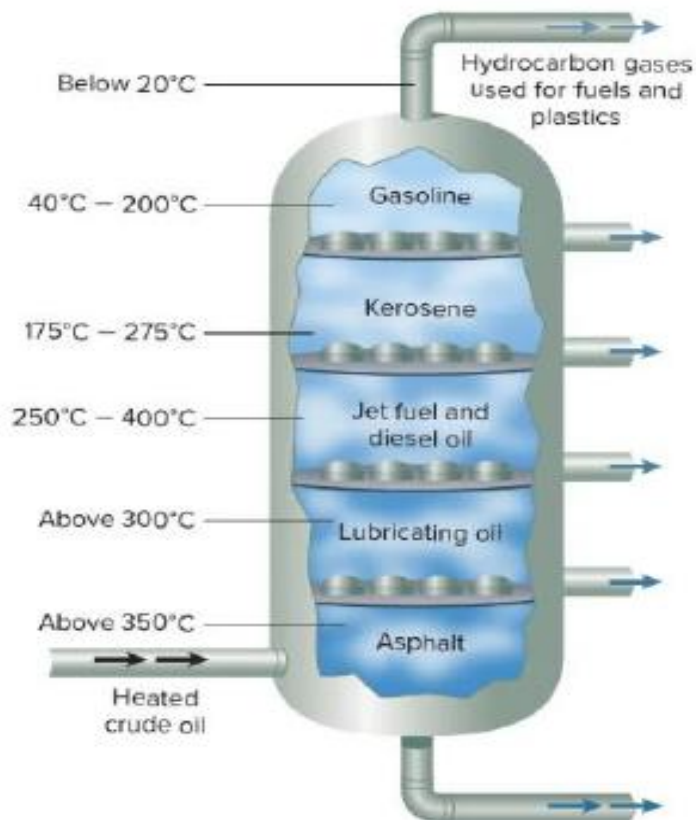
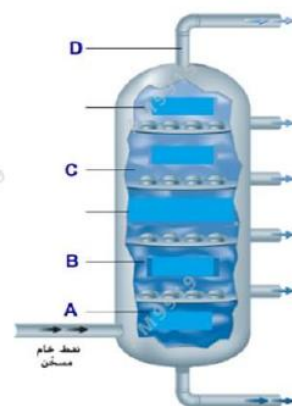


**Figure 17** Fractions are separated in a fractionating tower by their boiling points. Larger hydrocarbons have high boiling points and condense on the bottom plates. The smallest hydrocarbons have much lower boiling points and are collected at the top of the tower as gases.

**Infer** How might these fractions be further separated?

Fractions of the crude oil are separated in a fractionating tower shown in the figure below. Which of the following statements is incorrect?



|   |                                                                                    |   |                                                                              |
|---|------------------------------------------------------------------------------------|---|------------------------------------------------------------------------------|
| A | The hydrocarbons with much lower boiling points and condensed on the bottom plates | C | The hydrocarbons with smaller carbon chains condense at the top of the tower |
| B | The hydrocarbons with larger carbon chains condense on the bottom of the tower     | D | The hydrocarbons with high boiling points are condensed on the bottom plates |

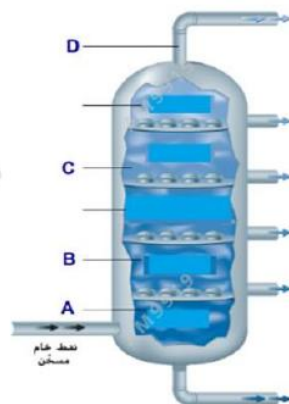
What are the properties of the crude oil fractions that condense on the bottom plates in a fractionating tower?

|   |                                                     |   |                                                    |
|---|-----------------------------------------------------|---|----------------------------------------------------|
| A | Smaller hydrocarbon chains have low boiling points  | C | Larger hydrocarbon chains have low boiling points  |
| B | Smaller hydrocarbon chains have high boiling points | D | Larger hydrocarbon chains have high boiling points |

Petroleum is separated into fractions in a fractionating tower. Which hydrocarbons condense on the top plates?

|   |                                              |   |                                               |
|---|----------------------------------------------|---|-----------------------------------------------|
| A | Larger hydrocarbons with high boiling points | C | Smaller hydrocarbons with low boiling points  |
| B | Larger hydrocarbons with low boiling points  | D | Smaller hydrocarbons with high boiling points |

