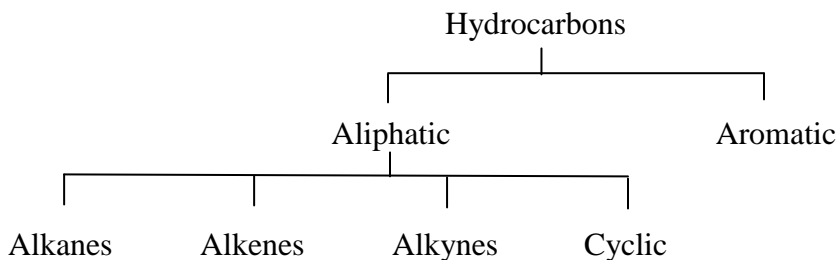


## SCH4U1

### HYDROCARBONS

Certain organic compounds contain only two elements - hydrogen and carbon. These are known as hydrocarbons. Hydrocarbons are divided into two main classes - **aliphatics** and **aromatics**. Aliphatic hydrocarbons are further divided into four families: alkanes, alkenes, alkynes, and their cyclic analogs (cycloalkanes, etc.).



A series of compounds in which each member differs from the next member by a constant amount is called a *homologous series* and the members of the series are known as *homologs*.

### ALKANES

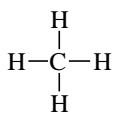
The family of alkanes forms a homologous series. Each member differs from the next by  $\text{CH}_2$ . Also, in each alkane, the number of hydrogen atoms equals two more than twice the number of carbon atoms. Therefore, the general formula for an alkane is  $\text{C}_n\text{H}_{2n+2}$ . A list of the first 10 alkanes is given below.

|                              |         |
|------------------------------|---------|
| $\text{CH}_4$                | methane |
| $\text{C}_2\text{H}_6$       | ethane  |
| $\text{C}_3\text{H}_8$       | propane |
| $\text{C}_4\text{H}_{10}$    | butane  |
| $\text{C}_5\text{H}_{12}$    | pentane |
| $\text{C}_6\text{H}_{14}$    | hexane  |
| $\text{C}_7\text{H}_{16}$    | heptane |
| $\text{C}_8\text{H}_{18}$    | octane  |
| $\text{C}_9\text{H}_{20}$    | nonane  |
| $\text{C}_{10}\text{H}_{22}$ | decane  |

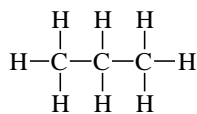
Note in each case the Greek or Latin prefixes used to indicate the number of carbons in the particular alkane. Also note that every one ends in -ane. Learn the above list very well as these root names are the basis of all hydrocarbons.

## Expanded Structural Diagrams

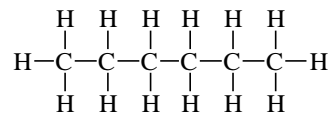
The normal structures (n-alkanes) of a few alkanes are shown below.



methane

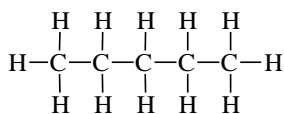


n-propane

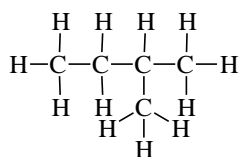


n-hexane

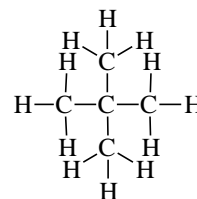
Different compounds that have the same molecular formula are called **isomers**. The three different isomers of pentane ( $\text{C}_5\text{H}_{12}$ ) are shown below. Since they are unique compounds, they have unique names and properties.



n-pentane  
(bp  $36^\circ\text{C}$ )



isopentane  
(bp  $28^\circ\text{C}$ )



neopentane  
(bp  $9^\circ\text{C}$ )

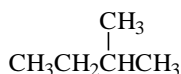
Structures can also be shown using condensed or line diagrams.

### Condensed Structural Diagrams:

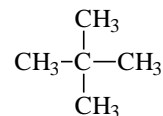
These diagrams all carbon atoms and the number of hydrogens bonded to each.



n-pentane



isopentane



neopentane

### Line Diagrams:

These diagrams show only the carbon-carbon bonds themselves.



n-pentane



isopentane



neopentane

In line diagrams, it is assumed that each carbon has four bonds and that hydrogens are attached at the appropriate locations. The number of hydrogens present must be determined by completing the bonding capacity of carbon (4).

Using prefixes such as (n) or (iso) or (neo) might appear as a suitable method of nomenclature. This works for simple alkanes such as butane (C<sub>4</sub>H<sub>10</sub>) and pentane (C<sub>5</sub>H<sub>12</sub>). However, it becomes hopeless when larger alkanes are considered. For example there are 5 isomers of hexane (C<sub>6</sub>H<sub>14</sub>), 9 isomers of heptane (C<sub>7</sub>H<sub>16</sub>) and 75 isomers of decane (C<sub>10</sub>H<sub>22</sub>).

Another problem arises as far as nomenclature is concerned. Hydrogens can be replaced or *substituted* by other elements or groups. For example a hydrogen of methane (CH<sub>4</sub>) may be replaced by a chlorine atom to form chloromethane (CH<sub>3</sub>Cl). Branched alkanes contain substitutions derived from smaller alkanes.

These substituted groups are named by dropping the -ane from the name of the corresponding alkane and replacing it by -yl. They are known collectively as **alkyl groups**. The general formula for an alkyl group is C<sub>n</sub>H<sub>2n+1</sub> since it contains one less hydrogen than the parent alkane with the formula C<sub>n</sub>H<sub>2n+2</sub>.

To devise a system of nomenclature that could be used for even the most complicated compounds, the International Union of Pure and Applied Chemists (IUPAC) developed a system that is used throughout the world today. Since this system follows much the same pattern for all families of organic compounds, we shall consider it in some detail as applied to alkanes.

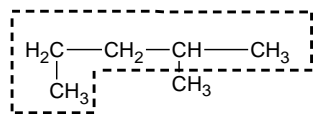
## ALKANES AND ALKYL RADICALS

| Alkane  | Formula                         | Melting Point (°C) | Phase at Room Temperature | Alkyl Group  | Formula                         |
|---------|---------------------------------|--------------------|---------------------------|--------------|---------------------------------|
| Methane | CH <sub>4</sub>                 | -183               | gas                       | methyl       | CH <sub>3</sub>                 |
| Ethane  | C <sub>2</sub> H <sub>6</sub>   | -172               | gas                       | ethyl        | C <sub>2</sub> H <sub>5</sub>   |
| Propane | C <sub>3</sub> H <sub>8</sub>   | -187               | gas                       | propyl       | C <sub>3</sub> H <sub>7</sub>   |
| Butane  | C <sub>4</sub> H <sub>10</sub>  | -135               | gas                       | butyl        | C <sub>4</sub> H <sub>9</sub>   |
| Pentane | C <sub>5</sub> H <sub>12</sub>  | -130               | liquid                    | pentyl(amyl) | C <sub>5</sub> H <sub>11</sub>  |
| Hexane  | C <sub>6</sub> H <sub>14</sub>  | -94                | liquid                    | hexyl        | C <sub>6</sub> H <sub>13</sub>  |
| Heptane | C <sub>7</sub> H <sub>16</sub>  | -91                | liquid                    | heptyl       | C <sub>7</sub> H <sub>15</sub>  |
| Octane  | C <sub>8</sub> H <sub>18</sub>  | -57                | liquid                    | octyl        | C <sub>8</sub> H <sub>17</sub>  |
| Nonane  | C <sub>9</sub> H <sub>20</sub>  | -54                | liquid                    | nonyl        | C <sub>9</sub> H <sub>19</sub>  |
| Decane  | C <sub>10</sub> H <sub>22</sub> | -30                | liquid                    | decyl        | C <sub>10</sub> H <sub>21</sub> |

### Naming Branched Alkanes

Branched alkanes can be named by following a simple sequence of steps:

1. Find the longest continuous chain of carbon atoms (the main chain). It is not necessary that the longest chain be written in a straight line.



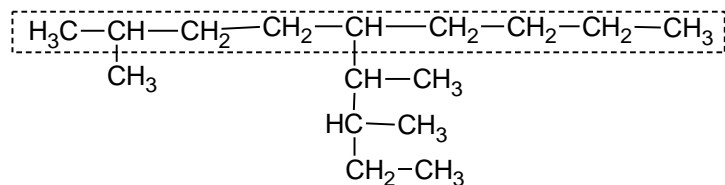
*The longest continuous chain contains 5 carbon atoms.*

2. Name this chain by adding "-ane" to the stem name (e.g. **pentane**).

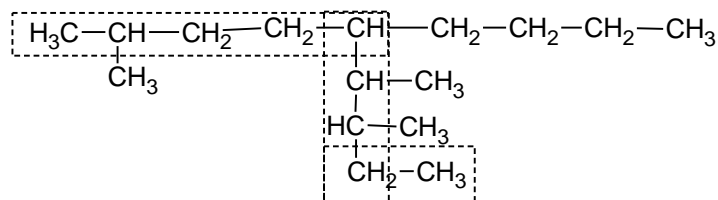
3. Pick out the alkyl groups attached to the main chain.



10. If chains of equal length are competing for selection as the main chain, choose that chain which has the greatest number of alkyl groups as the main chain.



2 alkyl groups (incorrect)



4 alkyl groups (correct)

5-butyl-2,6,7-trimethylnonane

11. Other common groups are frequently found attached to hydrocarbon chains. Their names are:

F- fluoro;

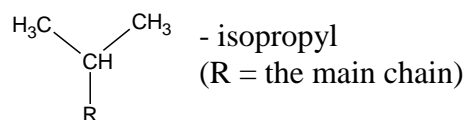
Cl- chloro;

Br- bromo;

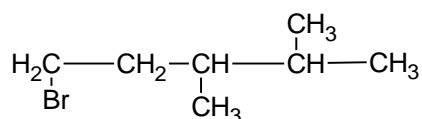
I- iodo;

NO<sub>2</sub>- nitro;

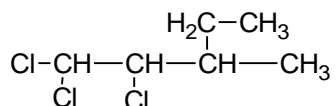
NH<sub>2</sub>- amino



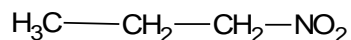
Examples of compounds containing these groups are:



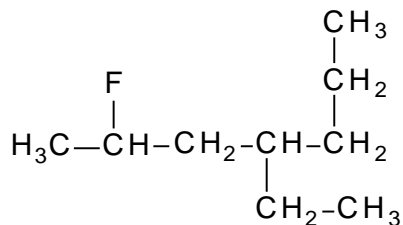
1-bromo-3,4-dimethylpentane



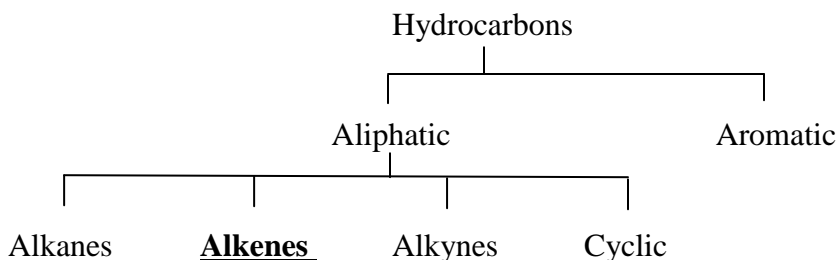
1,1,2-trichloro-3-methylpentane



1-nitropropane



4-ethyl-2-fluoroheptane



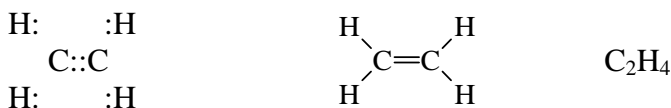
## ALKENES

The alkenes are a class of compounds that contain less hydrogen than the alkanes and which can be converted into alkanes by the addition of hydrogen.

