

SCH4U

Grade 12 University Chemistry



Lesson 5 - Hydrocarbons

Unit 2: Organic Chemistry

Have you ever wondered why there are so many different types and a great diversity of life forms present on Earth? From butterflies, birds, giraffes, humans, and an array of plants, living organisms are all vastly unique. Yet all of these living organisms share one thing in common: they are comprised of carbon based compounds.

The science of carbon-based chemistry is called **organic chemistry**, and it is the focus of this unit. You learned the basics of organic chemistry in your grade 11 chemistry course and you will review and extend this knowledge in this unit. The various types of organic compounds and their practical uses such as polymers and plastics will be discussed.

Overall Expectations

- demonstrate an understanding of the structure of various organic compounds, and of chemical reactions involving these compounds;
- investigate various organic compounds through research and experimentation, predict the products of organic reactions, and name and represent the structures of organic compounds using the IUPAC system and molecular models;
- evaluate the impact of organic compounds on our standard of living and the environment.

Lesson 5: Hydrocarbons

Organic chemistry is a branch of chemistry that deals with molecules that contain the elements carbon and hydrogen. Organic compounds not only comprise living organisms, but they are also widely used as natural and synthetic polymers. In this lesson, you will learn about the basic organic compounds, referred to as **hydrocarbons**. These compounds are often used in the petroleum industry, so you will also learn about the oil refinement process.

What You Will Learn

After completing this lesson, you will;

- describe some physical properties of the classes of organic compounds in terms of solubility in different solvents, molecular polarity, odour, and melting and boiling points;
- use appropriate scientific vocabulary to communicate ideas related to organic chemistry (e.g., functional group, polymer);

Hydrocarbons

Hydrocarbons are the foundation molecules of a branch of chemistry referred to as **Organic Chemistry**. Organic compounds contain the elements **Carbon** and **Hydrogen**. Some examples of common organic compounds include methane (CH_4), propane (C_3H_8), and butane, (C_4H_{10}). Organic compounds are also the main component of plants and animals, and account for the wide diversity of living organisms on our planet. The main reason for this diversity is the unique bonding nature of the element carbon. Carbon is able to form four (4) covalent bonds with carbon atoms or other elements. This means that carbon can form a variety of shapes from chains to rings with single, double, or triple covalent bonds. Two atomic models (Bohr and Lewis) for carbon are shown below.

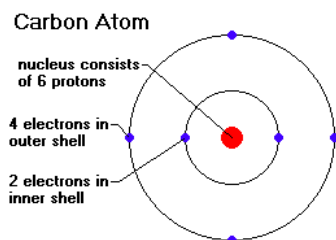


Figure 5.1 – Bohr-Rutherford diagram for a carbon atom

Figure 5.2 – Lewis structure for a carbon atom



Saturation

As mentioned above, compounds that contain both carbon and hydrogen are referred to as hydrocarbons. When a hydrocarbon has no double bonds it is referred to as being a **saturated hydrocarbon**. Saturated hydrocarbons contain only single carbon-carbon (C-C) bonds.

Examples

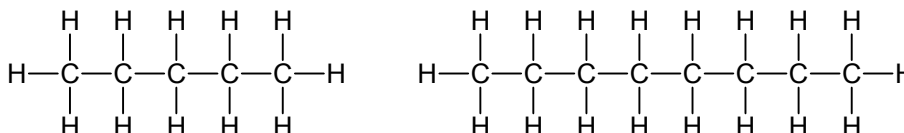


Figure 5.3- Saturated hydrocarbons

When a hydrocarbon has double or triple bonds it is called **unsaturated**.

Examples

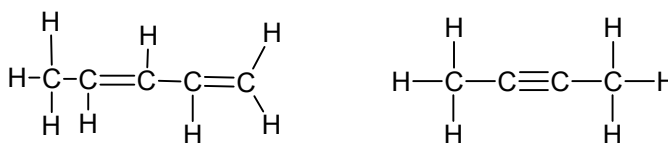


Figure 5.4 – Unsaturated hydrocarbons

Structural Isomers

Isomers are compounds that have the same formula, but different structures and properties. For example both 1-butene, 2-butene have the molecule formula C_4H_8 , but are structurally unique.

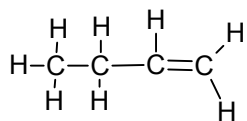


Figure 5.5 - 1-butene

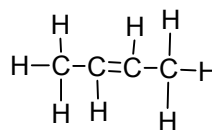


Figure 5.6 -2-butene

You may notice that 1-butene and 2-butene are structurally differentiated by location of the double bond in the carbon atoms. Both molecules have the same molecular formula, C_4H_8 .

Naming Hydrocarbons

There are three classes of hydrocarbons, named based on the degree of saturation they contain.

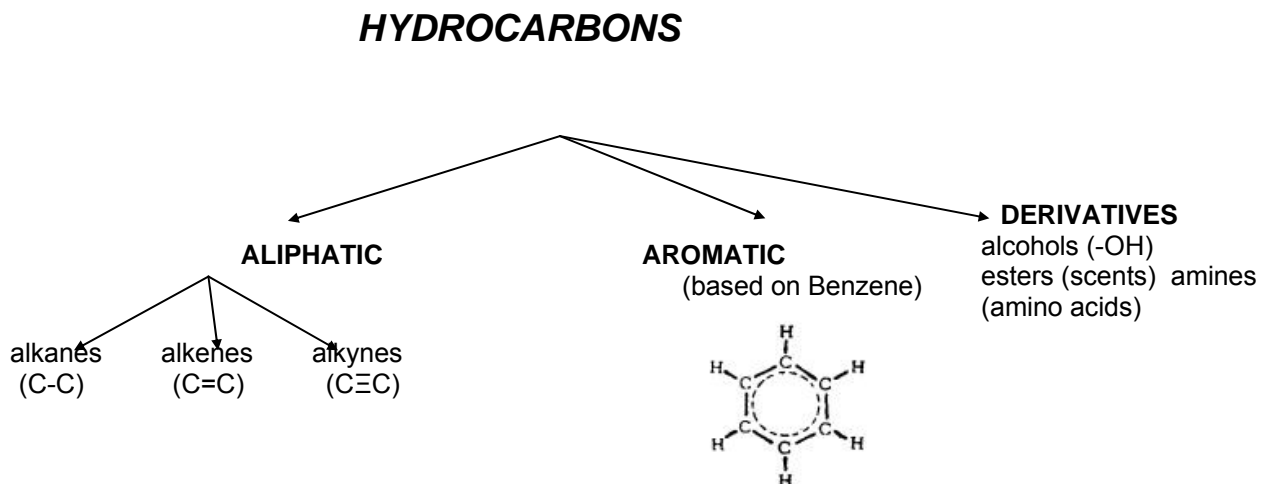


Figure 5.7: Classification of Hydrocarbons

Alkanes: Saturated Hydrocarbons

Alkanes contain only single covalent carbon-hydrogen bonds. Alkanes are referred to as **saturated** hydrocarbons meaning

Alkanes can be written in **structural formula** or **condensed formula**.

Table 5.1 Structural and Condensed forms for Butane

Structural	Condensed
<pre> H H H H H — C — C — C — C — H H H H H </pre>	CH ₃ CH ₂ CH ₂ CH ₃

Naming Alkanes

Organic compounds (including alkanes) are generally named using the I.U.P.A.C system, which stands for **I**nternational **U**nion of **P**ure and **A**ppplied **C**hemistry. I.U.P.A.C is a systematic method for naming and drawing organic compounds. This system uses prefixes and it is generally based on how many carbon atoms the molecule contains. Alkanes have the generic formula C_nH_{2n+2}. The prefixes for the first 10 alkanes are summarized in table 5.2.

Table 5.2 – Alkanes

Name	Chemical Formula
Methane	CH ₄
Ethane	C ₂ H ₆
Propane	C ₃ H ₈
Butane	C ₄ H ₁₀
Pentane	C ₅ H ₁₂
Hexane	C ₆ H ₁₄
Heptane	C ₇ H ₁₆
Octane	C ₈ H ₁₈
Nonane	C ₉ H ₂₀
Decane	C ₁₀ H ₂₂

Memory Tip

Mary **e**ats **p**eanut **b**utter **p**ancakes **h**appily **h**ugging **o**ur **n**ew **d**og

Alkyl Groups

An alkyl group is a branch of a molecule derived from an alkane. For example, a methyl group (CH₃) is a fragment of a methane molecule (CH₄). The *-yl* ending means "a fragment of an alkane formed by removing a hydrogen". You will use alkyl groups occasionally when naming organic molecules. Table 5.3 summarizes the first ten alkyl groups.

Table 5.3: Alkyl Groups

Alkyl group	Prefix	Formula
Methyl-	Meth	-CH ₃
Ethyl-	Eth	-C ₂ H ₅
Propyl-	Prop	-C ₃ H ₇
Butyl-	But	-C ₄ H ₉
Pentyl-	Pent	-C ₅ H ₁₁
Hexyl-	Hex	-C ₆ H ₁₃
Heptyl-	Hept	-C ₇ H ₁₅
Octyl-	Oct	-C ₈ H ₁₇
Nonyl-	Non	-C ₉ H ₁₉
Decyl-	Dec	-C ₁₀ H ₂₁

Isomers of Alkyl groups

When alkyl groups have three or more C atoms, they may be attached to a parent chain either at their end C atom, or at one of the middle C atoms. Figure 5.8 below shows the various isomers for butyl and propyl alkyl groups.

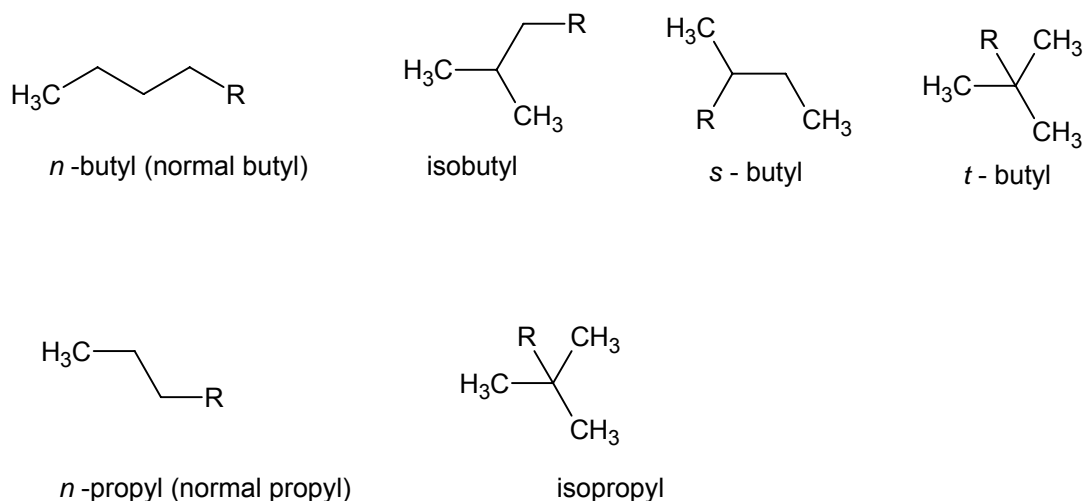
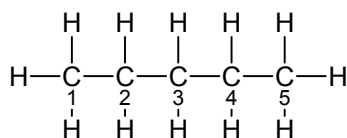


Figure 5.8: Isomers of Propyl and Butyl Alkyl Groups

IUPAC Rules for Naming Alkanes

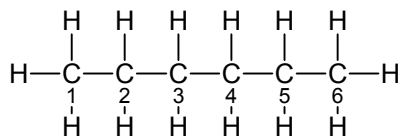
1. Identify the longest carbon chain.
2. Number the carbon atoms, starting with the end that is close to the branches, if they are present.
3. Name each branch and identify its location on the parent chain by the number of the carbon at the point of attachment.
4. When more than one branch is present, the branches are listed in alphabetical order.