Fractions of the crude oil are separated in a fractionating tower shown in the figure below. Which of the following statements is correct?



|   |                                                                               |   |                                                                                |
|---|-------------------------------------------------------------------------------|---|--------------------------------------------------------------------------------|
| A | The hydrocarbons with high boiling points condense at the top of the tower    | C | The hydrocarbons with larger carbon chains condense at the bottom of the tower |
| B | The hydrocarbons with much lower boiling points condense on the bottom plates | D | The hydrocarbons with smaller carbon chains condense on the bottom plates      |



### Get It?

**Compare** the masses of compounds collected at the top of the tower to those collected at the bottom.

## Practice :

1- What process is used to separate petroleum into different useful compounds?

- A) Filtration
- B) Evaporation
- C) Fractional distillation
- D) Freezing

2- During fractional distillation, compounds are separated based on their:

- A) Color
- B) Density only
- C) Boiling points
- D) Melting points

3- Where are **lighter compounds** with **lower boiling points** collected in the distillation tower?

- A) At the bottom of the tower
- B) At the top of the tower
- C) In the middle of the tower
- D) Outside the tower

4- Where are **heavier compounds** with **higher boiling points** collected?

- A) At the top of the tower
- B) At the bottom of the tower
- C) On the sides of the tower
- D) They escape as gases

5- Which statement best compares the compounds at the top and bottom of the fractional distillation tower?

- A) Compounds at the top are heavier and have higher boiling points.
- B) Compounds at the top are lighter and have lower boiling points.
- C) Compounds at the bottom are lighter and evaporate easily.
- D) Compounds at the bottom are gases.

6- Why are compounds at the bottom of the tower heavier?

- A) They contain fewer carbon atoms.
- B) They contain more carbon atoms and stronger intermolecular forces.
- C) They are gases that cool down faster.
- D) They dissolve easily in water.

## Uses for Petroleum Compounds :

- The lightest fractions from the top of the tower include butane and propane, which are used for fuel.
- The fractions that condense on the upper plates and contain from five to ten carbons are used for gasoline and solvents.
- Below these are fractions with 12 to 18 carbons that are used for kerosene and jet fuel.
- The bottom fractions go into lubricating oil, and the residue is used for paving asphalt.



- **Other petroleum products** are obtained by further purifying crude oil fractions using different techniques to isolate individual compounds.
- After these are separated, they can be converted into substituted hydrocarbons.
- Chemists use these to make products ranging from medicines such as aspirin to insecticides, printers' ink, and flavorings.
- Aromatic dyes from crude oil have almost completely replaced natural dyes, such as indigo and alizarin.
- The first synthetic dye was a bright purple called mauve that was accidentally discovered in coal tar compounds.



## Practice :

1- Which compounds are collected at the **top** of the fractional distillation tower?

- A) Heavy oils and asphalt
- B) Butane and propane
- C) Kerosene and jet fuel
- D) Lubricating oil

2- What are **butane and propane** mainly used for?

- A) Making plastics
- B) Fuel
- C) Lubricants
- D) Dyes

3- The fractions that contain **five to ten carbon atoms** are used for:

- A) Kerosene and jet fuel
- B) Gasoline and solvents
- C) Asphalt and wax
- D) Lubricating oil

4- Fractions with **12 to 18 carbon atoms** are used for:

- A) Jet fuel and kerosene
- B) Gasoline and propane
- C) Lubricating oil and diesel
- D) Asphalt and coal tar

5- The **bottom fractions** of petroleum are used for:

- A) Making perfumes
- B) Lubricating oil and asphalt
- C) Gasoline and solvents
- D) Synthetic fibers

## Summary Notes:

- Petroleum fractions are **separated by boiling points**.
- **Light fractions** (top): butane & propane → fuel.
- **Middle fractions**: gasoline → cars, solvents.
- **Heavier fractions**: kerosene → jet fuel.
- **Bottom fractions**: lubricating oil & asphalt.
- Other uses: making **medicines, plastics, and dyes** (mauve, indigo, alizarin).

## Depolymerization

- **Depolymerization** : Disposing of polymers has become a problem because polymers have been used so widely and many polymers do not decompose.
- One way to combat this is by recycling, which recovers clean plastics for reuse in new products, Many communities recycle plastics.
- Another approach is depolymerization.