Since alkenes evidently contain less than the maximum quantity of hydrogen, they are referred to as unsaturated hydrocarbons (alkanes are saturated hydrocarbons since they contain the maximum number of hydrogens per carbon atom).

All alkenes contain a carbon to carbon double bond (that is two carbons share two pairs of electrons instead of the normal sharing of one pair of electrons).

The simplest alkene is ethene (ethylene)

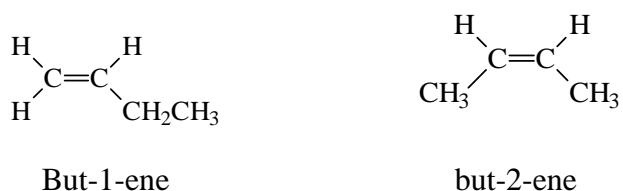


Its structure is very comparable to that of ethane with the single bond replaced by a double bond

The next alkene is propene (propylene).



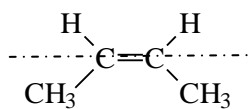
In butene (butylene), the double bond may be found in more than one location.



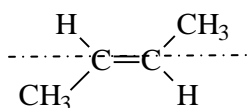
Note that for all three alkenes mentioned so far, the number of hydrogens is exactly double the number of carbons ( $\text{C}_2\text{H}_4$ ,  $\text{C}_3\text{H}_6$ ,  $\text{C}_4\text{H}_8$  etc.). Therefore, the general formula for alkenes is  $\text{C}_n\text{H}_{2n}$ .

## Geometric (*cis-trans*) Isomers

The structure of but-2-ene can be represented in two ways:

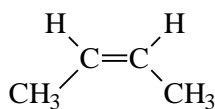


I

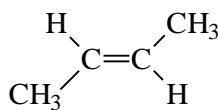


II

Since a carbon-carbon double bond (or sigma + pi bond) is not free to rotate, these represent two unique geometric forms of 2-butene. If a plane is drawn through form I above, both methyl groups are on the same side of the plane. In form II, the methyl groups lie on opposite sides of the plane. These two forms are known as *cis* (from Latin “on this side”) and *trans* (from Latin “across”) isomers of but-2-ene.

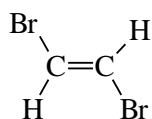


*Cis*-but-2-ene

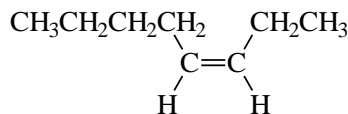


*trans*-but-2-ene

This type of isomerism can occur around any C=C bond as long as two different groups are bonded to each carbon involved in the double bond.

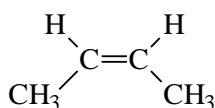


*trans*-1,2-dibromoethene

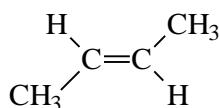


*cis*-oct-3-ene

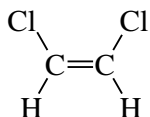
Geometric isomers are closely related but do have distinct properties.



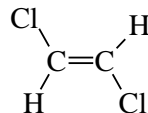
*cis*-but-2-ene (bp = 4°C)



*trans*-but-2-ene (bp = 1°C)



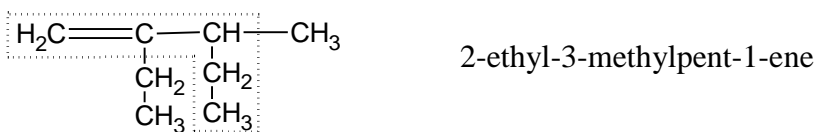
*cis*-1,2-dichloroethene  
(mp = -81°C; bp = 60°C)



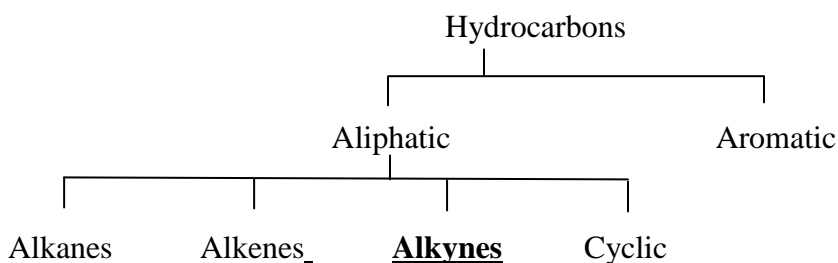
*trans*-1,2-dichloroethene  
(mp = -81°C; bp = 48°C)

Common names of alkenes are seldom used except for three simple alkenes: ethylene, propylene, and butylene. Most alkenes today are named by using the IUPAC naming system which is similar to that used for alkanes.

Alkenes are named in the same way as alkanes, except that the ending "-ene" is used. The main chain must contain both carbon atoms of the double bond, even if it is possible to find a longer continuous chain which does not pass through both double bonded carbon atoms.



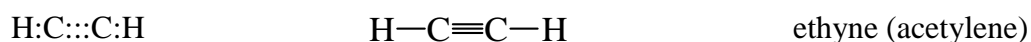
Thus, in this example the main chain has five carbon atoms even though a six-carbon chain can be found. The atoms of the main chain are numbered to give the double-bonded carbon atoms the lowest numbers, but we write only the lower of the two numbers to locate the double bond. The name of the main chain in the above example is therefore 1-pentene. The complete name of the alkene is 2-ethyl-3-methyl-1-pentene.



## ALKYNES

Alkanes have the general formula  $C_nH_{2n+2}$ ; alkenes have the general formula  $C_nH_{2n}$ . Now we will discuss the kinds of hydrocarbons that have the general formula  $C_nH_{2n-2}$ , the alkynes.

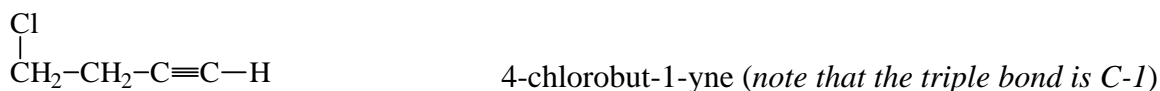
The carbon-carbon triple bond (or sigma + 2 pi bonds) is the characteristic feature of the alkynes. The simplest member of the alkynes is ethyne (acetylene).



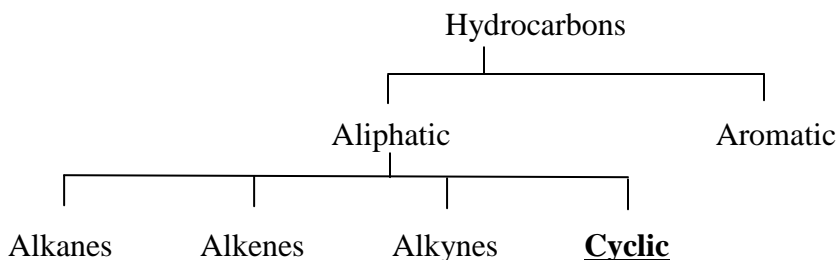
Like the alkanes and alkenes, the alkynes form a homologous series, the increment again being the  $-\text{CH}_2-$  group.

The rules for IUPAC nomenclature are exactly the same as for the naming of alkenes except that the ending  $-\text{yne}$  replaces the  $-\text{ene}$  of alkenes. The parent structure is the longest continuous chain that contains the triple bond, and the positions both of substituents and of the triple bond are indicated by numbers. The triple bond is given the number of the first triple bonded carbon encountered, starting from the end of the chain nearest the triple bond.

Examples of alkynes are:



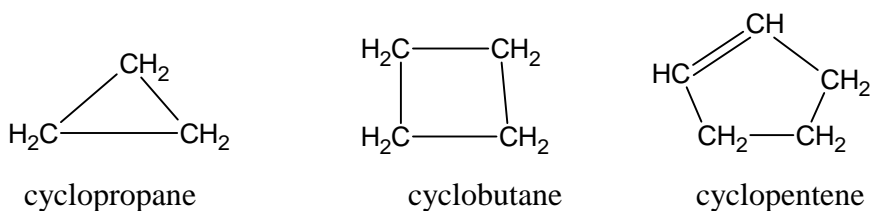




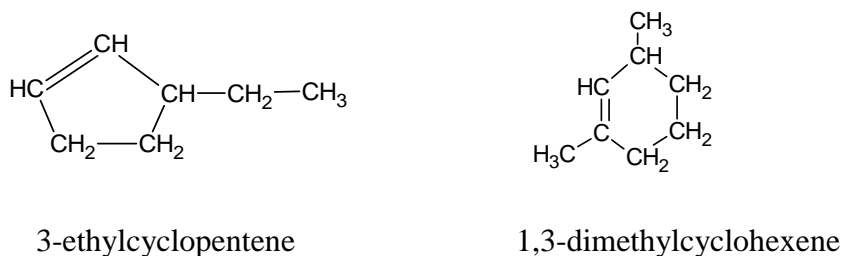
### CYCLIC ALIPHATICS

In the compounds that we have studied in previous sections, the carbon atoms are attached to one another to form *chains*; these are called open chain compounds. In many compounds, however, the carbon atoms are arranged to form *rings*; these are called **cyclic compounds**.

Cyclic aliphatic hydrocarbons are named by prefixing **cyclo** to the name of the corresponding open chain hydrocarbon having the same number of carbon atoms as the ring.

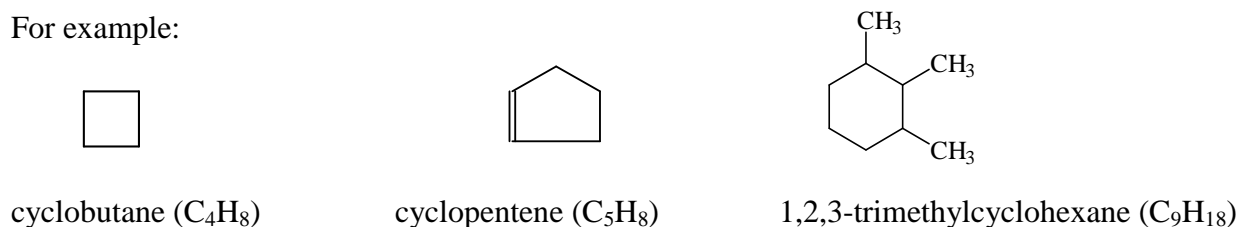


Substituents on the ring are named, and their positions are indicated by numbers, the lowest combination of numbers being used. In simple cycloalkenes and cycloalkynes, the double- and triple-bonded carbons are considered to be carbons 1 and 2. Therefore, numbering always begins at the start of the double or triple bond in such a way as to give the first substitution the lowest carbon number.



For convenience, aliphatic rings are often represented by simple geometric figures (line diagrams). A triangle represents cyclopropane, a square for cyclobutane, a pentagon for cyclopentane, a hexagon for cyclohexane, and so on. It is understood that the appropriate number of hydrogens are at each corner of the figure, unless some other group is indicated.

For example:



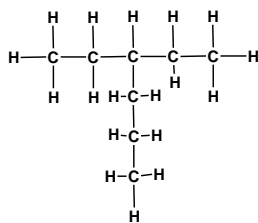
Note that the formation of the ring removes two hydrogens from the formula of any cyclic hydrocarbon. For example, the alkane butane has the formula C<sub>4</sub>H<sub>10</sub> whereas cyclobutane has the formula C<sub>4</sub>H<sub>8</sub>.

## Aliphatic Hydrocarbons Practice

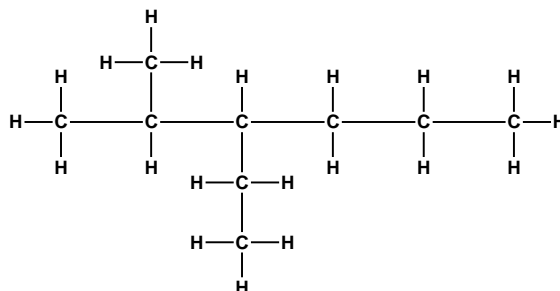
Read p. 8 - 18 of the textbook and answer these questions..