Example 1: Name the following alkane



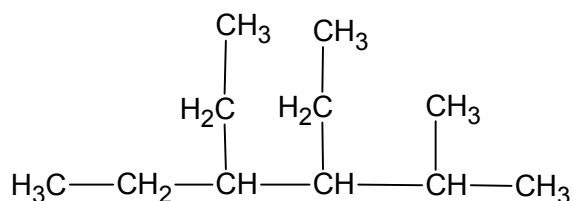
Solution 1: Since this alkane contains five carbons, it is named **pentane**.

Example 2: Name the following alkane

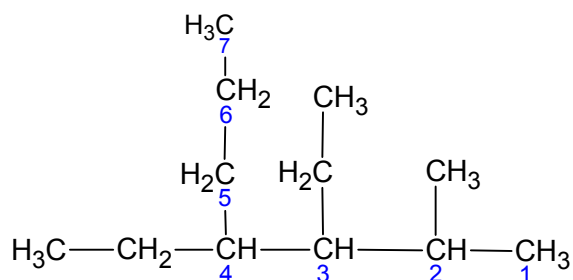


Solution 2: Since this alkane has 6 carbon atoms, it is termed **hexane**.

Example 3: Name the following hydrocarbon



Solution 3: Locate the longest chain. Be careful, this is not necessarily the longest straight chain.



The parent chain is 7 carbons long, so the parent name is heptane.

Now, examine your side chains, carbon 2 methyl, carbons 3 and 4 three ethyl groups. Make sure you have given the lowest numbers possible to your branches (alkyl groups).

Now name your alkane, List your alkyl groups in alphabetical order.

3, 4-diethyl, 2- methyl heptane

Physical Properties of Alkanes

- Because carbon and hydrogen have very similar electronegativities, alkane molecules are essentially non polar.
- Dispersion forces increase as the number of carbons increases.
- Boiling point increases as the number of carbon chains increases in the molecule.
- Have low density; most are less dense than water.
- Immiscible (not soluble) with water.

Chemical Properties of Alkanes

- Generally have low chemical reactivity
- The most important chemical reaction of alkanes is a **combustion** reaction, because it is a highly **exothermic** reaction. Alkanes are the most important fuel chemicals.

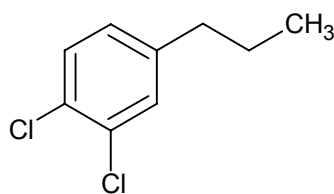
Alkenes and Alkynes: UnSaturated Hydrocarbons

The method for naming alkenes and alkynes is similar to the method for naming Alkanes, except that the carbon chain chosen as the main chain must contain the **double or triple bond**, even if it is not the longest chain. The ending –“**ene**”, indicates the presence of a double bond, and the ending –“**yne**” indicates the presence of a triple bond.

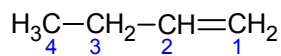
IUPAC Rules for Naming Alkenes and Alkynes

1. Identify the longest continuous chain of carbon atoms containing the double bond and assign the base name. The main chain must contain the double bond or triple, even though it may not be the longest chain.
2. Number the main chain beginning at the end that will result in the lowest possible number for the double or triple bond. You need the number that locates the double or triple bond. If the bond is between carbon three and four, use the lower number 3.

Example 4: Name the following molecule

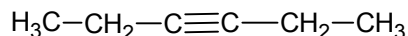


Solution 4: First of all, number the carbon atoms to give the lowest possible number to the double bond.

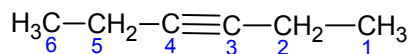


Since this hydrocarbon has four carbon atoms it is named **butene**

Example 5: Name the following molecule



Solution 5: Again start off by numbering your carbon chain, giving the lowest number possible to the triple bond



This molecule has six carbon atoms, and contains a triple bond, so it is termed **3-hexyne**

Aromatic Hydrocarbons

The benzene ring is considered the parent molecule for aromatics.

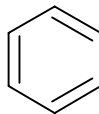
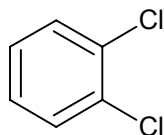


Figure 5.8: Benzene

Naming

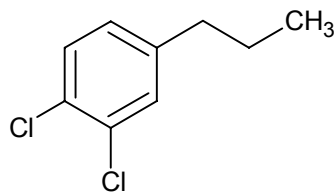
1. Base name is “benzene”
2. Same rules apply in numbering carbons however longest carbon alkyl group/side chain will become first carbon. You do not need to number the alkyl group if there is only one.

Example 7: Name the following molecule;



Solution 7: 1,2-dichlorobenzene

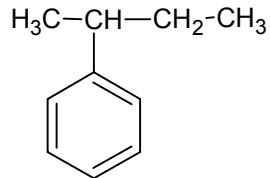
Example 8: Name the following molecule;



Solution 8: 1-propyl-3,4-dichlorobenzene

Sometimes the benzene ring is considered a chain rather than the parent. When the benzene is the branch rather than the parent, the benzene is called “**phenyl**”

Example 9: Name the following molecule;



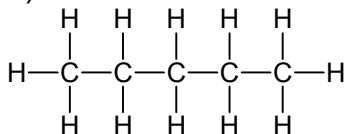
Solution 9: 2-phenylbutane or s-butylbenzene



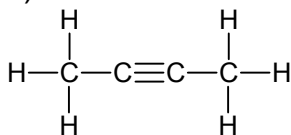
Support Questions

- Compare organic compounds to inorganic compounds. Provide an example of each.
- Define the term hydrocarbon. Compare saturated and unsaturated hydrocarbons.
- Draw the structural formula for each of the following;
 - methane
 - 2-pentene
 - octane
 - 2-pentyne
 - 3-hexyne
 - decene
 - 3,3,5-trimethyloctane
 - cyclobutane
 - 1,1-diethylcyclohexane
 - 4-methyl-2-pentyne
 - 3,4-dimethylcyclohexene
 - 1,2,4-trimethylbenzene
 - 3-phenylpentane
- Write the IUPAC name for the each of the following;

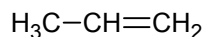
a)



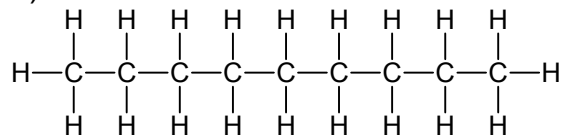
c)

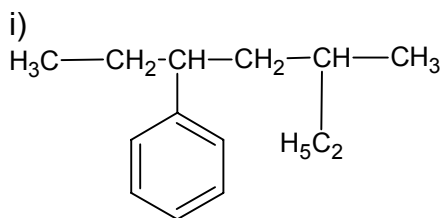
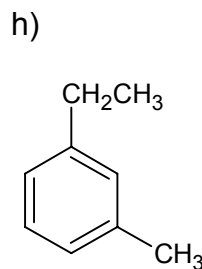
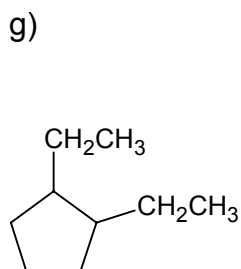
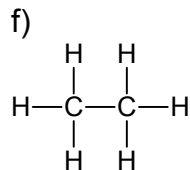
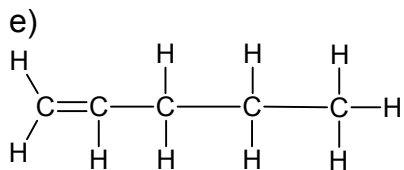


b)



d)





Fractional Distillation and Cracking

Petroleum is a mixture of hydrocarbons of varying molecular sizes and states; therefore, its composition varies widely from region to region around the world.

Fractional distillation (Figure 5.9) is a process for separating petroleum into its hydrocarbon components using boiling points. Each hydrocarbon component (fraction) has its own range of boiling points. A large furnace is used to vaporize the liquid components. As each fraction reaches a point in the distillation tower where the temperature is just below its boiling point, it condenses and becomes a liquid again. The liquid fraction is then taken away from the tower by pipes.

Heavier hydrocarbons (larger molecules) have higher boiling points. They condense first and are removed in the lower sections of the tower. The lighter hydrocarbons, with lower boiling points, reach the higher levels of the tower before they are separated. Once the fractions are removed from the tower, they may be chemically processed or purified further to make them marketable.

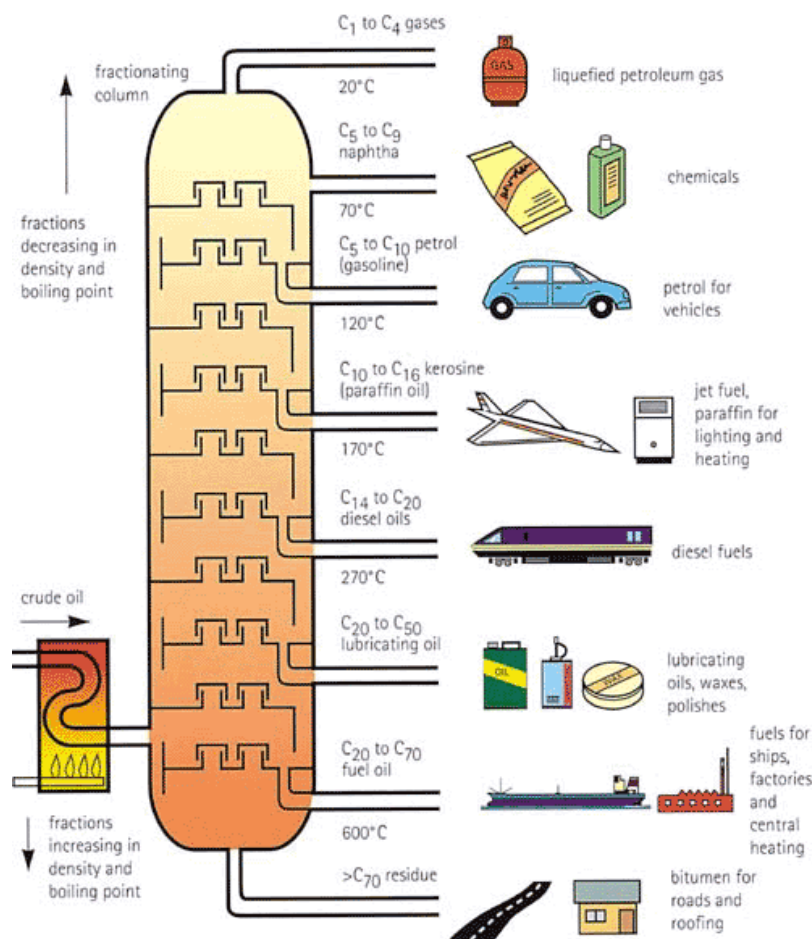


Figure 5: Fractional distillation

Often hydrocarbons are found in long straight chains. They are often broken into smaller branched chained hydrocarbons. This process is called **cracking**, and occurs with the aid of a catalyst. A catalyst speeds up a reaction without being used up in the reaction itself.