■ **Figure 21** Plastics can be recycled into many structures, such as decks, gazebos, and this bench.

30

Practice :

1- What is the main environmental problem caused by polymers?

- A) They are too light to recycle.
- B) Many polymers do not decompose naturally.
- C) They are easily broken down by microorganisms.
- D) They can dissolve in water quickly.

2- What is one effective way to reduce problems caused by polymer waste?

- A) Burning all plastic waste
- B) Throwing polymers in landfills
- C) Recycling clean plastics for reuse
- D) Using more non-biodegradable materials

3-What happens during recycling of polymers?

- A) Old polymers are converted into new products.
- B) Polymers are converted into fossil fuels.
- C) Polymers are destroyed completely.
- D) New polymers are made from metal waste.

4-Which of the following is an example of a recycled polymer product mentioned in the text?

- A) Plastic bottles
- B) Wooden chairs
- C) Benches made from recycled materials
- D) Paper boxes

5- What is the main goal of **recycling polymers**?

- A) To recover clean plastics for use in new products.
- B) To make polymers heavier and stronger.
- C) To replace all natural materials with plastics.
- D) To create new fossil fuels.

6- What does the bench in Figure 21 represent?

- A) The use of natural materials.
- B) A product made from recycled polymer materials.
- C) A new type of natural wood.
- D) A non-recyclable structure.

- **Depolymerization** is a process that uses heat or chemicals to break the long polymer chain into its monomer fragments.
- These monomers can then be reused.
- However, each polymer requires a different depolymerization process and much research is needed to make this type of recycling economical.

18. **Describe** why depolymerization can be an expensive process.

### Practice :

1- What is **depolymerization**?

- A) The process of forming polymers from monomers.
- B) The process of breaking polymers into their monomer fragments.
- C) The process of freezing polymers for reuse.
- D) The process of melting polymers into new shapes.

2- What is usually used in the depolymerization process?

- A) Water and air
- B) Heat or chemicals
- C) Light and sound
- D) Sand and salt

3- What is the main purpose of depolymerization?

- A) To create new elements
- B) To reuse monomers from broken polymers
- C) To increase the size of polymers
- D) To destroy all plastics completely

4- Why can depolymerization be an **expensive process**?

- A) It requires special types of plastics.
- B) It uses cheap materials.
- C) Each polymer requires a different process and much research.
- D) It produces very little waste.

## Polymers

Did you ever loop together strips of paper to make a paper chain for decoration, or have you ever strung paper clips together? A paper chain can represent the structure of a polymer, as shown in **Figure 19**. Some of the smaller molecules from petroleum are monomers that act like links in a chain. *Mono-* means one. A **monomer** is a small molecule that can combine with itself repeatedly to form a long chain. When these links are hooked together, they make new, extremely large molecules known as polymers. **Polymers** are long chains of monomers. Often, two or more different monomers, known as copolymers, combine to make one polymer molecule.



### Get It?

Compare and contrast a monomer and a polymer.

### Practice :

1- What is a **monomer**?

- A) A large molecule made of repeating units
- B) A small molecule that can join with others to form a polymer
- C) A type of metal used in reactions
- D) A mixture of many compounds

2- What is a **polymer**?

- A) A single atom
- B) A short chain of metals
- C) A long chain made up of repeating monomers
- D) A chemical that cannot bond

3- What happens when monomers link together?

- A) They form metals.
- B) They form large molecules called polymers.
- C) They separate into smaller atoms.
- D) They lose all their bonds.

4- Which of the following statements is **true** about polymers?

- A) Polymers are made of repeating units of monomers.
- B) Polymers are small, simple molecules.
- C) Polymers cannot be formed from petroleum.
- D) Polymers exist only in gases.

5- When two or more different monomers combine, the resulting polymer is called a:

- A) Homopolymer
- B) Copolymer
- C) Hydrocarbon
- D) Macromolecule

### Summary Notes:

- **Monomer:** a small molecule that can bond repeatedly to form a chain.
- **Polymer:** a large molecule made from repeating monomers.
- The prefix "**mono-**" means *one*.
- **Copolymer:** made from two or more different monomers.
- The paper chain analogy helps visualize how monomers link to form polymers.

## Explain Your Thinking

19. **Predict** Based on the names of the polymers in this lesson, what do you think the polymer made from the monomer **terpene** is called?