1. Butane exists in the form of two structural isomers. Draw the structural formula and write the IUPAC name of each.
2. Draw the condensed straight-chain structures for heptane and nonane.
3. Match each name in a-d with the correct structure in e-h.
  - a. 3-ethyl-2-methylhexane
  - b. 3-ethyl-4-methylhexane
  - c. 2,2- dimethylhexane
  - d. 3-ethylhexane

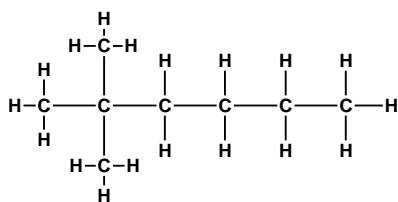
e.



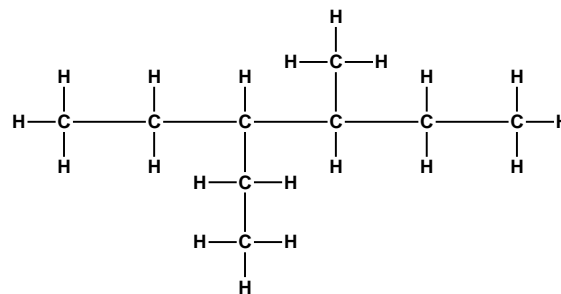
f.



g.

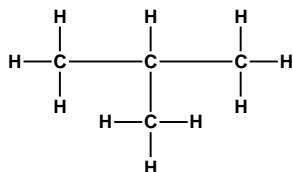


h.

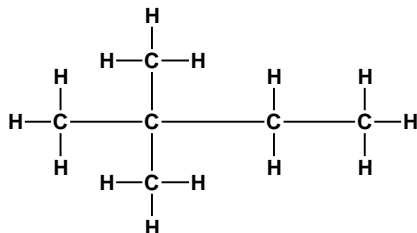


4. Write the names of the following alkanes:

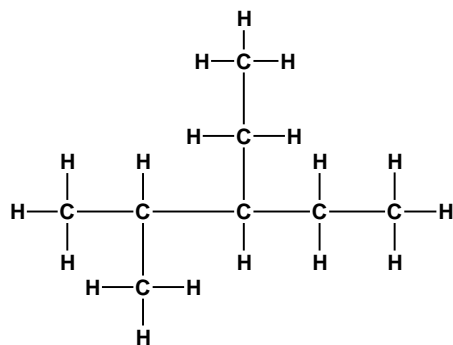
a.



b.



c.



5. How many hydrogen atoms would be in a molecule of an alkane containing 15 carbon atoms? 50 carbon atoms?

6. Draw the condensed structural formulas of the following compounds:

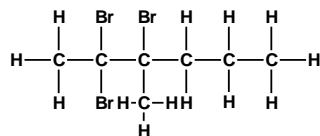
a. 2-methylbutane

b. 3,3-dichlorohexane

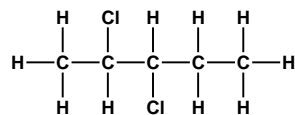
c. 4-ethyl-2,3,4-trimethyldecane

7. Write the correct name for each of the following structures:

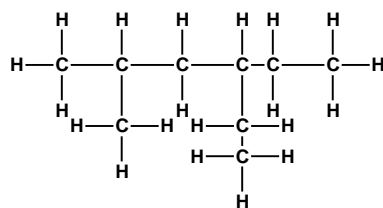
a.



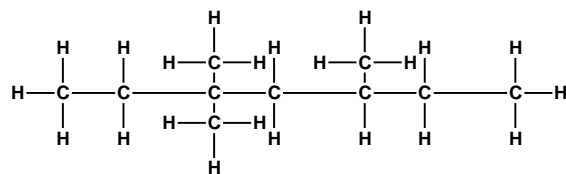
c



b.



d



# Alkanes, Alkenes, Alkynes and Cyclic Hydrocarbons

Name or draw the following compounds:

|    | Chemical structure  | IUPAC Name |
|----|---|------------|
| 1  | $\begin{array}{c} \text{Cl} \\   \\ \text{H}_3\text{C}-\text{CH}_2-\text{CH}-\text{CH}_3 \end{array}$   | .....      |
| 2  | $\begin{array}{c} \text{CH}_3 \\   \\ \text{H}_3\text{C}-\text{CH}-\text{CH}_2-\text{HC}-\text{CH}_3 \\   \quad   \\ \text{CH}_2 \quad \text{CH}_2 \\   \quad   \\ \text{CH}_3 \quad \text{CH}_3 \end{array}$   | .....      |
| 3  | $\begin{array}{c} \text{Br} \quad \quad \text{Br} \quad \quad \text{Cl} \\   \quad \quad   \quad \quad   \\ \text{H}_3\text{C}-\text{CH}-\text{CH}_2-\text{CH}-\text{CH}-\text{C}-\text{CH}_3 \\   \quad \quad   \quad \quad   \\ \text{CH}_3 \quad \quad \text{Cl} \end{array}$            | .....      |
| 4  | $\begin{array}{c} \text{CH}_3 \\   \\ \text{H}_3\text{C}-\text{C}-\text{CH}_2-\text{CH}-\text{CH}_2-\text{CH}_2 \\   \quad   \quad   \\ \text{CH}_2 \quad \text{NH}_2 \quad \text{NO}_2 \\   \\ \text{CH}_2 \\   \\ \text{CH}_3 \end{array}$  | .....      |
| 5  | $\begin{array}{c} \text{CH}_3 \\   \\ \text{H}_3\text{C}-\text{CH}-\text{CH}_2-\text{C}-\text{CH}_2-\text{CH}_3 \\   \quad   \\ \text{CH}_3 \quad \text{CH}_3 \end{array}$  | .....      |
| 6  | $\begin{array}{c} \text{CH}_3 \\   \\ \text{HC}-\text{CH}_2-\text{CH}-\text{CH}-\text{CH}_3 \\   \quad   \quad   \\ \text{CH}_2 \quad \text{Cl} \quad \text{Cl} \\   \\ \text{Cl}-\text{CH} \\   \\ \text{CH}_3 \end{array}$  | .....      |
| 7  | $\begin{array}{c} \text{NH}_2 \quad \quad \text{NH}_2 \\   \quad \quad   \\ \text{H}_3\text{C}-\text{C}-\text{CH}_2-\text{C}-\text{CH}_3 \\   \quad \quad   \\ \text{NO}_2 \quad \quad \text{NO}_2 \end{array}$   | .....      |
| 8  | $\begin{array}{c} \text{Cl} \quad \quad \text{Cl} \quad \quad \text{Cl} \\   \quad \quad   \quad \quad   \\ \text{Cl}-\text{C}-\text{CH}_2-\text{C}-\text{CH}_2-\text{C}-\text{CH}_3 \\   \quad \quad   \quad \quad   \\ \text{Cl} \quad \quad \text{Cl} \quad \quad \text{Cl} \end{array}$ | .....      |
| 9  | $\begin{array}{c} \text{CH}_3 \\   \\ \text{H}_3\text{C}-\text{C}-\text{CH}_2-\text{CH}-\text{CH}_3 \\   \quad   \\ \text{CH}_2 \quad \text{Br} \\   \\ \text{CH}_3 \end{array}$  | .....      |
| 10 | $\begin{array}{c} \text{Br} \\   \\ \text{H}_3\text{C}-\text{CH}_2-\text{C}-\text{CH}_2-\text{CH}_3 \\   \\ \text{Cl} \end{array}$  | .....      |
| 11 | $\begin{array}{c} \text{NO}_2 \quad \quad \text{Br} \\   \quad \quad   \\ \text{H}_3\text{C}-\text{CH}-\text{CH}_2-\text{CH}_2 \end{array}$   | .....      |

12

2,3-dichloropentane

13

3-bromo-2-methylheptane

14

1,2-dichloropropene

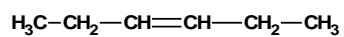
15

4,4-diamino-2,3,6-trichlorooctane

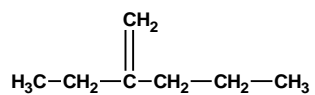
16

2,2,3,3,4-pentachloropentane

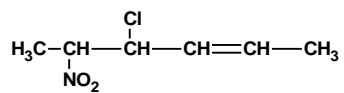
17



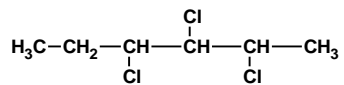
18



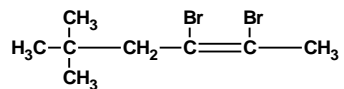
19



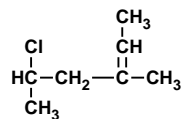
20



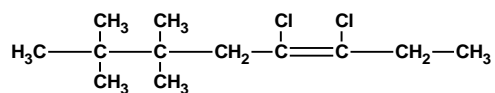
21



22



23



24

5-amino-3-chloropent-1-ene

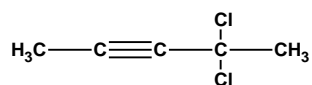
26

4-chloro-2,2-dinitrohept-3-ene

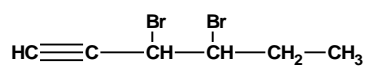
27

*trans*-oct-3-ene

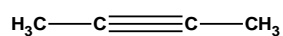
28



29



30



31

5,5-dimethylhex-2-yne

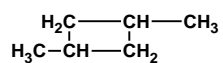
32

5-aminohept-3-yne

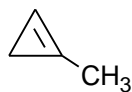
33

- a. pentane
- b. pent-2-ene
- c. pent-1-yne

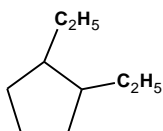
34



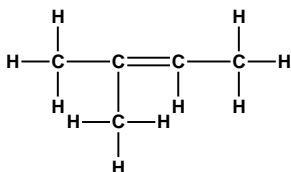
35



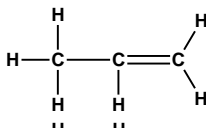
36



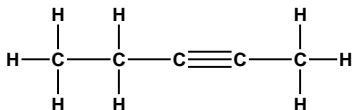
37



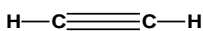
38



40



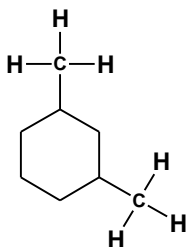
41



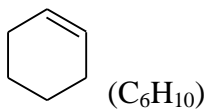
42



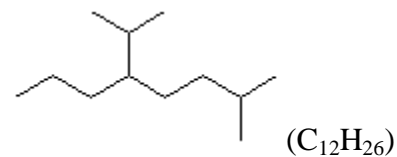
43



44

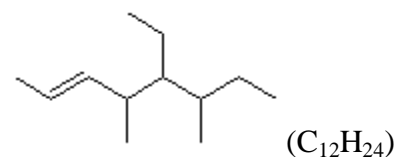


45

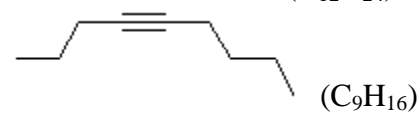


(recall that in line diagrams, lines represent carbon-carbon bonds; this contains isopropyl)

46



47



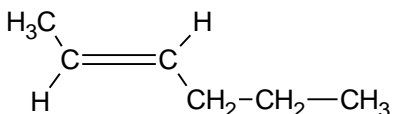
48

1,3-diaminopropane  
(line diagram)

49

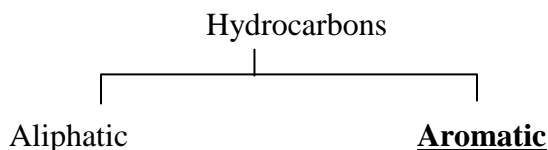
*trans*-5-ethyl-4,5-dimethylhept-2-ene  
(line diagram)

50

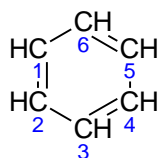


(indicate if it is *cis* or *trans* isomer)

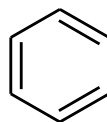
## AROMATIC HYDROCARBONS



The aromatic hydrocarbons are benzene and compounds containing a benzene ring. Benzene has the chemical formula  $C_6H_6$  and consists of a ring of six carbon atoms. Based on the chemical formula, one proposed structure for benzene was the following:

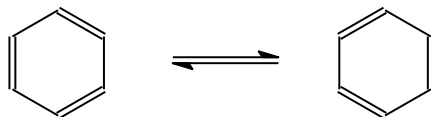


or

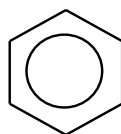


This structure would be called cyclohexatriene using the IUPAC system for naming aliphatic hydrocarbons that we have studied previously. However, the properties of benzene are very different than those of other double or triple bonded hydrocarbons. For example, benzene is a very stable molecule while alkenes and alkynes are both very reactive.