Support Questions

5. Explain the process of fractional distillation and cracking.



Key Question #5

1. Draw the structural formula for the following hydrocarbons. (20 marks – 2 marks each)

a) propane

c) octane

e) 2-ethyloctane

g) 2-phenylpropane

j) n-propylbenzene

b) 2-butyne

d) hexane

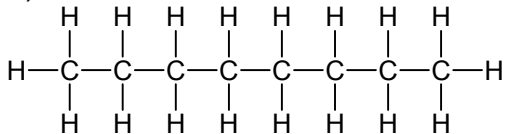
f) methylcyclopentane

h) 4-s-butyloctane

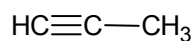
k) 1,3-dimethylcyclohexane

2. Name the following hydrocarbons. (9 marks)

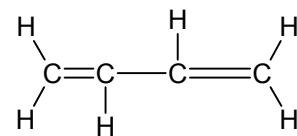
a)



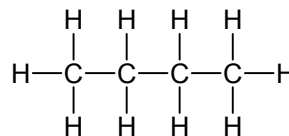
b)



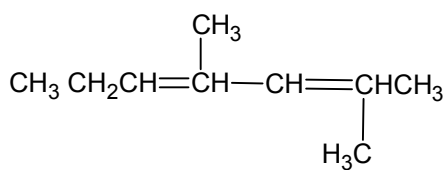
c)



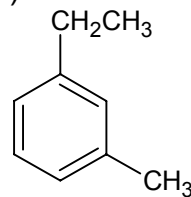
d)



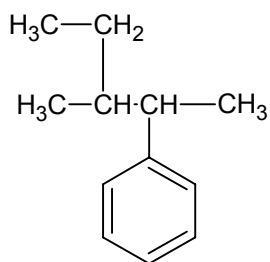
e)



f)



g)



3. Research and then design a laboratory set-up that would enable you to separate a mixture of three hydrocarbons with different boiling points. Draw and label a diagram of your set-up, and develop the procedure you will use to separate the hydrocarbons. State your references. (10 marks)
4. For each of the following names, determine if it is a correct name for an organic compound. If it is incorrect, state the correct name. (7 marks)
- | | |
|------------------------|------------------------|
| a) 2-dimethylhexane | b) 3-methyl-1-pentyne |
| c) 2,4-dimethylheptene | d) 3,3-ethylpentane |
| e) 3,4-dimethylhexane | f) 1,5-dimethylbenzene |
| g) 3,3-dimethylbutane | |

SCH4U

Grade 12 University Chemistry



Lesson 6 – Functional Groups

Lesson Six: Functional Groups

In lesson five, you were introduced to organic compounds, and a large division of organic compounds called hydrocarbons. In this lesson, you will learn about the other classes of organic compounds.

What You Will Learn

After completing this lesson, you will;

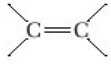
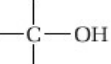
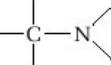
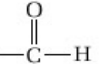
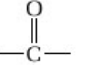
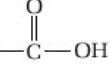
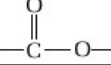
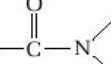
- distinguish among the different classes of organic compounds, including alcohols, aldehydes, ketones, carboxylic acids, esters, ethers, amines, and amides, by name and by structural formula;
- describe some physical properties of the classes of organic compounds in terms of solubility in different solvents, molecular polarity, odour, and melting and boiling points;
- use the IUPAC system to name and write appropriate structures for the different classes of organic compounds, including alcohols, aldehydes, ketones, carboxylic acids, esters, ethers, amines, amides, and simple aromatic compounds;
- identify some nonsystematic names for organic compounds (e.g., acetone, isopropyl alcohol, acetic acid);

Naming Organic Compounds

Functional Groups

Organic compounds are an extremely diverse group of compounds with a variety of physical and chemical properties. In order to better understand these properties, chemists have organized organic compounds into useful groups called **functional groups**. Functional groups provide a useful way to classify organic compounds because compounds with the same functional group often have similar physical properties such as boiling point, melting point, and solubility. Functional groups are also based on intermolecular forces (Hydrogen Bonding, Dipole-Dipole interactions, and Dispersion forces). Compounds with the same functional group react chemically in very similar ways. The main functional groups that you will learn in this unit are summarized in table 6.1 following.

Table 6.1 – Organic Functional Groups**Table 1.4** Common Functional Groups

Type of compound	Suffix	Functional group	Example
alkane	-ane	none	propane
alkene	-ene		propene
alkyne	-yne	$\text{—C}\equiv\text{C—}$	propyne
alcohol	-ol		propanol
amine	-amine		propanamine
aldehyde	-al		propanal
ketone	-one		propanone
carboxylic acid	-oic acid		propanoic acid
ester	-oate		methyl propanoate
amide	-amide		propanamide

Observe that each functional group has its own unique cluster of atoms. We will discuss each functional group in detail in this lesson, starting with the alcohol functional group.

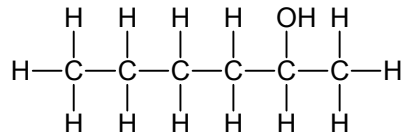
Naming and Identifying Organic Compounds

Alcohols - Alcohols have a hydroxyl R-OH functional group. (Note R represents the parent chain)

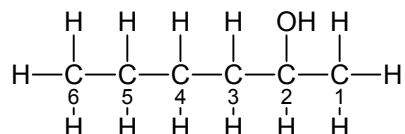
Naming;

1. Alcohols are named for the parent alkane; parent chain ends in “ol” (“e” dropped from “ane”)
2. Parent chain must include functional group and carbons are numbered so that the “hydroxyl” group has the lowest number

Example 1: Name the following alcohol

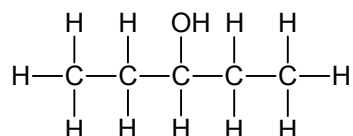


Solution 1: First begin by numbering off carbon atoms. Number the carbon atoms to give the lowest number possible to the hydroxyl (-OH) group.

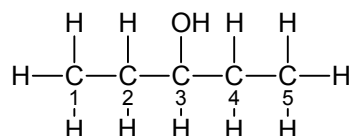


This carbon is six carbons long, so the prefix is “hex”. Since the hydroxyl group is on the second carbon, this molecule is named **2-hexanol**.

Example 2: Name the following alcohol



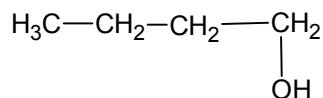
Solution 2: First begin by numbering off carbon atoms. Number the carbon atoms to give the lowest number possible to the hydroxyl (-OH) group.



This carbon is five carbons long, so the prefix is “pent”. Since the hydroxyl group is on the third carbon, this molecule is named **3-pentanol**.

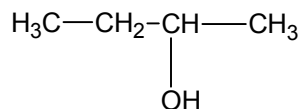
1° 2° and 3° alcohols - Alcohols are sub classified according to the type of carbon which the -OH group is attached.

Primary alcohols (1°) are an alcohol in which the hydroxyl functional group is attached to a carbon which is only attached to one other carbon.



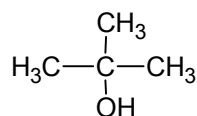
1-butanol (1° alcohol)

Secondary alcohols (2°) are alcohols in which the hydroxyl functional group is attached to a carbon which is itself attached to two other carbon atoms.



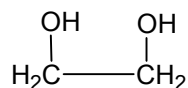
2-butanol (2° alcohol)

Tertiary Alcohols (3°) are an alcohol in which the hydroxyl functional group is attached to a carbon which is itself attached to three other carbon atoms.



2-methyl-2-propanol (3° alcohol)

Polyalcohols - Alcohols that contain more than one hydroxyl group are called **polyalcohols**. The suffixes –diol and triol are added to the entire alkane name to indicate two and three –OH groups.



1,2-ethandiol (ethylene glycol)

Cyclic Alcohols - When cyclic hydrocarbons have –OH groups, they are often referred by their common names as alcohols. Examples include menthol and cholesterol, as depicted below.

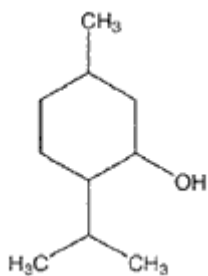


Figure 6.1: Menthol

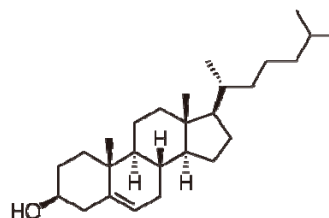


Figure 6.2: Cholesterol

Aromatic Alcohols - The simplest aromatic is an alcohol with an attached –OH. It is called a phenol and is depicted in figure 6.3 below. Phenol is a colourless solid that is slightly soluble in water. Phenol is a component of many products such as plastics, drugs, dyes, and weedkillers.

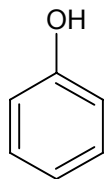


Figure 6.3: Phenol

Properties of Alcohols

- extremely flammable; highly poisonous
- smaller alcohols are more polar than longer chain alcohols
- H-bonding allows for great solubility in water and high melting/boiling points
- solubility decreases with increasing chain length
- boiling point increases with increasing chain length

CH ₃ OH	CH ₃ CH ₂ OH	CH ₃ CH ₂ CH ₂ OH
methanol	ethanol	propanol
Bp: 64.7°C	Bp: 78.5°C	Bp: 97.2°C

Ethers - Ethers contain two alkyl groups joined by an oxygen atom (R-O-R).

Naming

Ethers can be named using two methods;

Method 1: The longest alkyl is parent alkane; second alkyl is numbered and named “-oxy” For example, methoxy ethane

Method 2: The two alkyl groups are named in alphabetical order, followed by the word “ether”. For example, methyl ethyl ether

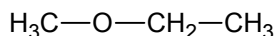
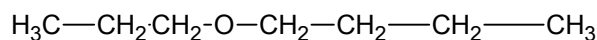
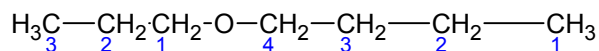


Figure 6.4 methoxyethane or methyl ethyl ether

Example 3: Name the following Ether



Solution 3: Begin by numbering the two alkyl chains on either side of the oxygen atom.



We have a three carbon and a four carbon chain. Using method 1, this ether would be named ethoxy butane, while using method two; this would be named ethyl butyl ether.