### Practice :

1- What is the most likely name of the polymer made from the monomer **terpene**?

- A) Polymonomer
- B) Polyterpene
- C) Terpenoid
- D) Terpolymer

2- If the monomer is **ethylene**, what is the polymer called?

- A) Polyethylene
- B) Polyethane
- C) Polymethane
- D) Ethylpoly

3- What does the prefix **poly-** mean in the name of a polymer?

- A) One
- B) Few
- C) Many
- D) Small

4- Which of the following is a **correctly named polymer** based on its monomer?

- A) Monomer: propene → Polymer: polypropene
- B) Monomer: propene → Polymer: monopoly
- C) Monomer: propene → Polymer: propanol
- D) Monomer: propene → Polymer: monoprene

- **Polyesters** Synthetic fibers called polyesters are made from an organic acid that has two  $\text{-COOH}$  groups and an alcohol that has two  $\text{-OH}$  groups.
- Polyester is strong because these chains are closely packed together.
- Many varieties of polyesters can be made, depending on what alcohols and acids are used. Polyesters can be woven or knitted into durable fabrics.

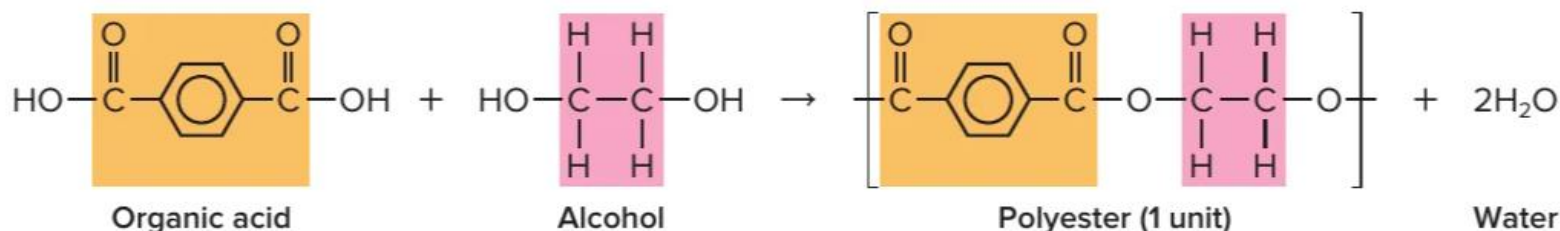


**Figure 20** Polyesters are formed when an organic acid with two  $\text{-COOH}$  groups combines with an alcohol that has two  $\text{-OH}$  groups.

## Practice :

1- What are **polyesters** made from?

- A) Organic acids and bases
- B) Organic acids with two  $\text{-COOH}$  groups and alcohols with two  $\text{-OH}$  groups
- C) Metals and water
- D) Sugars and oxygen

2- What type of polymerization reaction forms polyesters?

- A) Addition polymerization
- B) Condensation polymerization
- C) Substitution reaction
- D) Oxidation reaction

3- What is produced as a **byproduct** during the formation of polyester?

- A) Oxygen
- B) Carbon dioxide
- C) Water
- D) Methane

4- Why is polyester a **strong material**?

- A) Because it is made from metals
- B) Because its chains are closely packed together
- C) Because it contains oxygen atoms
- D) Because it reacts with acids

5- What determines the **variety of polyester** produced?

- A) The type of alcohols and acids used
- B) The temperature of production
- C) The color of the polymer
- D) The number of carbon atoms only

6- Which of the following correctly represents the **functional groups** involved in making polyesters?

- A)  $\text{-OH}$  and  $\text{-NH}_2$
- B)  $\text{-COOH}$  and  $\text{-OH}$
- C)  $\text{-COOH}$  and  $\text{-COH}$
- D)  $\text{-NH}_2$  and  $\text{-CH}_3$

7- What kind of polymer is **polyester** classified as?

- A) Addition polymer
- B) Natural polymer
- C) Condensation polymer
- D) Metallic polymer

#### Summary Notes:

- Polyesters are synthetic fibers made by condensation polymerization.
- They form from organic acids ( $\text{-COOH}$ ) and alcohols ( $\text{-OH}$ ), releasing water.
- The strength of polyester comes from closely packed chains.
- Different alcohols and acids  $\rightarrow$  different types of polyesters.
- Polyesters are used in fabrics, textiles, and durable materials.

GOOD LUCK