In fact, benzene has 6 *identical* carbon-carbon bonds in its structure. Benzene can be thought of as a hybrid of two “resonance forms” of cyclohexatriene:

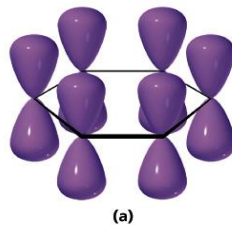


Either of these structures is identified as benzene although neither is actually correct. Instead, a common way to represent benzene is a ring of 6 carbons with a circle in the middle:

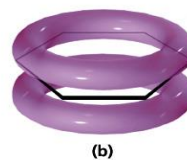


In other words, the electrons involved in the “double” bonds or pi bonds are shared equally among all 6 carbons. These pi electrons are said to be *delocalized* in this arrangement. Every carbon is  $sp^2$  hybridization state with one electron involved in pi bonding. This means that benzene has a planar structure as shown in these models:

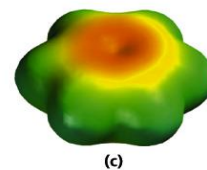
a) 6 half-filled  $p$  orbitals



b)  $\pi$ -bonding (delocalized electrons)



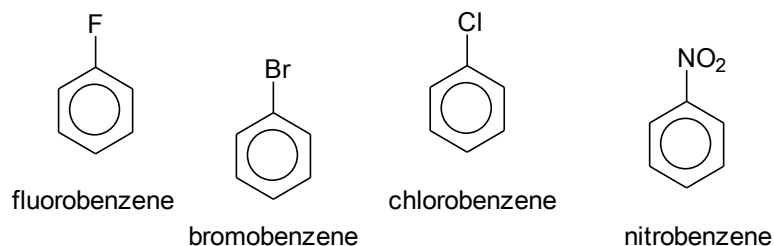
c) electron density diagram



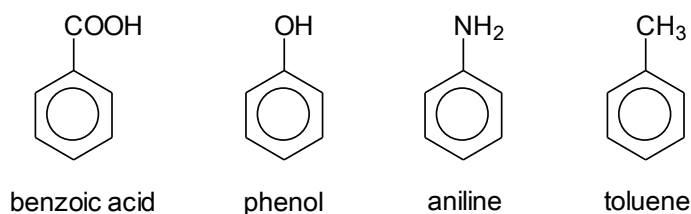


## Aromatic Nomenclature

For many of the derivatives of benzene, we simply prefix the name of the substituent group to the word benzene. For example:

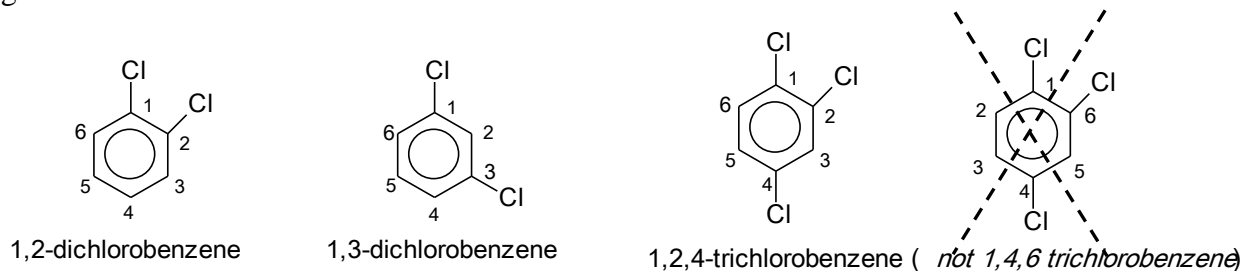


Some derivatives, however, have common names that do not follow the IUPAC system:

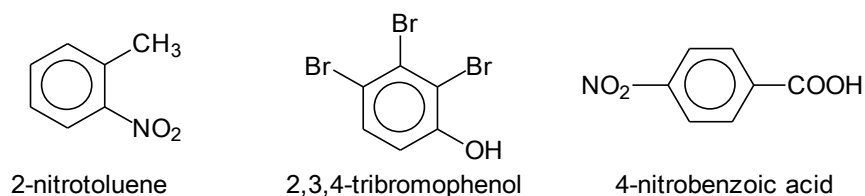


Benzoic acid and phenol are always known by these names and must be memorized. Aniline is also known as aminobenzene and toluene is also known as methylbenzene.

If several groups are substituted on the benzene ring, we also indicate their relative position. If all groups are the same, each substituted group is given a number to produce a sequence that gives the lowest combination of numbers.

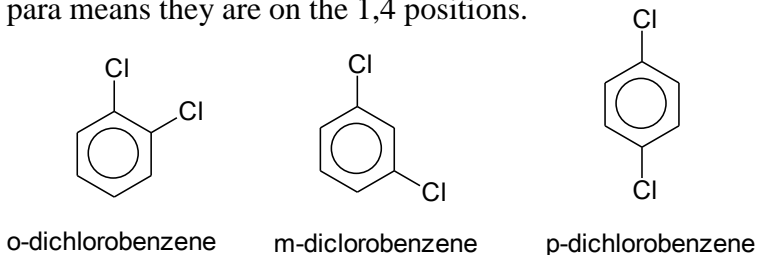


If the last named group has no number, it is understood to be at position 1. If a special name is used (e.g. phenol), the compound is named so the special group (e.g. the hydroxyl group on phenol) is at position 1.

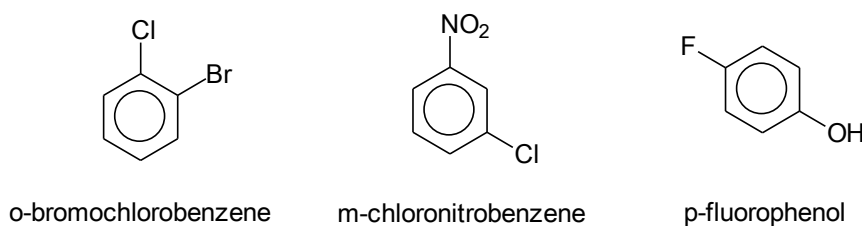


## Ortho, Meta and Para

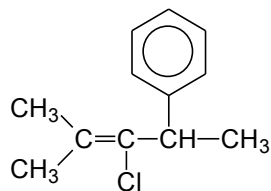
The various isomers of disubstituted benzene rings are often named using an alternative system. The names *ortho*, *meta* and *para* (prefixes *o*, *m* or *p*) identify the relative positions of two groups on the ring. Ortho means the two groups are on the 1,2 positions, meta means they are on the 1,3 positions and para means they are on the 1,4 positions.



If the two groups are different, simply add the two prefixes with benzene. If one of the groups confers a special name, then the compound is named as a derivative of this compound.



Occasionally, benzene groups are found as substitutions on more complex hydrocarbon chains (e.g. alkenes or alkynes). In these compounds, the benzene is treated as a substitution and given the name *phenyl*. Be careful not to confuse a phenyl group with the compound phenol!



3-chloro-2-methyl-4-phenylpent-2-ene

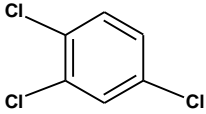
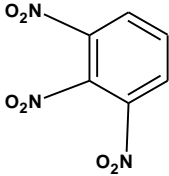
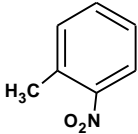
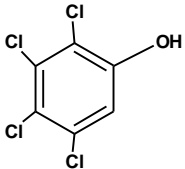
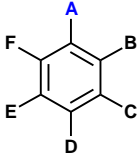
## ISOMERS

**Structural Isomers** are compounds with the same chemical formula but different arrangement of atoms. For example, the ortho, meta and para forms of dichlorobenzene shown above are all isomers with the chemical formula  $C_6H_4Cl_2$ . These compounds have the same molecular mass, but their physical and chemical properties are slightly different. **Geometric Isomers** are isomers where the atoms are arranged in the same way BUT they still have a different 3-dimensional arrangement. One form of this is *cis-trans* isomerism found in some alkenes.

To identify a pair of compounds as identical, isomers or different compounds, follow these clues.

1. Determine the chemical formula for the two compounds. Are they different? If YES, the compounds are not isomers but are different compounds.
2. If the chemical formula are the same, examine the spatial arrangement of atoms in the structure. Are the atoms joined in the same arrangement or are the atoms joined differently (structural isomerism)? Remember that there may be several ways to draw the same compound. If there are double bonds, examine if there are possible geometric (*cis-trans*) isomers.

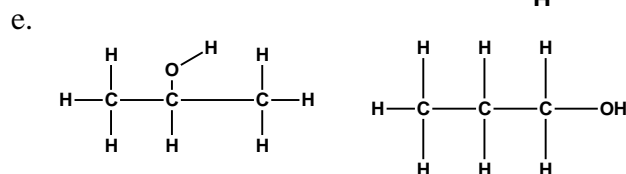
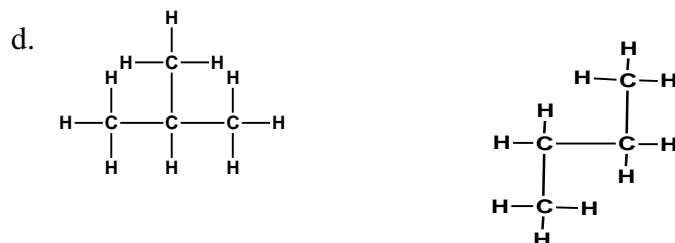
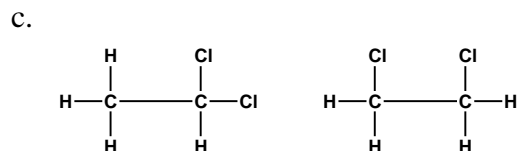
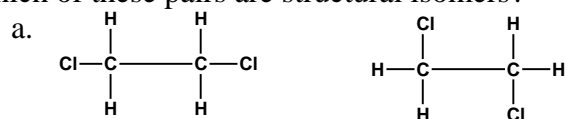
# Aromatic Hydrocarbons

|    | Chemical structure   | IUPAC Name  |
|----|--|---|
| 1a |   | .....   |
| 1b |   | .....   |
| 2a |   | .....   |
| 2b |    | .....   |
| 3  |  | p-nitrophenol   |
| 4  |  | 2,3-dibromo-5-chloro nitrobenzene   |
| 5  | <p>Consider the following structure representing a benzene molecule substituted with a number of different groups. (A, B, C, D, E and F)</p>  | <p>State whether the following pairs of groups are ortho, meta or para to each other.</p> <p>a) B&amp;D                      f) F &amp; B<br/>           b) F &amp; C                    g) B &amp; C<br/>           c) E &amp; F                    h) F &amp; A<br/>           d) A &amp; C                    i) E &amp; C<br/>           e) B &amp; E</p> |


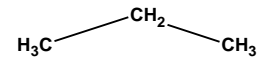
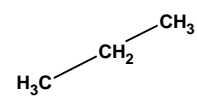
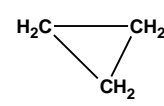
Do Questions 7 and 8 on p. 21 of Nelson *Chemistry 12* (see below):

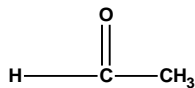
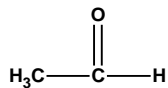
# Isomers

1. Which of these pairs are structural isomers?

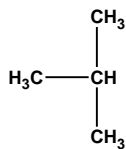
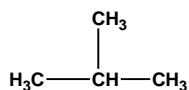


2. Examine each of the following pairs of structures and decide if the two are identical, isomers or different compounds.