Properties of Ethers

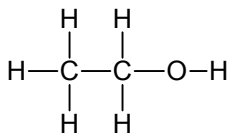
- Ethers are less polar than alcohols. Ether can bond with water by Hydrogen bonds but not other ether molecules
- Ethers have lower melting/boiling points than comparable alcohols
- Ethers are soluble in water; solubility decreases with increased chain length (number of carbon atoms)
- Ethers are extremely flammable



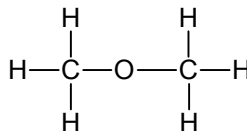
Support Questions

6. Name the following molecules

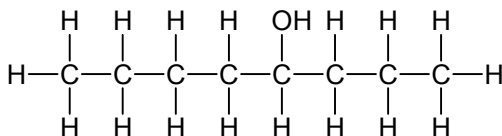
a)



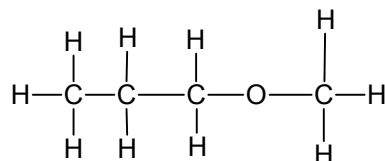
b)



c)



d)



7. Draw the structural formula for each of the following;

a) diethyl ether

b) 2-pentanol

c) ethoxybutane

d) propanol

8. Explain why 3-butanol is an incorrect name. What is the correct name for this alcohol?

Aldehydes & Ketones

Aldehydes and Ketones contain functional Groups with the C=O Bond (Carbonyl Group).

Aldehydes - In aldehydes, the carbonyl group is always located at one end of the parent chain

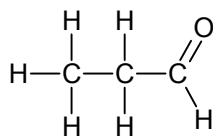


Figure 6.5 An aldehyde functional group

Naming Aldehydes

1. Use alkane parent name, except drop the “e” and end in “al”
2. All other rules as in alcohol apply except by definition the carbonyl group is in position 1; therefore no position number is stated when naming.

Example 4: Name the following aldehyde



Solution 4: This aldehyde is named butanal.

Ketones - Ketones have the carbonyl group in the middle of a chain.

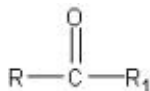
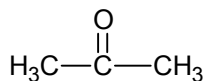


Figure 6.6 – A Ketone functional group

Naming Ketones

1. Use alkane parent name except drop “e” and add “one”
2. Same rules as alcohols

Example 5: Name the following ketone



Solution 5: Since this ketone is three carbons long, it is named propanone.

Properties of Aldehydes and Ketones

- Short chain aldehydes (methanal, ethanal) are foul smelling
- Long chain aldehydes (higher Molar Mass) are pleasant smelling
- Although the C=O (carbonyl group) of aldehydes and ketones is polar, they have lower boiling points and are less soluble in water than alcohols of similar sizes. These properties are because aldehydes and ketones do not have -OH hydroxyl groups and therefore do not form *hydrogen bonds*.

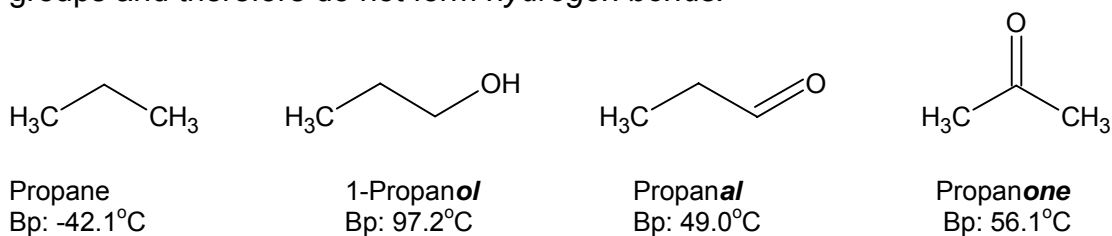


Figure 6.7 – Comparing Boiling Points (Bp) of various functional groups



Support Questions

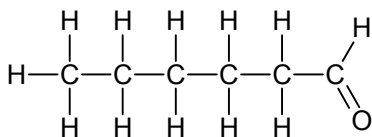
9. Draw the following organic molecules;

- a) 3-hexanone
c) pentanal

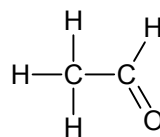
- b) 2-butanone
d) octanal

10. Name the following organic molecules;

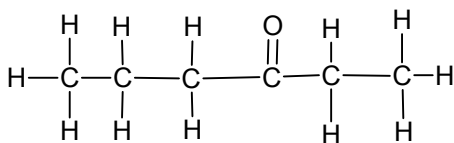
a)



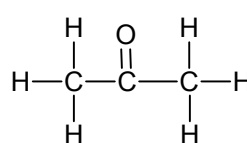
b)



c)



d)



Carboxylic Acids - Carboxylic acids contain the carboxyl group, R-COOH

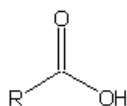
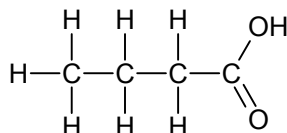


Figure 6.8 – An aldehyde functional group

Naming

1. Longest possible chain which contains carbonyl group becomes parent name
2. Always on first carbon (groups)
3. Parent name drops “e” and add “oic acid”

Example 6: Name the following carboxylic acid



Solution 6: This carboxylic acid is named **butanoic acid**

Carboxylic acids also exist as aromatics. The simplest aromatic that contains a carboxyl functional group is benzoic acid, following.

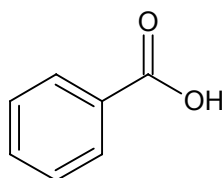


Figure 6.9: Benzoic Acid

Benzoic acid is often used as a preservative in foods and beverages. Some other carboxylic acids and their uses/origin are summarized in table 6.2 following.

Table 6.2: Common Carboxylic Acids

Carboxylic acid	Origin
Oxalic Acid	-spinich, rubarb
Tartaric Acid	-grapes, bannanas
Citric Acid	-citrus fruits
Ascorbic Acid (Vitamin C)	-found in many fruits and vegetables
Acetylsalicylic Acid	-common name is Aspirin -used for pain relief

Properties of Carboxylic Acids

- Carboxylic acids are polar molecules and are capable of Hydrogen bonding, and therefore have high boiling points.
- Many carboxylic acids have multiple functional groups which also increases the boiling point

Esters - Esters are made from the reaction of an alcohol and a carboxylic acid

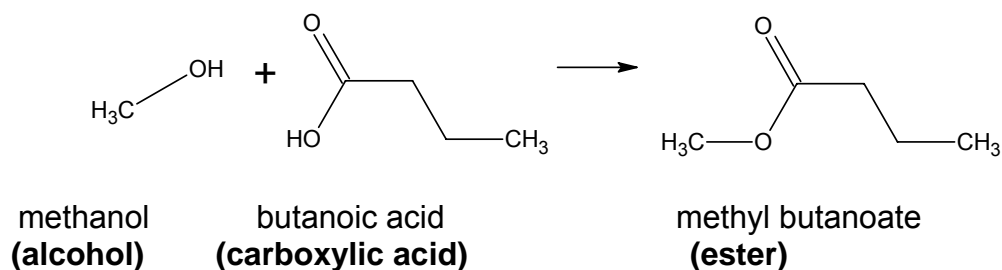


Figure 6.9: The formation of an ester

The above reaction depicted in figure 6.9 is also termed an **esterification** reaction. Esters contain the RCOOR functional group, where R is a hydrogen atom or alkyl group

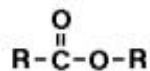
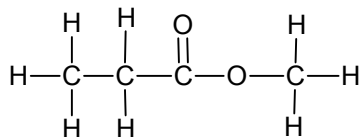


Figure 6.10 – An ester functional group

Naming

1. Parent name derived from carbon chain containing carbonyl group
2. Changes from “oic acid” to “oate”
3. Alkyl group which is attached to single bonded “O” proceeds parent name

Example 7: Name the following ester



Solution 7: This ester is named **propyl methanoate**

Properties of Esters

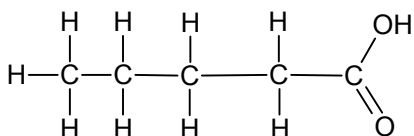
- Esters tend to be volatile liquids at room temperature
- Esters are found in many waxes, scented candles, lipstick (scent/flavour)



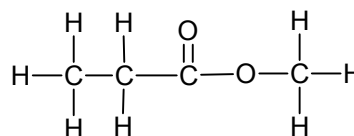
Support Questions

11. Name the following molecules

a)



b)



12. Draw the structural diagram for the following molecules

a) heptanoic acid

b) propyl methanoate

Amines - Have the amino functional group (R-NR'₂)

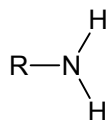


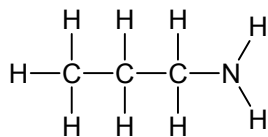
Figure 6.10 – An amine functional group

Most amines are derivatives of ammonia (NH₃)

Naming

1. The longest alkyl attached to nitrogen (amino group) is parent alkane; suffix “**–amine**”,

Example 7: Name the following amine



Solution 7: Since this amine has three carbons attached, it is named **propyl amine**

Properties of Amines

- Carbon-Nitrogen (C-N), and Nitrogen-Hydrogen (N-H) bonds are polar
- The solubility of amines decreases with increased chain length
- Amines are often toxic, may have medicinal properties
- Many amines have offensive fishy odours (decay and decomposition)
- Like ammonia, amines act as weak bases

Amides - Amides have the ROHRR functional group where R is a hydrogen atom or alkyl group

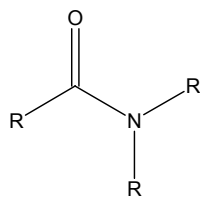
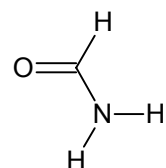


Figure 6.11 An amide functional group

Naming

1. Name the parent acid (contains C=O), replace –oic acid with “-amide”

Example 8: Name the following amide



Solution 8: This amide is termed **methylamide**

Properties of Amides

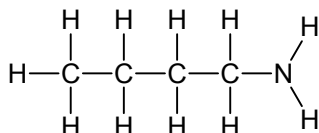
- Amides are often used for artificial sweeteners (aspartame)



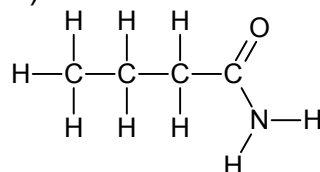
Support Questions

13. Name the following molecules;

a)



b)



14. Draw the structural diagrams for the following;

a) butyl amine

b) ethyl amide



Key Question #6

1. Draw each of the following compounds. (18 marks – 2 marks each)

a) 4-decanol

b) octanoic acid

c) ethanal

d) methyl ethanoate

e) pentyl amine

f) 1,2-propanediol

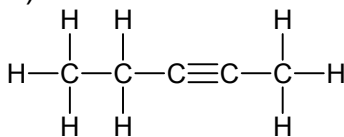
g) 3-methyl-1-butanol

h) 2-pentanone

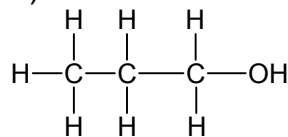
i) 3-methylheptanoic acid

2. Identify the functional group family to which each one of these organic molecules belongs. (6 marks)

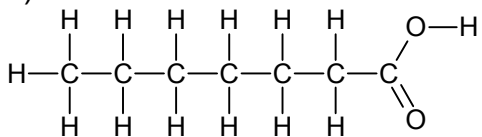
a)



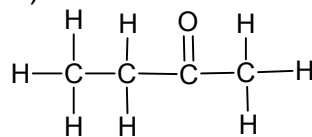
b)



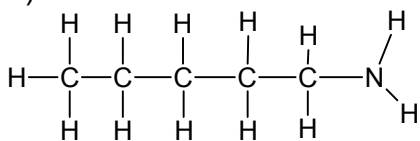
c)



d)



e)



f) butyl ethanoate

3. Research and complete a table similar to the one following. (8 marks)

Molecule	Organic Family (1 mark each)	Use/Application (2 marks each)
Acetone		
Aspartame		
Citric Acid		
Ethane		

4. Arrange the following compounds in order of increasing boiling point, and give reasons for your answer. (5 marks)

- a) Butane
c) Octane

- b) 1-butanol
d) 1-octanol

5. Write the structural formula for each of the following compounds; (8 marks)

- a) A secondary alcohol with the formula $\text{C}_4\text{H}_{10}\text{O}$
 b) An ether with the formula $\text{C}_4\text{H}_8\text{O}$
 c) A carboxylic acid with the formula $\text{C}_2\text{H}_4\text{O}_2$
 d) An ester with the formula $\text{C}_2\text{H}_4\text{O}_2$

SCH4U

Grade 12 University Chemistry



Lesson 7 – Types of Organic Reactions

Lesson 7: Types of Organic Reactions

In Lesson 6, you learned about all of the organic families that comprise organic compounds. In this lesson, we will focus on the reactions that result in the formation of these compounds, and their practical applications.

What You Will Learn

After completing this lesson, you will;

- describe different types of organic reactions, such as substitution, addition, elimination, oxidation, esterification, and hydrolysis;
- predict and correctly name the products of organic reactions, including substitution, addition, elimination, esterification, hydrolysis, oxidation, and polymerization reactions (e.g., preparation of an ester, oxidation of alcohols with permanganate);

Types of Organic Reactions

Millions of reactions take place everyday in the trillions of cells in your body. Since living organisms are comprised of organic compounds, many of the reactions we will discuss in this lesson also occur in the cells of your body.

Addition Reactions

Addition reactions involve the addition of one or more particles to an organic molecule. These reactions occur with unsaturated hydrocarbons (i.e. alkenes and alkynes), which you will recall from lesson 5, unsaturated hydrocarbons are organic molecules that contain at least one double or triple bond in their parent carbon chain. Examples of unsaturated hydrocarbons are shown in Figure 7.1.

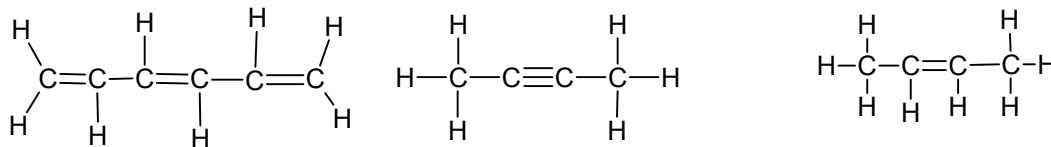


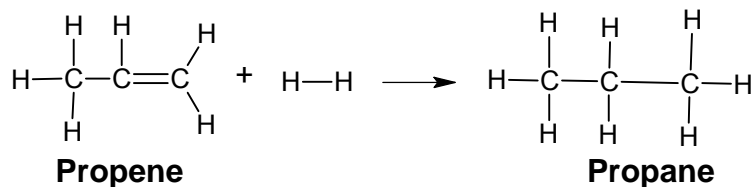
Figure 7.1: Unsaturated Hydrocarbons

There are four types of addition reactions:

- A. Hydrogenation
- B. Halogenation
- C. Hydrohalogenation
- D. Hydration

A. Hydrogenation Reaction

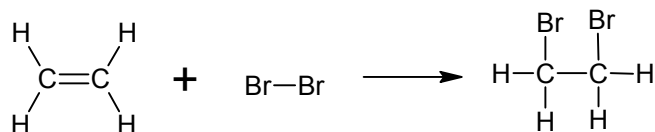
In this reaction, hydrogen gas ($H_{2(g)}$) is added to an unsaturated hydrocarbon. The hydrogen gas is under high temperature and pressure.



Hydrogenation provides many food industry benefits such as longer shelf life. This makes food easier to handle and store. The overall cost of food is also lower. However, consumption of excess hydrogenated oils can cause health problems such as atherosclerosis, which is the hardening of the artery walls in your body.

B. Halogenation (with Br_2 or Cl_2) Reaction

This type involves the addition of a halogen (F_2 , Br_2 , and Cl_2) to an unsaturated hydrocarbon.

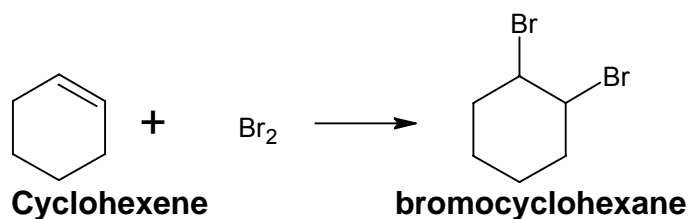


Ethane

1,2-dibromoethane

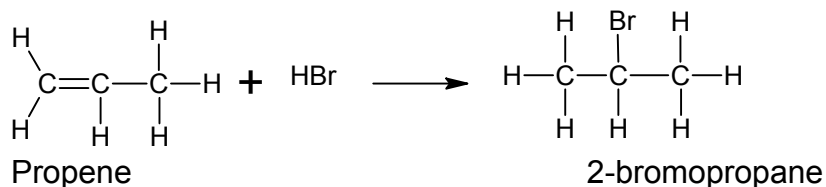
Halogenation reactions are extremely common in manufacturing factories. One huge drawback of the halogenation reaction is that they produce can produce chlorofluorocarbons (CFC's). Chlorofluorocarbons are also commonly known as freons and were first developed in 1930's. They were widely used, especially in all types of cooling devices because they are non flammable, non toxic, cheap, evaporated and condensed easily. However, Freon depletes the ozone layer. The ozone layer is a crucial part of our atmosphere which absorbs ultraviolet (UV radiation). One chlorine molecule has ability to destroy one thousand ozone molecules.

Halogenation Reactions can also occur with aromatic hydrocarbons. An example is provided below.

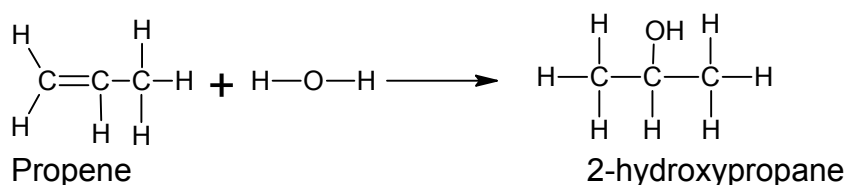


C. Hydrohalogenation Reaction

A halogen atom combined with hydrogen is termed a hydrogen halide. Examples include hydrogen fluoride (HF), hydrogen bromide (HBr), and hydrogen chloride (HCl). Hydrogen halides can combine with saturated hydrocarbon to produce alkanes.



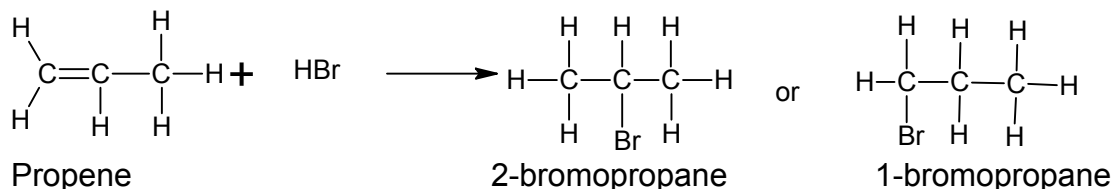
D. Hydration Reaction



Markinov's Rule

When molecules of non-identical atoms are added to a double bond, two different products are theoretically possible

For example - when hydrogen bromide is added to propene, two products are possible: 2-bromopropane or 1-bromopropane



Experiments show that only one product is actually formed in cases such as the above.

Markinov's Rule

*When a hydrogen halide or water is added to an alkene or alkyne, the hydrogen atom bonds to the carbon atom within the double bond that already has more hydrogen atoms. This rule is often remember using the phrase **"The Rich Get Richer"**.*

If we consider the example above, the first carbon atom in the propene double bond has 2 hydrogen atoms, while the second has only one. Therefore the first atom gets richer by getting another hydrogen atom, and the second carbon atom receives the bromine atom. Therefore the product predicted in this reaction is 2-bromopropane.

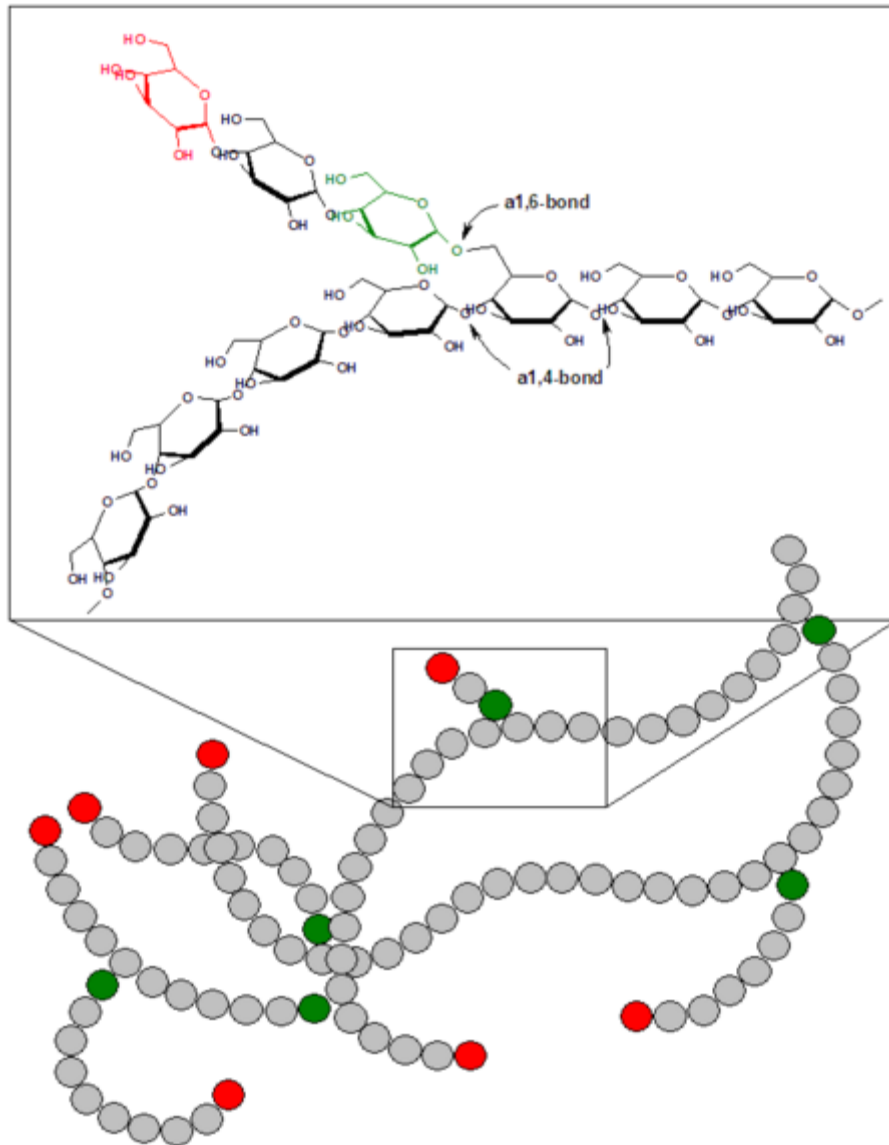
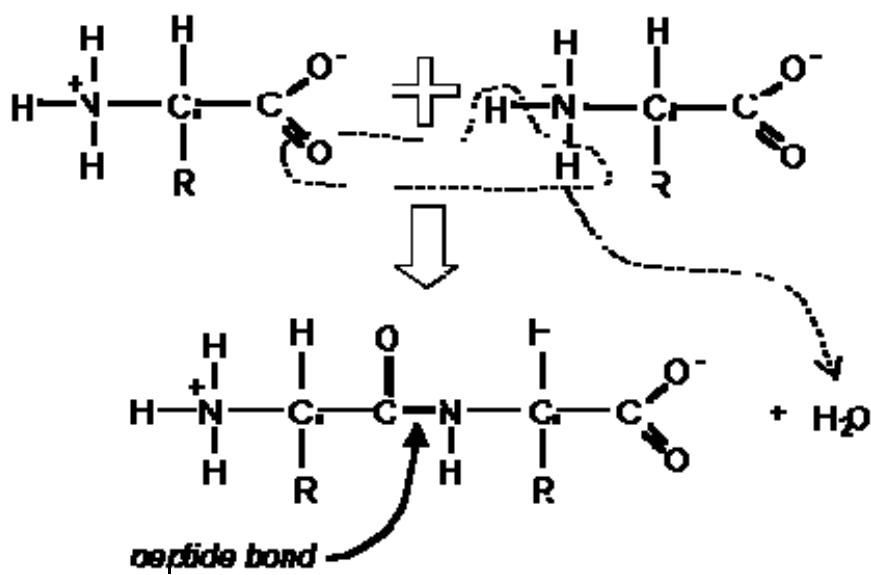