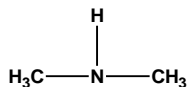
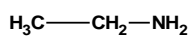
|    | Chemical structure  | Chemical structure  | Identical /<br>isomers/<br>different<br>compounds |
|----|---|---|---|
| a. |  | $\text{H}_3\text{C}-\text{CH}_3$  | .....   |
| b. |  |  | .....   |
| c. | $\text{H}_3\text{C}-\text{CH}_2-\text{OH}$  | $\text{H}_3\text{C}-\text{CH}_2-\text{CH}_2-\text{OH}$                              | .....   |
| d. | $\text{H}_3\text{C}-\text{CH}=\text{CH}_2$  |  | .....   |
| e. |   |   | .....   |



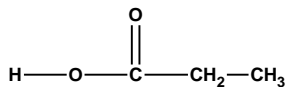
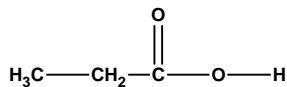
f.



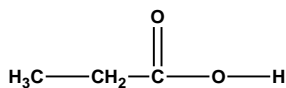
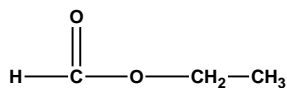
g.



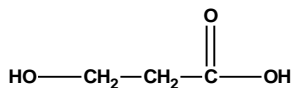
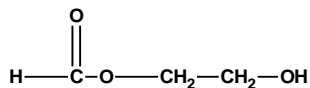
h.



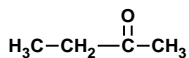
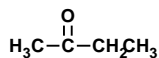
i.



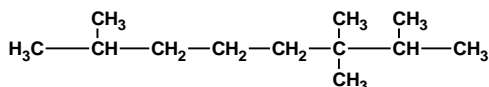
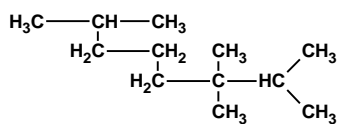
j.



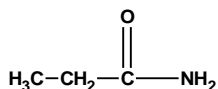
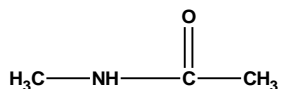
k.



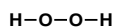
l.



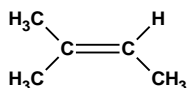
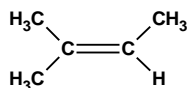
m.



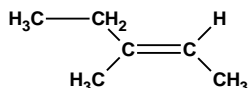
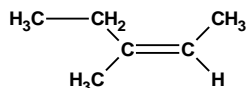
n.



o.



p.



## FUNCTIONAL GROUPS I

The characteristics of organic compounds (boiling point, odour, reactivity etc.) depend on the composition and arrangement of atoms. For example the properties of **alkanes** depend greatly on the number of carbon atoms in the hydrocarbon chain due to the increased strength of the van der Waal attractions. **Alkenes** have lower boiling points but greater chemical reactivity than their saturated counterparts. In an alkene, it is the presence (and position) of the double bond that is responsible of these properties. Any atom, group of atoms or organization of bonds that determines the specific properties of a molecule is known as a **functional group**.

The double bond in an alkene and the triple bond of an alkyne are functional groups. A functional group can also be an atom or group of atoms attached to some carbon in a hydrocarbon chain. The most common atoms encountered are oxygen, nitrogen or both. Even chlorine attached to an alkane can be considered a functional group and this class of hydrocarbons is called alkyl halides. When discussing functional groups, it is common to use **R** to represent the **rest of the molecule** to which the functional group is attached.

Two common oxygen-containing functional groups attached to hydrocarbons are the hydroxyl group (**R-OH**) and the carbonyl group (**R-C=O**). Depending on how these are arranged, these can form four types of organic compounds shown below.

**Table 1:** Structures and Examples of Aldehydes, Ketones and Carboxylic Acid

| General Structure   | Type            | Example  |                        |
|---|-----------------|--|------------------------|
| $R-O-H$   | alcohol         | $\begin{array}{c} H & H \\   &   \\ H-C & -C-OH \\   &   \\ H & H \end{array}$                   | ethan <u>o</u> l       |
| $\begin{array}{c} O \\    \\ R-C \\   \\ H \end{array}$           | aldehyde        | $\begin{array}{c} H & & O \\   & & // \\ H-C & -C & \\   & & \backslash \\ H & & H \end{array}$  | ethan <u>a</u> l       |
| $\begin{array}{c} O \\    \\ R-C-R' \end{array}$                  | ketone          | $\begin{array}{c} H & O & H \\   &    &   \\ H-C & -C & -C-H \\   & &   \\ H & & H \end{array}$  | propan <u>o</u> ne     |
| $\begin{array}{c} O \\    \\ R-C \\ \backslash \\ OH \end{array}$ | carboxylic acid | $\begin{array}{c} H & & O \\   & & // \\ H-C & -C & \\   & & \backslash \\ H & & OH \end{array}$ | ethan <u>o</u> ic acid |

As you may see from Table 1, the hydroxyl group appears in two types of organic compounds (alcohols and carboxylic acids) while the carbonyl group is found in three (aldehydes, ketones, acids).

Since the functional group is considered the most important part of the molecules, the nomenclature is based on the group. Fortunately, most of the rules for organic nomenclature still apply (see Table 1). We simply change the end of the root name from -ane to either -ol, -al,

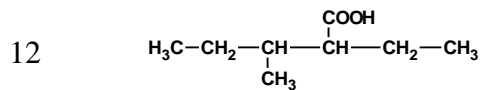


# Alcohols, Aldehydes, Ketones and Carboxylic Acids

Name or draw the following compounds:

|     | Chemical structure  | IUPAC Name                 |
|-----|---|----------------------------|
| 1   | $\begin{array}{c} \text{H}_3\text{C}-\text{CH}-\text{CH}_2-\text{CH}_2-\text{OH} \\   \\ \text{NO}_2 \end{array}$   | .....                      |
| 2   | $\begin{array}{c} \text{Cl} \quad \text{Cl} \\   \quad   \\ \text{H}_3\text{C}-\text{C}-\text{CH}-\text{CH}-\text{CH}_3 \\   \quad   \\ \text{Cl} \quad \text{OH} \end{array}$                      | .....                      |
| 3   | $\begin{array}{c} \text{Cl} \quad \text{H}_2\text{C}-\text{CH}_2-\text{CH}_2-\text{OH} \\   \quad   \\ \text{H}_3\text{C}-\text{CH}-\text{C}-\text{CH}_2-\text{CH}_3 \\   \\ \text{Cl} \end{array}$ | .....                      |
| 4   |   | 2,5-dinitrohexan-3-ol      |
| 5   |   | 2,2-diamino propanol       |
| 6   | $\begin{array}{c} \text{H} \\   \\ \text{H}_3\text{C}-\text{CH}-\text{CH}-\text{CH}_2-\text{C}=\text{O} \\   \quad   \\ \text{Cl} \quad \text{Cl} \end{array}$                                      | .....                      |
| 7   | $\begin{array}{c} \text{CH}_3 \quad \text{CH}_3 \quad \text{H} \\   \quad   \quad   \\ \text{H}_3\text{C}-\text{CH}-\text{CH}_2-\text{CH}-\text{C}=\text{O} \end{array}$                            | .....                      |
| 8   | $\begin{array}{c} \text{H}_3\text{C}-\text{CH}_2-\text{CH}_2-\text{C}-\text{CH}_2-\text{CH}_3 \\    \\ \text{O} \end{array}$  | .....                      |
| 9   | $\begin{array}{c} \text{NO}_2 \quad \text{O} \\   \quad    \\ \text{H}_3\text{C}-\text{C}-\text{CH}_2-\text{C}-\text{CH}_3 \\   \\ \text{NO}_2 \end{array}$   | .....                      |
| 10  |   | 2-chloro-2-methyl propanal |
| 11a | $\text{H}_3\text{C}-\text{CH}_2-\text{CH}_2-\text{COOH}$  | .....                      |
| 11b | $\text{H}_3\text{C}-\text{COOH}$  | .....                      |
| 11c | $\text{H}-\text{COOH}$  | .....                      |

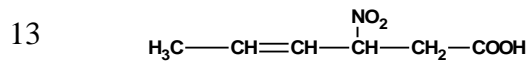





---



---




---

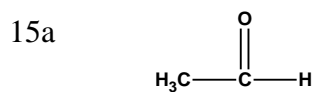


---

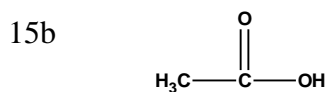
14

*cis*-4,5-dichlorohepten-4-oic acid

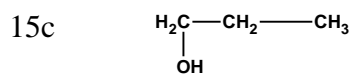
**For each of the following, name the functional group and state the type of organic compound**



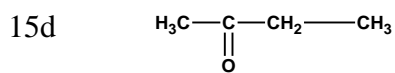

---



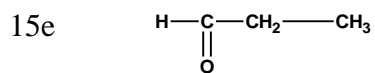

---



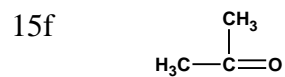

---




---




---

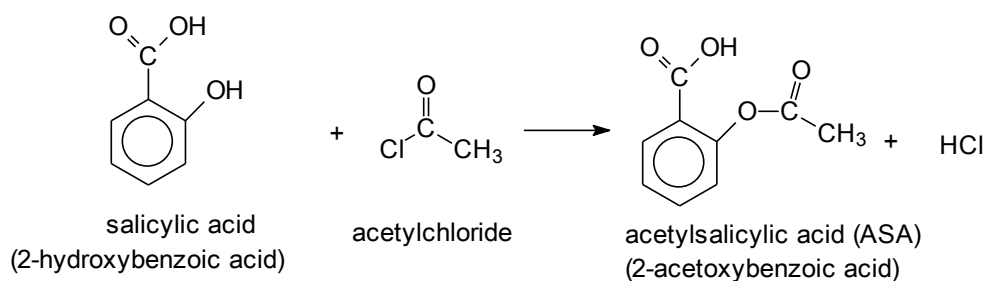



---

## ORGANIC REACTIONS I

Organic compounds form the basic building blocks of life. Understanding the reactions they undergo is essential for an understanding of biological chemistry (biochemistry). Organic chemists are also able to create or synthesize new compounds with unique and useful properties using chemical reactions.

One famous example is the synthesis of acetylsalicylic acid (ASA), commonly called aspirin. People have known since ancient times that an extract of willow bark can reduce pain and inflammation. Chemists eventually identified the active compound as salicylic acid (2-hydroxybenzoic acid). However this substance causes several undesirable side-effects such as stomach irritation and nausea. However a French chemist, Charles Gerhardt, synthesized a new compound, acetylsalicylic acid, in 1853. This new compound had fewer side-effects than natural salicylic acid and was marketed by the German company Bayer in 1899 under the trade name Aspirin™. Up until the marketing of acetaminophen (Tylenol™) in 1956, Aspirin was the most common treatment for mild to moderate pain.