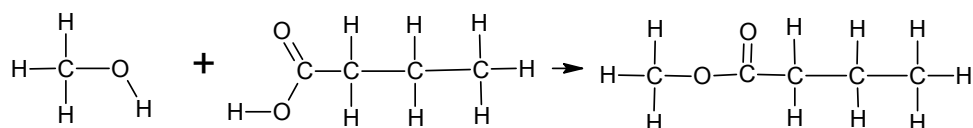
Figure 7.2 Glycogen

Proteins are also formed from condensation reactions between amino acids



In condensation reactions, water is removed from the reactants. Proteins have many important roles in biological systems such and build important structures.

Many important organic compounds such as ester and ethers are also formed from condensation reactions.



Methanol(alcohol)

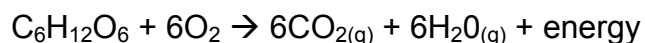
Butanoic acid (carboxylic acid)

Methoxybutanoate (ester)

Combustion Reactions

The last type of organic reaction that will be discussed in this lesson is the combustion reaction. In a combustion reaction, an organic molecule is combined with oxygen. Products of combustion reactions are carbon dioxide and water. Combustion reactions are also highly exothermic, meaning large amounts of heat or energy are produced during these reactions.

Perhaps the most common combustion reaction is the process of cellular respiration. Living organisms convert the nutrients that they consume into carbon dioxide gas and water vapour, and in the process, convert the nutrients into cellular energy or ATP (or adenosine triphosphate). The overall reaction for this process is



Humans also rely on combustion reactions daily, as combustion of many hydrocarbons, such as coal and gas (fossil fuels) produce large amounts of energy that we use to run our automobiles, heat our homes, and many other practical uses.

One serious drawback about the burning of fossil fuels is the excessive amount of carbon dioxide that is produced. Carbon dioxide is considered a “greenhouse gas”, meaning that it traps heat in our atmosphere, which may lead to smog and global warming.

Oxidation and Reduction

- change in the number of Hydrogen or Oxygen atoms bonded to Carbon
- one reactant is oxidized while the other is reduced
- in organic chemistry, **oxidation** is defined as a reaction where carbon forms *more* bonds to oxygen (less bonds to hydrogen)
- in organic chemistry, **reduction** is defined as a reaction where carbon forms *fewer* bonds to oxygen (more bonds to hydrogen)

When an alcohol is mildly oxidized, an aldehyde is produced. Further oxidation results in the formation of a carboxylic acid.

Elimination Reaction

- atoms are removed from a molecule to form a double bond
- one reactant breaks up to give two products (reverse of Addition Rxn)

Summary: Reactions of Functional Groups

REACTIONS OF ALKENES AND ALKYNES

- double/triple bond allow for several Addition Rxns
 - ✓ H and OH (from H₂O)
 - ✓ H and X (from HX), where X = Cl, Br, or I
 - ✓ X and X (from X₂), where X = Cl, Br, or I
 - ✓ H and H (from H₂)
- if one or more reactants in an addition reaction are symmetrical, only one product is possible; if both reactants are asymmetrical, more than one product is possible (products are **isomers** of each other)
- **MARKOVNIKOV'S RULE:** *the halide atom or OH group in an addition reaction is usually added to the more substituted carbon atom -- the carbon atom that is bonded to the largest number of other hydrogen atoms. “The rich get richer”*
- since alkynes have triple bonds, two addition reactions can take place in a row

REACTIONS OF AROMATIC COMPOUNDS

- benzene's stable ring does not usually accept the addition of other atoms
- aromatic compounds undergo **substitution reactions** where a hydrogen atom or a functional group is replaced by a different functional group

REACTIONS OF ALCOHOLS

- **Substitution** occurs when an alcohol reacts with a halogen acid (HCl, HBr, HI)
- **Elimination (dehydration)** occurs when alcohol is heated with a strong acid and dehydrating agent such as H₂SO₄
- **Oxidation** of an alcohol produces an aldehyde or a ketone; an aldehyde can be further oxidized to a carboxylic acid

REACTIONS OF ALDEHYDES AND KETONES

- **Oxidation** of an aldehyde produces a carboxylic acid; ketones do not undergo oxidation (they do not have a hydrogen atom available to be removed)
- **Reduction** of aldehydes produces primary alcohols; reduction of ketones produces secondary alcohols

REACTIONS OF CARBOXYLIC ACIDS



} Condensation
(Dehydration)
Rxns

REACTIONS OF ESTERS AND AMIDES

- **Hydrolysis** of ester or amide *cleaves* molecule into two products



- hydrolysis may occur in either acidic or basic environment
- hydrolysis usually requires heat

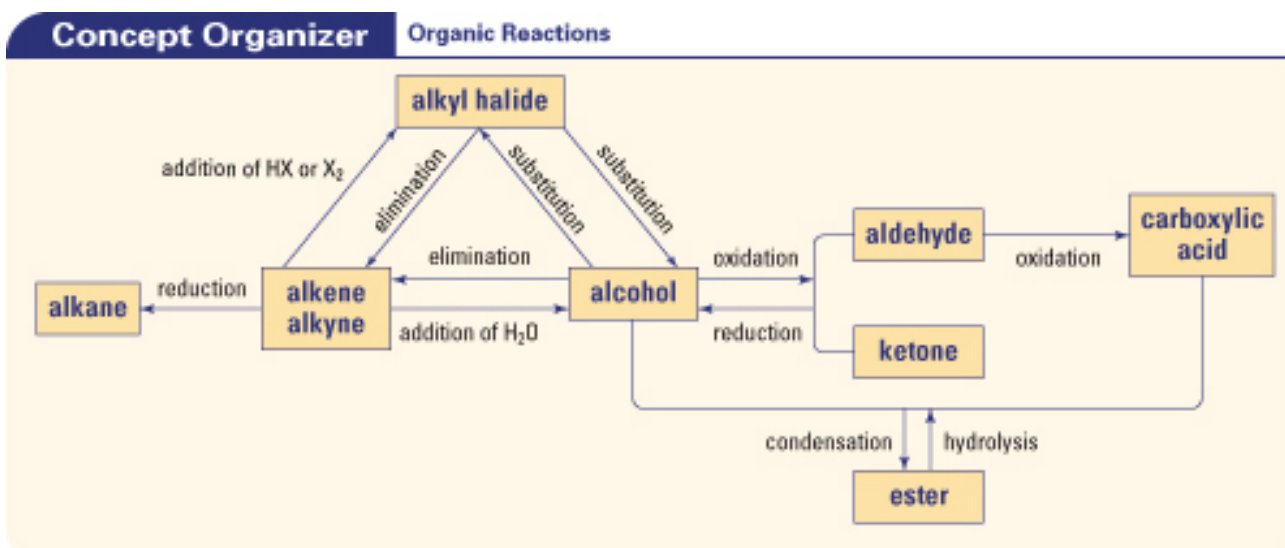


Figure 7.3: Organic Reactions



Support Questions

15. Write a balanced equation to represent the combustion of the following hydrocarbons.
- ethane
 - 2-heptene
16. Draw structural formulae to show how each of the following addition reactions
- 2-butene and hydrogen gas
 - 3-hexene and bromine
17. Draw the structural formulae to show the formation of the following esters.
- methanol and ethanoic acid
 - ethanol and propanoic acid
18. Write an equation to illustrate each of the following equations;
- a substitution reaction of propane
 - a halogenation reaction of benzene
 - the preparation of 2-pentanone from an alcohol



Key Question #7

1. Complete the following reactions. Draw structural formula for each reaction. In each case state the type of reaction that is occurring. (16 marks – 4 marks each)
 - a) 4-nonene and fluorine gas
 - b) hexane and oxygen gas
 - c) pentanol and butanoic acid
 - d) propene and hydrogen gas
2. Research the formation and uses of CFC such as Freon. What is the current legislature for the use compounds? Why is there such concern? In addition write an opinion piece about the need for such compounds – are there alternatives? (10 marks)
3. Write an equation to illustrate each of the following equations: (8 marks)
 - a) the complete combustion of ethanol
 - b) the preparation of hexyl ethanoate from an acid
 - c) an addition reaction of an alkene to produce an alcohol
 - d) the hydrolysis of methyl pentanoate
4. Describe a procedure to synthesize the ester ethyl ethanoate, starting from ethene. Include in your answer details of the conditions and safety precautions required for the procedure. (10 marks)
5. The distinction between “natural” and “synthetic” products is usually based on the source of the product, whether it is made by living organisms or in a lab. Sometime there is no difference between the products except that the method by which the product is produced. For example, bananas can naturally produce a chemical called pentyl ethanoate (natural flavour). Pentyl ethanoate can also be synthesized by artificial means in the laboratory (artificial flavour). (15 marks)
 - a) Write an equation for the synthesis of pentyl ethanoate.
 - b) In your opinion, what criteria should be used to distinguish a “natural” product from a “synthetic” product?
 - c) Research the differences in the source and processing of vanilla flavouring. Write a report on your findings.

SCH4U

Grade 12
University Chemistry



Lesson 8 – Polymers

Lesson 8: Polymers

In lesson 7, you learned about the three types of organic reactions that form many organic compounds. In this lesson, we will learn one more important reaction: the polymerization reaction. This reaction forms the many natural and synthetic polymers that will be discussed in this lesson, as well as their practical applications.

What You Will Learn

After completing this lesson, you will;

- demonstrate an understanding of the processes of addition and condensation polymerization;
- describe a variety of organic compounds present in living organisms, and explain their importance to those organisms (e.g., proteins, carbohydrates, fats, nucleic acids).
- present informed opinions on the validity of the use of the terms organic, natural, and chemical in the promotion of consumer goods;
- describe the variety and importance of organic compounds in our lives (e.g., plastics, synthetic fibres, pharmaceutical products);
- analyse the risks and benefits of the development and application of synthetic products (e.g., polystyrene, aspartame, pesticides, solvents);
- provide examples of the use of organic chemistry to improve technical solutions to existing or newly identified health, safety, and environmental problems (e.g., leaded versus unleaded gasoline; hydrocarbon propellants versus chlorofluorocarbons [CFCs]).

Polymers

Many of organic molecules, such as plastics, and many of the essential molecules in your body, are **polymers**. These very long molecules are made by linking many smaller molecules called **monomers**. Many polymers are made of just one type of monomer, but they can be made from a combination of two or more different monomers.

Manufacturing of **synthetic polymers** can be dangerous. Several reactants are carcinogens (cancer-causing agents) and some products are highly toxic. As well, synthetic polymers, including most plastics, do not degrade in the environment. Examples of synthetic polymers are polyethene (plastics), adhesives, rubber, and Styrofoam.

Natural polymers include DNA, proteins, and complex carbohydrates such as cellulose, starch, and glycogen. As discussed in lesson 10, these reactions occur by condensation reactions.

Addition Polymerization

- monomers with double bonds are joined together by multiple addition reactions

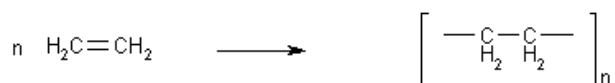


Figure 8.1: The process of addition polymerization

Condensation Polymerization

In condensation polymerization, monomers are joined together by the formation of ester or amide bonds

- each monomer must have two functional groups (one at each end of molecule)
- water is produced
- polymers that contain amide bonds are called **nylons** or **polyamides**
- polymers that contain ester bonds are called **polyesters**

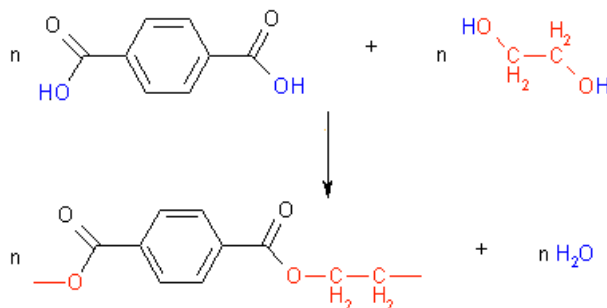


Figure 8.2: Formation of a polymer from a condensation reaction.

Polymers are a part of your everyday life. They also happen to be organic! Natural polymers include cellulose (the “fibre” in your food), DNA and rubber. Synthetic polymers include plastics, styrofoam, and silly putty!

Natural Polymers

Amino Acids & Proteins

- found in meat, milk, eggs, legumes, wool, leather, silk, bones, etc.
- 20 common amino acids in the human body, each has a carboxylic acid and a unique side chain
- shape and function of a protein depends on its sequence of amino acids

Figure 8.3 shows how a protein is formed from the condensation reaction that occurs between amino acids.

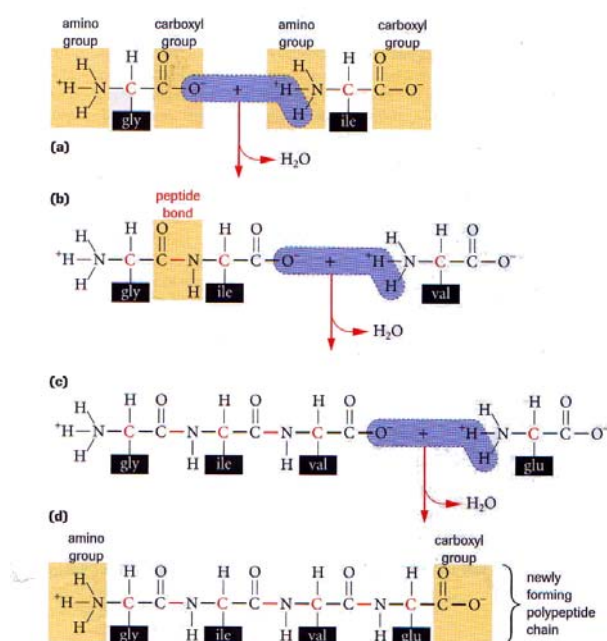


Figure 8.3: The formation of a protein (polypeptide chain)

Once amino acids have joined together, they arrange themselves in dense globular structures called protein. The various levels of protein structure are depicted and outlined in figure 8.4.

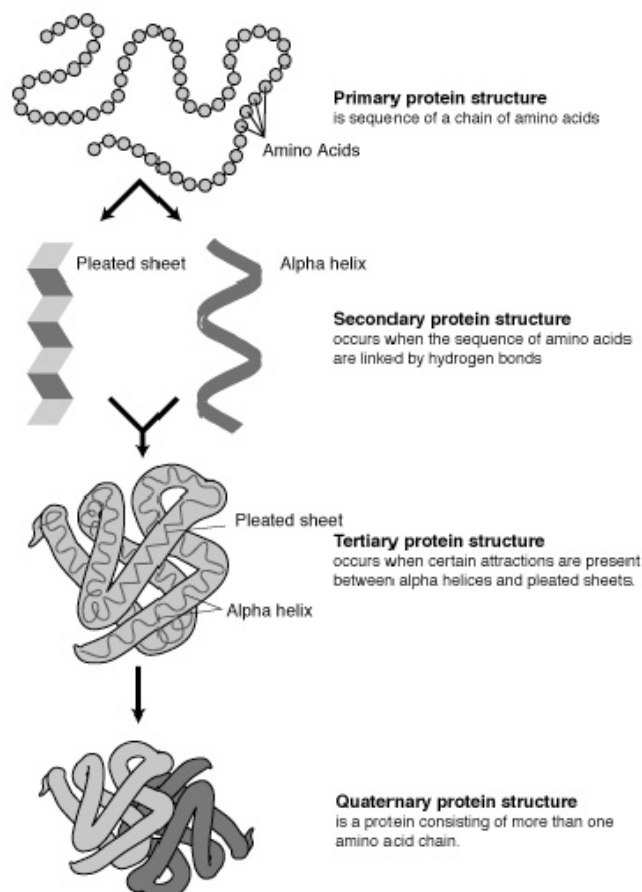


Figure 8.4: Level of Protein Structure

Carbohydrates

- found in bread, pasta, potatoes, fruits
- primary source of energy for the body (cellular respiration)
- monosaccharides and disaccharides can form polysaccharides
- many molecule can link together to form large storage molecules, such as glycogen (which you already saw in figure 7.) starch, and cellulose. Starch is the storage form of carbohydrates in plants, while glycogen is the storage form of carbohydrates in animals. Cellulose is found in plant cell walls in depicted in figure 8.5.

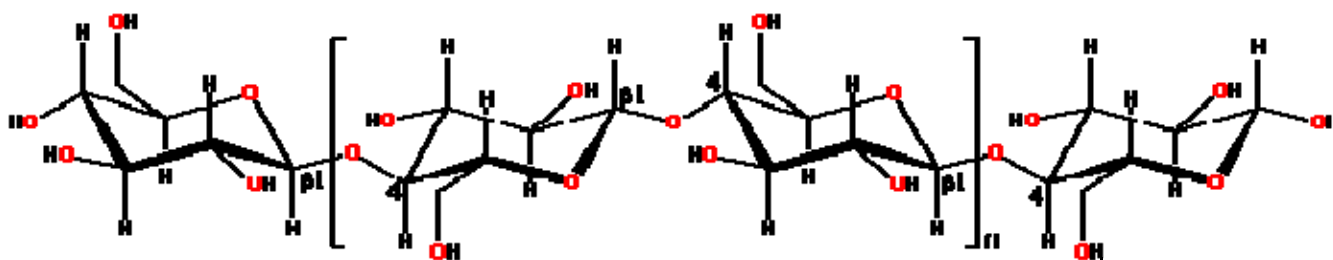


Figure 8.5: Cellulose

Lipids

- soluble in non-polar solvents (benzene, hexanes)
- fats: contain glycerol bonded three long chain carboxylic acids
- oil: same structure as fats, but liquid at room temperature
- waxes: esters of long-chain alcohols and carboxylic acids
- provide long-term storage of energy, may act structurally (cell membranes, protection of major organs), regulatory hormones, vitamins

A Typical Fat

■ Glycerol head

■ Fatty Acid Tails

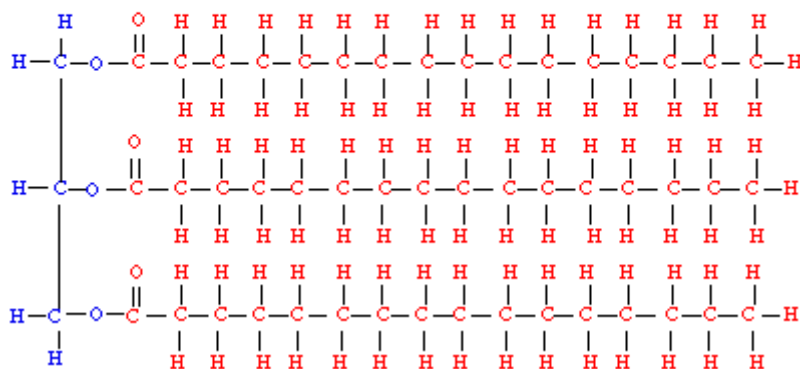


Figure 8.6: A triglyceride



Support Questions

19. Compare and contrast addition polymerization to condensation polymerization. Include examples of products that are formed in each case.



Key Question #8

1. Research and create a brochure about polymers on maximum 8½ x 11 inch paper. Your brochure should include the following;
 - Formation of and types of polymerization reaction (4 marks)
 - Examples of natural and synthetic polymers (4 marks)
 - Practical uses of polymers – minimum 10 (10 marks)
 - Drawbacks of some polymers – (5 marks)
 - References - must be from a reputable website, no search engine links or Wikipedia. (2 marks)
 - Layout, colour, creativity. (5 marks)

SCH4U

Grade 12
University Chemistry

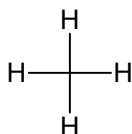


Support Question Answers

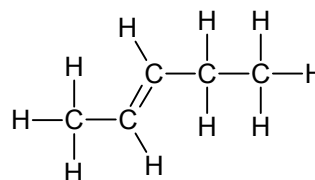
Support Questions Answers

- Organic compounds contain the elements carbon and hydrogen. Examples include methane, CH_4 , and octane C_8H_{18} . Inorganic compounds do not contain the combination of carbon and hydrogen, examples include water, H_2O , carbon dioxide, CO_2 , and salt, NaCl .
- Hydrocarbons contain carbon and hydrogen. Saturated hydrocarbons contain only single Carbon-Carbon (C-C) bonds. Examples include propane and butane. These molecules are often oils and waxes. Unsaturated hydrocarbons contain at least one double or triple bond. Examples include propene, and butyne. Unsaturated compounds tend to be liquids and tend to have lower melting points than their saturated counterparts.