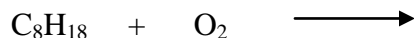
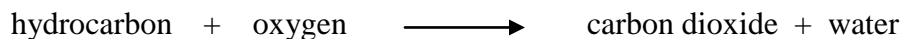
## TYPES OF ORGANIC REACTIONS

### REACTIONS OF ALKANES

Alkanes are generally unreactive but do undergo some characteristic reactions.

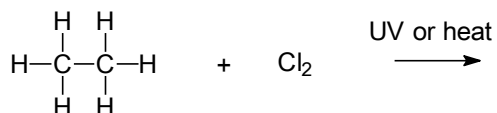
#### 1) COMBUSTION

This is the complete oxidation of a hydrocarbon.

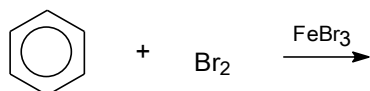


#### 2) SUBSTITUTION

This is the replacement (substitution) of hydrogen for a halogen atom.

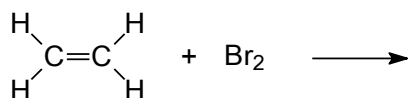


Aromatic hydrocarbons undergo a very similar reaction.



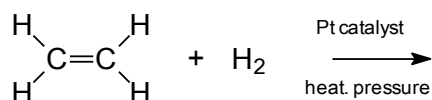
### 3) a) ADDITION WITH Br<sub>2</sub> or Cl<sub>2</sub>

The unsaturated hydrocarbons are much more reactive due to the presence of the double or triple bonds.

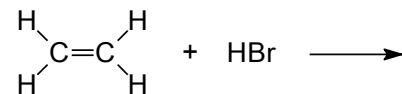


During the reaction, the red colour of bromine disappears as it reacts. Since alkanes do not react with halogens at room temperature, this can be used as a test for the presence of unsaturated hydrocarbons.

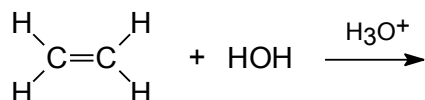
### b) ADDITION OF HYDROGEN (HYDROGENATION)



### c) ADDITION WITH HCl or HBr

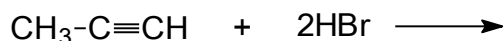
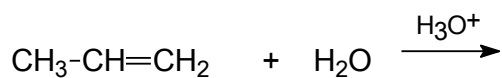


### d) ADDITION WITH WATER



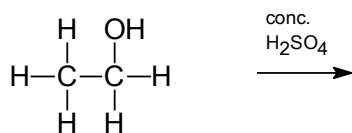
### Markovnikov's Rule

If the more than one product is possible, the more electronegative atom will end up on the carbon atom of the double bond that has the fewer hydrogens. This rule is known as Markovnikov's Rule.



### 4) ELIMINATION REACTIONS

The addition reaction of an alkene and water can be made to go in reverse. This is also called a dehydration reaction.

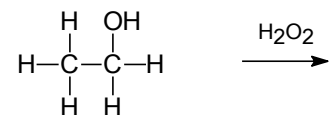


## 5) MILD OXIDATION REACTIONS

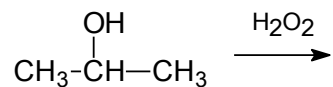
Complete oxidation of an organic compound forms carbon dioxide and water (Reaction 1). However a controlled oxidation of an alcohol can be used to create other functional groups. Using oxidizing agents such as  $\text{KMnO}_4$ ,  $\text{K}_2\text{Cr}_2\text{O}_7$  or  $\text{H}_2\text{O}_2$ , the following sequence of reactions is possible:



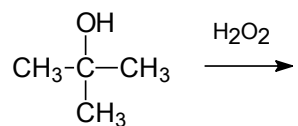
### a) Primary alcohols



### b) Secondary Alcohols



### c) Tertiary Alcohols

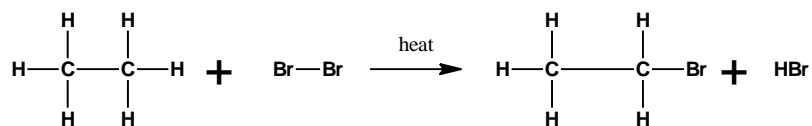


## Types of Organic Reactions

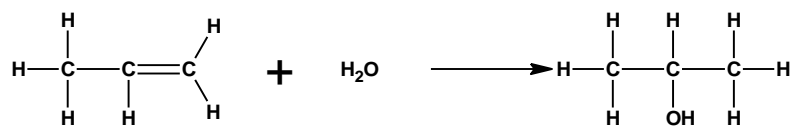
Textbook (p. 31 #1-4; p.44 #7,8; p.56 #6); p. 56 #6

1. Identify the type of organic reaction represented by each of the following equations:

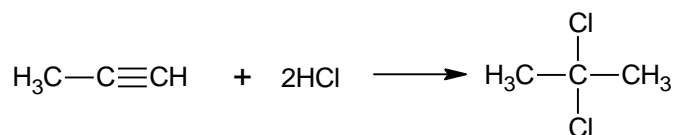
a.



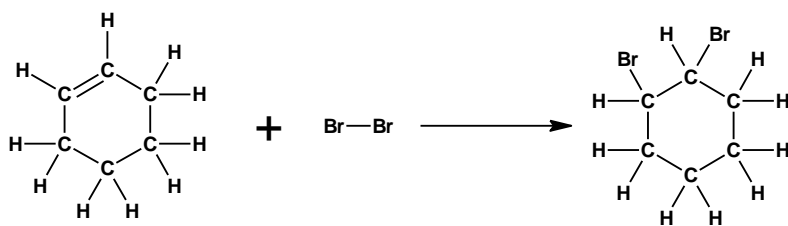
b.



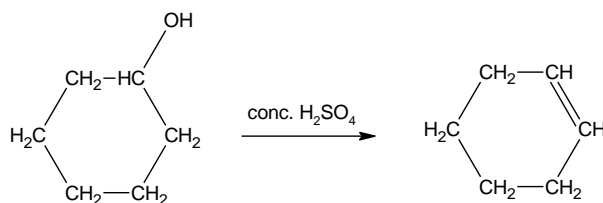
c.



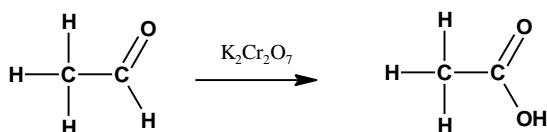
d.



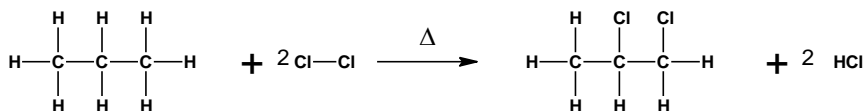
e.



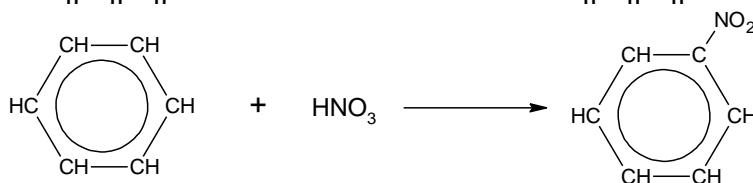
f.



g.



h.



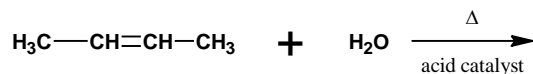
2. Write the equation for the addition reaction involving propene and bromine.

3. Complete the following equations by writing the structures of the products that form. If no reaction occurs, write "no reaction".

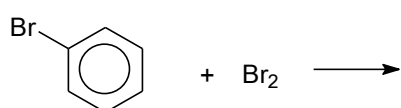
a.



b.

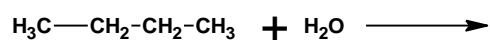


c.

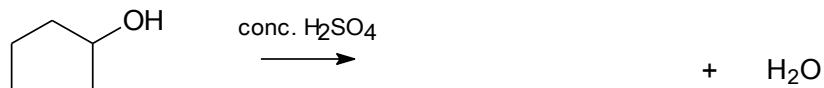


(3 possible products but ortho isomer is favoured)

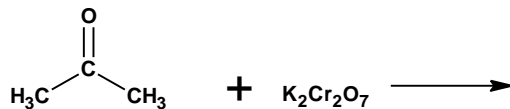
d.



e.



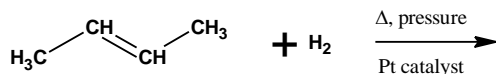
f.



g.



h.

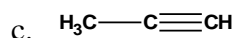
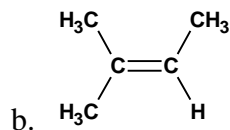
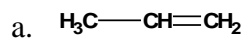


4. a) Write the equation for the complete oxidation (combustion) of butan-2-ol.

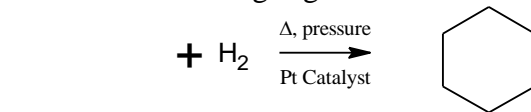
b) Write the equation for the mild oxidation of butan-2-ol with  $\text{KMnO}_4$ .

5. Write the equation for the addition of hydrochloric acid to ethene. What is the name of the product formed?

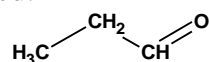
6. Predict the product formed when  $\text{HCl}$  is reacted with each of the following compounds. Use Markovnikov's Rule to predict the product.



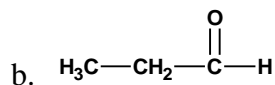
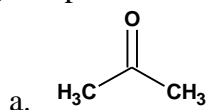
7. Describe the chemical test that could be carried out to distinguish between hexane and hexene.
8. Write the equation for the substitution reaction involving one molecule of each of ethane and bromine.
9. What is the structure of the missing organic reactant in each of the following:



10. Write the structure of the carboxylic acid that forms when the following aldehyde is oxidized:



11. Which of these two compounds is easily oxidized by  $\text{KMnO}_4$ ? Write the structure of the organic product of the oxidation.



12. What are the products of the mild oxidation of
- Propan-1-ol
  - Propan-2-ol

13. a) Draw the following expanded structures for these compounds.



b) Using oxidation numbers for carbon, show that this sequence of compounds represents an oxidation process:

## FUNCTIONAL GROUPS II

This section continues the discussion of four other functional groups by examining two oxygen-containing functional groups within hydrocarbon chains such as the ether group ( $\text{R-O-R}'$ ) and

the ester group ( $\text{R-O-C(=O)-R}'$ ). We will also be examining two nitrogen-containing functional

groups known as amines ( $\text{R-NH}_2$ ) and amides ( $\text{R-C(=O)-NH}_2$ ).