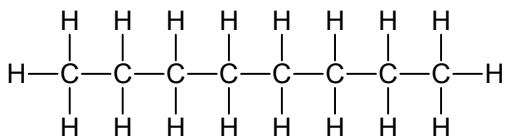
3. a) methane



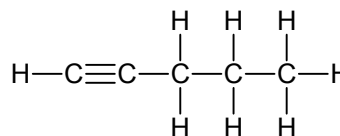
b) 2-pentene



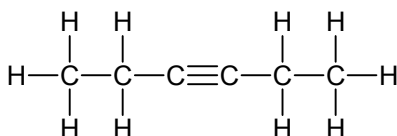
c) octane



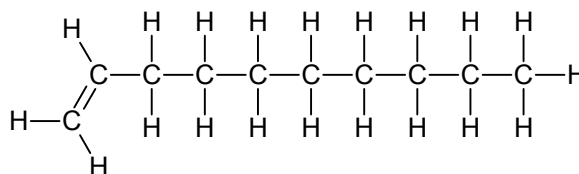
d) 2-pentyne



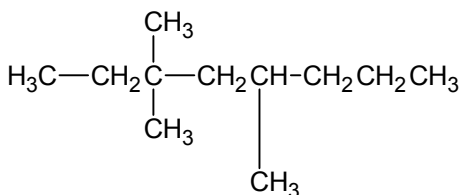
e) 3-hexyne



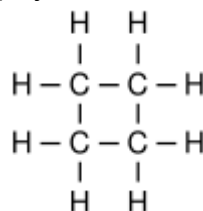
f) decene



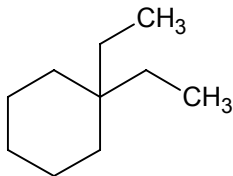
g) 3,3,5-trimethyloctane



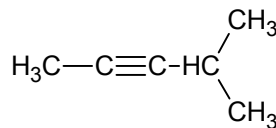
h) cyclobutane



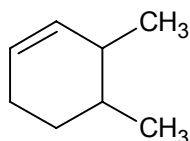
i) 1,1-diethylcyclohexane



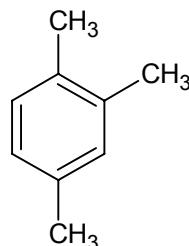
j) 4-methyl-2-pentyne



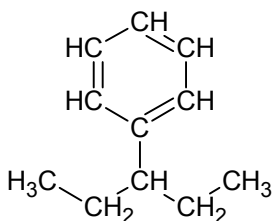
k) 3,4-dimethylcyclohexene



l) 1,2,4-trimethylbenzene



m) 3-phenylpentane

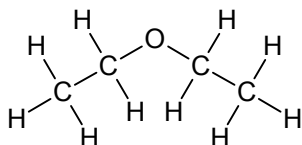


4. a) pentane
 b) propene
 c) 2-butyne
 d) nonane
 e) pentene
 f) ethane
 g) 1, 2-diethylcyclopentane
 h) 1-ethyl, 3-methylbenzene
 i) 2-ethyl, 4-phenylhexane

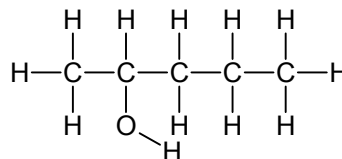
5. Fractional distillation can be used to separate the components of crude oil. The oil mixture is first heated into a boil, and then the oil gases rise up a tower or chamber, where they cool and condense at the respective boiling points. Cracking is the process of breaking larger hydrocarbons at high temperatures into smaller branched-chained hydrocarbons.

6. a) ethanol
 b) methoxy methane or dimethyl ether
 c) 4-octanol
 d) Methoxy propane or methyl propyl ether

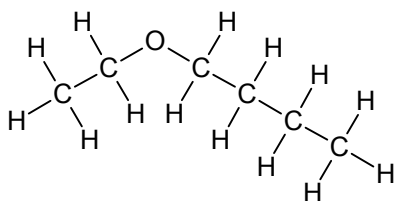
7. a) diethyl ether



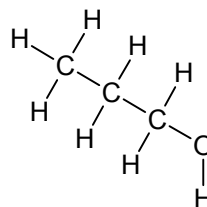
- b) 2-pentanol



- c) ethoxybutane

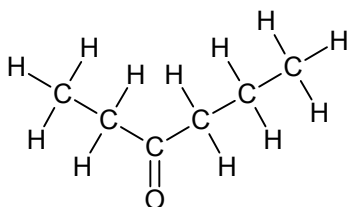


- d) propanol

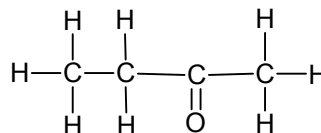


8. Using the IUPAC system, the carbon atoms are numbered to give the lowest number possible to the hydroxyl group. Since butane is only 4 carbon atoms long, the correct name would be 2-butanol.

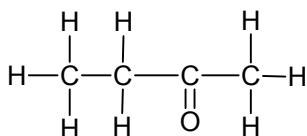
9. a) 3-hexanone



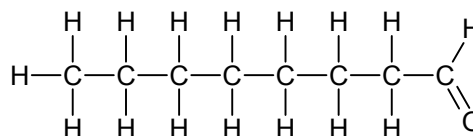
- b) 2-butanone



- c) pentanal



- d) octanal



10. a) hexanal
 c) 3-hexanone

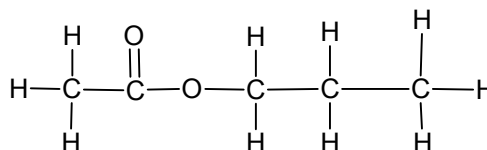
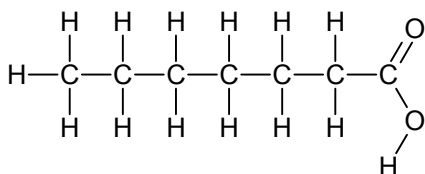
- b) ethanal
 d) 2-propanone

11. a) pentanoic acid

b) methyl propanoate

12. a) heptanoic acid

b) propyl methanoate

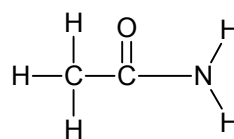
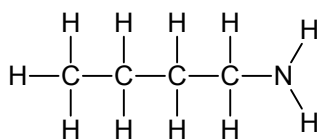


13. a) butyl amine

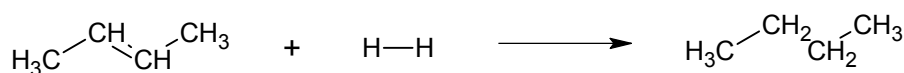
b) butylamide

14. a) butyl amine

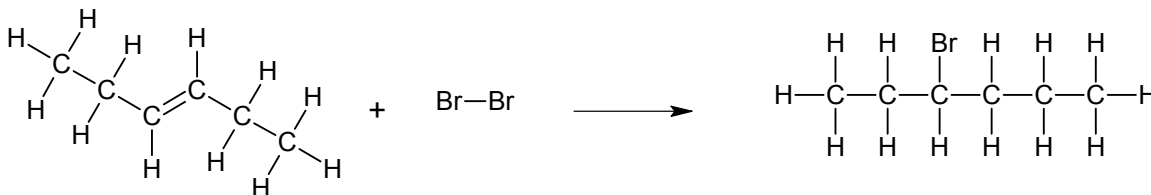
b) ethyl amide

15. a) ethane $\text{C}_2\text{H}_6 + 7/2\text{O}_2 \rightarrow 2\text{CO}_{2(g)} + 3\text{H}_2\text{O}_{(l)} + \text{heat}$ b) 2-heptene $\text{C}_7\text{H}_{14} + 21/2\text{O}_2 \rightarrow 7\text{CO}_{2(g)} + 7\text{H}_2\text{O}_{(l)} + \text{heat}$

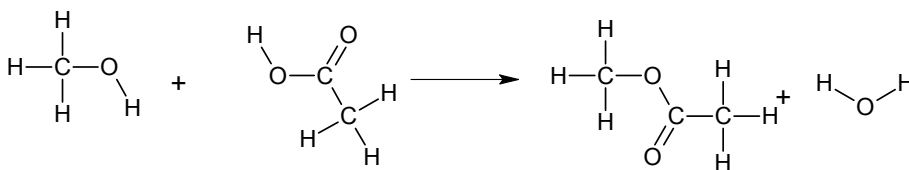
16. a) 2-butene and hydrogen gas



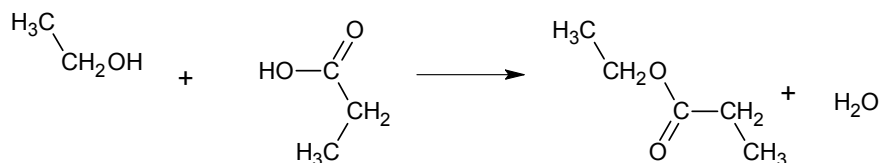
b) 3-hexene and bromine



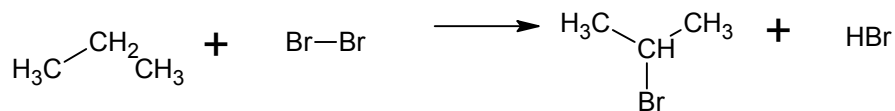
17. a) methanol and ethanoic acid



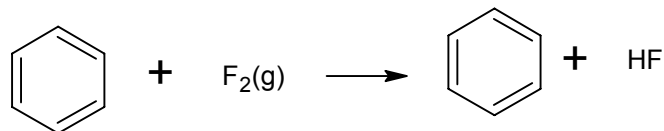
b) ethanol and propanoic acid



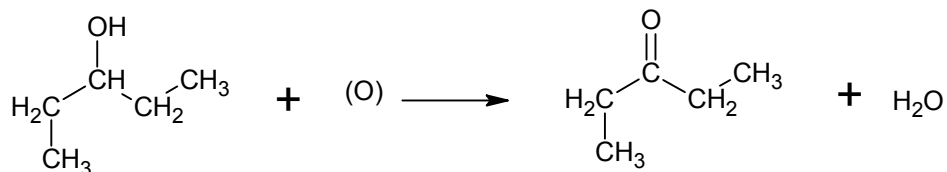
18. a) a substitution reaction of propane



b) a halogenation reaction of benzene



c) the preparation of 2-pentanone from an alcohol



19. In condensation polymerization, monomers are joined together by the formation of ester or amide bonds. Each molecule must have two functional groups and water is removed. Examples include; nylon, Kevlar, sodium, and polacrylate.

In addition reactions, monomers with double bonds are joined together by multiple addition reactions. Examples: various plastics, polypropylene