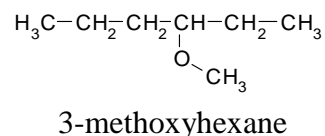
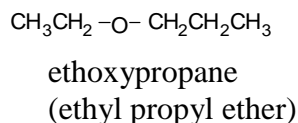
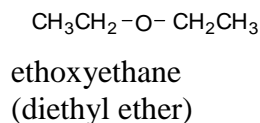
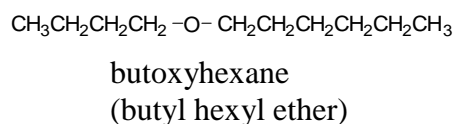
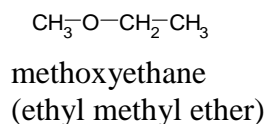
**Table 2:** Structures and Examples of Ethers, Esters, Amines, and Amides

| General Structure     | Type  | Example with IUPAC Name  |  |              |
|-----------------------|-------|--|--|--------------|
| $\text{R-O-R}'$       | ether | $\begin{array}{cccc} \text{H} & \text{H} & & \text{H} & \text{H} \\   &   & &   &   \\ \text{H}-\text{C}-\text{C}-\text{O}-\text{C}-\text{C}-\text{H} \\   &   & &   &   \\ \text{H} & \text{H} & & \text{H} & \text{H} \end{array}$ | ethoxyethane   |              |
| $\text{R-O-C(=O)-R}'$ | ester | $\begin{array}{cccc} \text{H} & \text{H} & & \text{O} & \text{H} \\   &   & &    &   \\ \text{H}-\text{C}-\text{C}-\text{O}-\text{C}-\text{C}-\text{H} \\   &   & & &   \\ \text{H} & \text{H} & & & \text{H} \end{array}$           | ethyl ethanoate  |              |
| $\text{R-NH}_2$       | amine | $\begin{array}{c} \text{H} \\   \\ \text{R}-\text{N} \\   \\ \text{H} \end{array}$   | $\begin{array}{c} \text{H} & \text{H} \\   &   \\ \text{H}-\text{C}-\text{N} \\   &   \\ \text{H} & \text{H} \end{array}$                    | aminomethane |
| $\text{R-C(=O)-NH}_2$ | amide | $\begin{array}{c} \text{O} \\    \\ \text{R}-\text{C}-\text{N}-\text{H} \\   \\ \text{H} \end{array}$  | $\begin{array}{c} \text{H} & \text{O} \\   &    \\ \text{H}-\text{C}-\text{C}-\text{N}-\text{H} \\   &   \\ \text{H} & \text{H} \end{array}$ | ethanamide   |

Naming of organic compounds involving these functional groups follows similar methods used in previous types of naming but they do have their differences, as explained below.

### Ethers

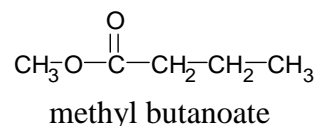
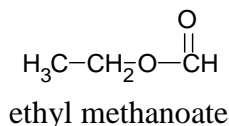
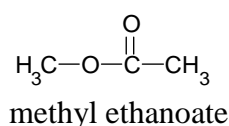
Ethers are molecules whose structure is very similar to water. In an ether the oxygen atom is bonded to two alkyl groups, they can either be the same or different. Ethers are named according to IUPAC by changing the *ane* ending of the *smaller* hydrocarbon name to *oxy* and then joining that to the alkane name of the *longer* hydrocarbon. You may also see the names of ethers written as the names of the two alkyl groups followed by the word ether.





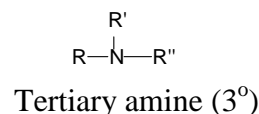
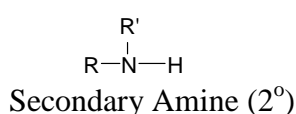
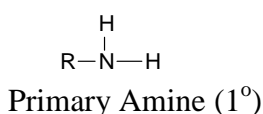
## Esters

Esters are formed from a reaction between alcohols and carboxylic acids. To name esters we use this knowledge to help us. The first part of the name is the name of the alkyl group from the alcohol, the second part comes from the acid name but the ending is changed from *-oic acid* to *-oate*.

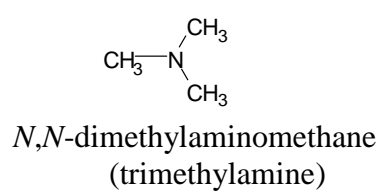
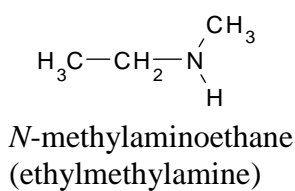
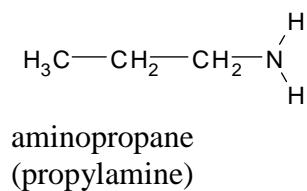


## Amines

Amines are classified as primary, secondary or tertiary depending on the number of alkyl groups (R groups) bonded to the nitrogen.

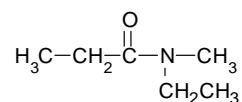
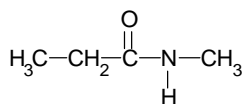
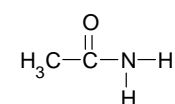


Amines can be named in two ways. The IUPAC way is to name it as a nitrogen derivative of an alkane. In this case you write the word amino and add the name of the alkyl group at the end. If you have a secondary or tertiary amine the name starts with the prefix *N-* followed by the name of the shortest alkyl group followed by amino and the longest alkyl chains' name. The other way amines are commonly named is as an alkyl derivative of ammonia. In this case you write the name of the alkyl group and add amine on the end. If the amine is secondary or tertiary you write the name the same way but include all of the alkyl groups' names.



## Amides

The amide has a structure similar to the ester however the oxygen atom in the chain of the ester is replaced by a nitrogen atom, thus giving you the amide. It occurs from a reaction between an acid and an amine. Naming amides is similar to naming esters. The first part of the name comes from the amine. The second part of the name is derived from the acid. The *-oic acid* ending is changed to *-amide*.



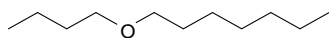
# Ethers, Esters, Amines and Amides

Name or draw the following compounds:

**Chemical structure**

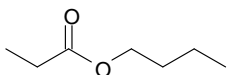
**IUPAC Name**

1



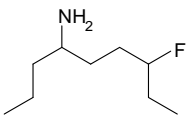
.....

2



.....

3

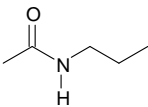


.....

4

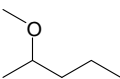
*N*-butyl hexanamide

5



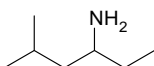
.....

6



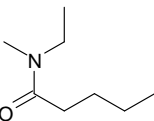
.....

7



.....

8



.....

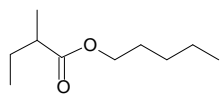
9

3-methoxy-5-methyl-4-nitro-heptane

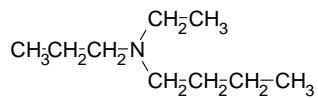
10

*N*-isopropyl ethanamide

11



12



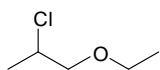
13

2,3-dibromo-5-aminononane

14

2-chloropropyl butanoate

15

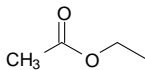


16

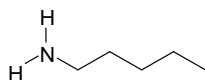
*N*-ethyl-*N*-methyl *trans*-4,5-difluoro-4-octenamide

**For each of the following, state the type of functional group(s) and name the organic compound**

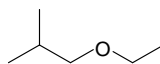
17



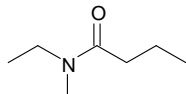
18



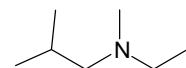
19



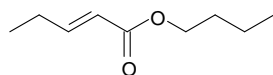
20



21

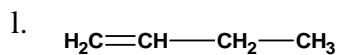
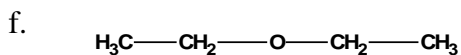
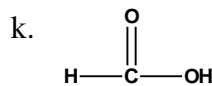
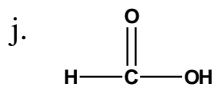
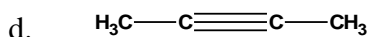
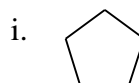
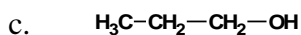
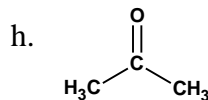
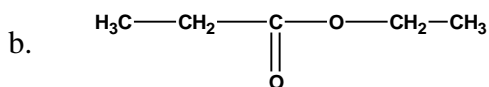
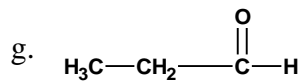
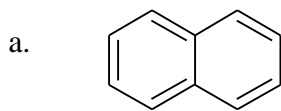


22





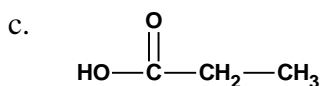
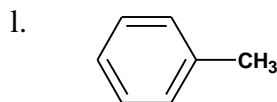
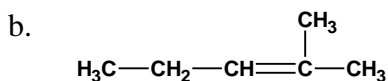
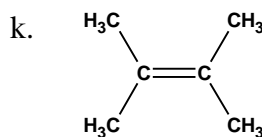
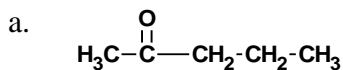
3. Name the type of organic compound each of the following would be classified as:

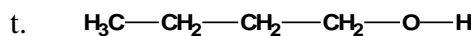
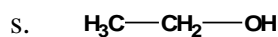
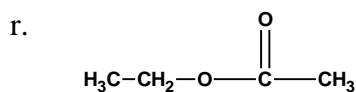
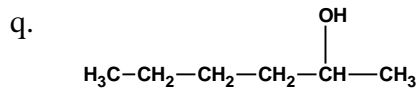
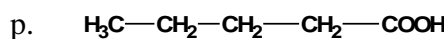
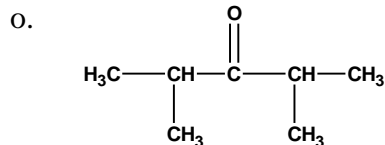
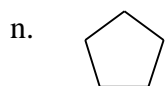
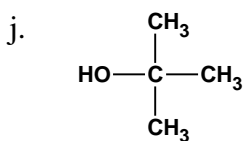
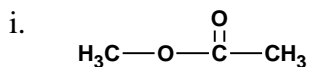
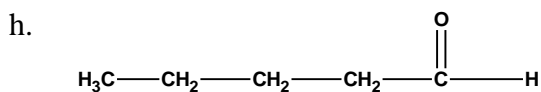
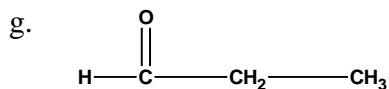
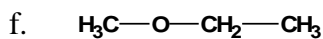
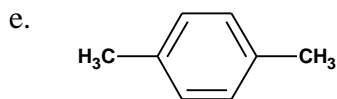
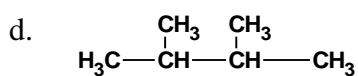


4. Draw the structural formula for:

- Methoxymethane
- Pentan-1-ol
- 1-aminobutane
- propanal
- propan-2-ol
- 2-methyloctan-4-ol
- 2-methoxypropane
- propyl ethanoate

5. Name the type of organic compound each of the following would be classified as:





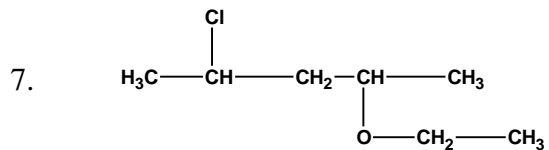
Name or draw the following compounds:

Chemical structure

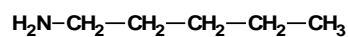
IUPAC name

6.

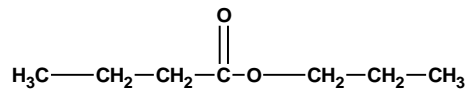
Ethoxyethane



8.



9.

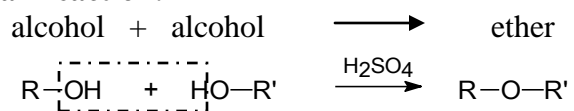


## ORGANIC REACTIONS II

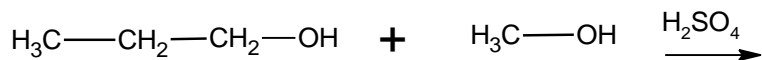
### 6) CONDENSATION REACTIONS

#### a) Formation of Ethers

##### General Reaction:

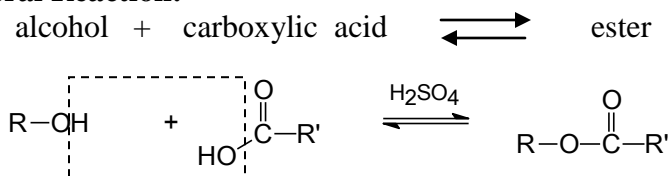


Example:

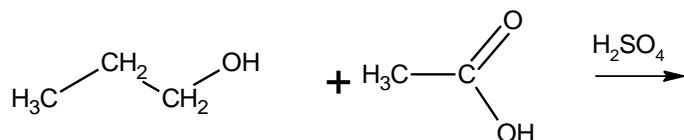


#### b) Formation / Decomposition of Esters

##### General Reaction:

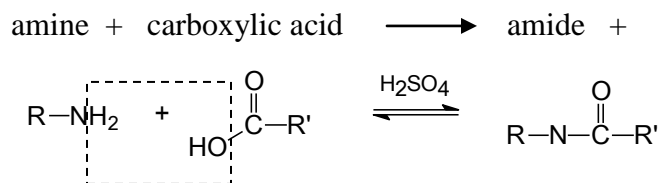


Example:

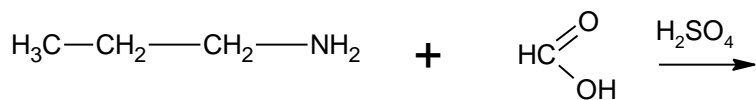


#### c) Amides

##### General Reaction:



Example:





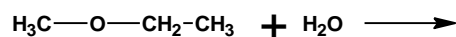




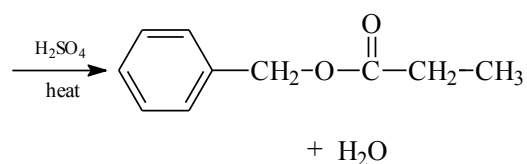
b.



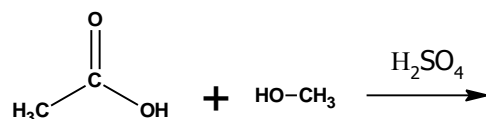
c.



d.



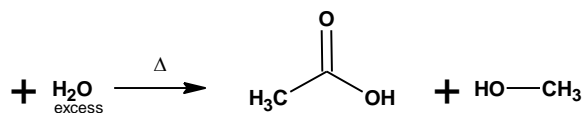
e.



4. a) Write the equation for the condensation of 1-butanol. Name the product.

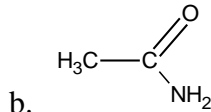
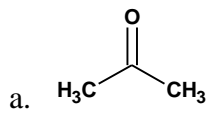
b) Write the equation for the condensation of 1-aminopentane and butanoic acid. Name the product.

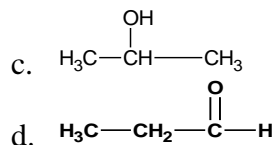
5. What is the structure of the missing organic reactant in each of the following:



a. \_\_\_\_\_

6. Which of these four compounds will undergo an acid-catalyzed reaction with methanoic acid? Write the structure of the organic product in each case.

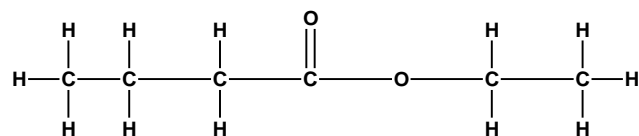




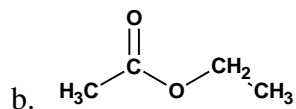
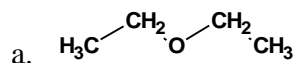
7. a) Write the equation for the reaction of 2-butanol with 2-pentenoic acid.

b) What is the name of the product?

8. Write the structural formulas of the alcohol and the carboxylic acid from which the following ester can be made.



9. Which of the following will be split apart by hydrolysis (reaction with water), and what are the structures of the products that form?



## PROPERTIES OF ORGANIC COMPOUNDS

Read the following textbook pages and fill in the chart below to form notes on the characteristic properties of each group of organic compounds listed below. Your notes may include information on their relative boiling point, polarity, odour and uses.

|                       |                   |
|-----------------------|-------------------|
| Hydrocarbons          | p. 22             |
| Alcohols              | p. 42             |
| Aldehydes and Ketones | p. 51             |
| Carboxylic Acids      | p. 60-61          |
| Ethers                | p. 46             |
| Esters                | p. 66, 89 (odour) |
| Amines                | p. 76             |
| Amides                | p.72              |

## Properties and Applications of Hydrocarbons

Recall:

- As molecular polarity increases, boiling point increases.
- As molecular polarity increases, solubility in water increases.

| Type             | Structure | Polarity | Solubility in Water | Uses |
|------------------|-----------|----------|---------------------|------|
| Alkanes          |           |          |                     |      |
| Alkenes          |           |          |                     |      |
| Alkynes          |           |          |                     |      |
| Aromatics        |           |          |                     |      |
| Alcohols         |           |          |                     |      |
| Aldehydes        |           |          |                     |      |
| Ketones          |           |          |                     |      |
| Carboxylic Acids |           |          |                     |      |
| Ethers           |           |          |                     |      |
| Esters           |           |          |                     |      |
| Amines           |           |          |                     |      |
| Amides           |           |          |                     |      |

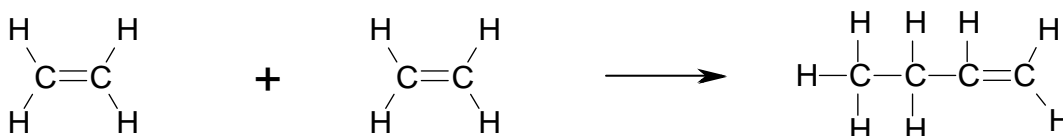
## POLYMERS AND POLYMERIZATION

**Polymers** are large molecules composed of a repeating sequence of **monomers**. A monomer is usually a small molecule or compound. A common monomer is ethene (ethylene),  $C_2H_4$ . Polymers are typically produced using two types of reactions; **addition polymerization** and **condensation polymerization** reactions.

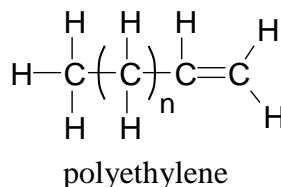
### Addition Polymerization Reactions:

Addition polymerization involves the bonding of monomers without the elimination of atoms. Bonding is accomplished by opening unsaturated bonds between carbon atoms in the molecules.

*Example of an Addition Polymerization Reaction using Ethene:*



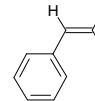




As polymerization continues, more ethene units are incorporated into the structure to form the polymer polyethylene. The final product may contain thousands of monomers, defined by the number  $n$ .



One or more of the hydrogen atoms in ethene can be replaced by groups such as  $-F$ ,  $-Cl$ ,  $-CH_3$ , and  $-COOCH_3$ . By substituting the hydrogen atoms synthetic polymers with trade names such as Teflon, Saran, and Lucite, or Plexiglas result. By varying the additional components of the molecule it is possible to create compounds with customized properties.

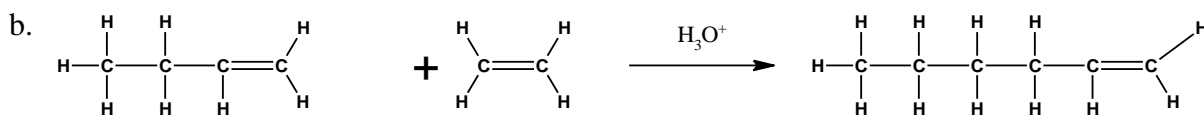
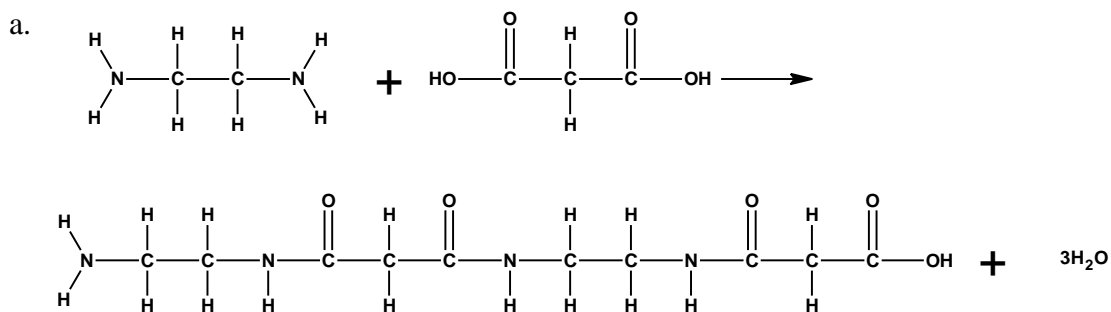
*Table 1: Examples of Common Monomers used in Addition Polymerization*

| Monomer Structure   | Monomer Name        | Polymer                  | Uses  |
|---|---------------------|--------------------------|---|
|  | ethylene            | polyethylene             | films, coating for milk cartons, wire insulation, plastic bags, bottles, toys   |
|  | vinyl chloride      | polyvinyl chloride (PVC) | raincoats, pipes, credit cards, bags, floor tiles, shower curtains, garden hoses, wire insulation, gutters, down spouts |
|  | styrene             | polystyrene              | electrical insulation, packing material, combs  |
|  | methyl methacrylate | Plexiglas, Lucite        | glass substitutes, paints   |
|  | tetrafluoroethylene | Teflon                   | gaskets, bearings, insulation, non-stick pan coatings, chemical resistant films   |

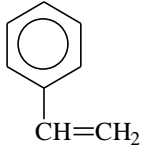


# Polymerization


1. Identify the type of polymerization in each of the following:

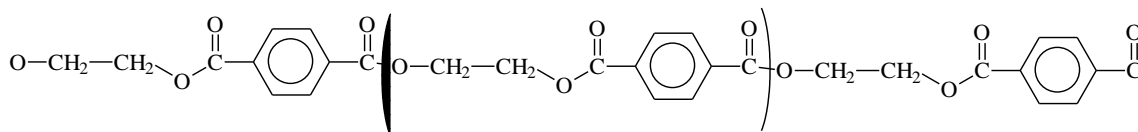



2. For each of the following, draw three linked monomer units of the polymer's structure:

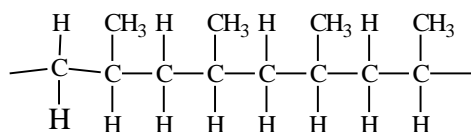
| Monomer  | Polymer   | Structure |
|--|---|-----------|
| a. $\begin{array}{c} \text{F} & \text{F} \\   &   \\ \text{C} = & \text{C} \\   &   \\ \text{F} & \text{F} \end{array}$  | Teflon<br>(non-stick coating)                       |           |
| c. $\begin{array}{c} \text{F} \\   \\ \text{H}_2\text{C} = \text{C} \\   \\ \text{CH}_3 \end{array}$                     | Tedlar<br>(used to weatherproof building materials) |           |
| d. $\begin{array}{c} \text{H} & \text{Cl} \\   &   \\ \text{C} = & \text{C} \\   &   \\ \text{H} & \text{H} \end{array}$ | Polyvinyl chloride<br>(PVC)                         |           |
| e.                                    | Polystyrene<br>(#6 plastic)                         |           |

3. Draw the structure for the monomer(s) from which the following polymer is made and name the type of polymer (addition, polyester or polyamide).

a) PETE (polyethylene terephthalate) 

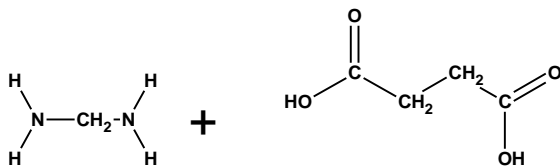


b) PP (polypropylene) 

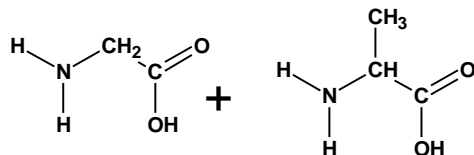


4. Draw the structure of the polymer which would form when the following molecules react. (draw two units)

a.



b.



c.

