Organic Chemistry – Normal & Branched Alkanes, Cycloalkanes

1. Fill in the blanks.

   A hydrocarbon is an organic molecule made of carbon and _____. When only carbon-carbon "single bonds" are involved, the hydrocarbon is called an _____. The hydrocarbon is also said to be _____ because it has the maximum possible number of hydrogen atoms attached to the carbon atoms.

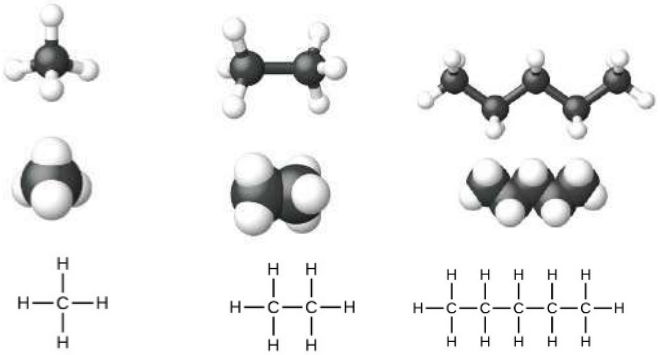
   The longest continuous chain of carbon atoms in the molecule is the _____ chain. Any other carbon chains in the molecule are called _____. A _____ alkane is one that has no branches.

   The first four normal alkanes are called methane, ethane, _____ and _____. If there are 6 carbons in the parent chain, its name is _____. If there are 8 carbon atoms in the parent chain, its name is _____.

   When naming a branch, the alkane name has its "-ane" ending changed to "-yl". So a 1-carbon branch is called _____. A 2-carbon branch is called _____.

   A 3-carbon branch is called propyl.

2. Give a **molecular formula** and **IUPAC name** for each of the following **normal alkanes**:



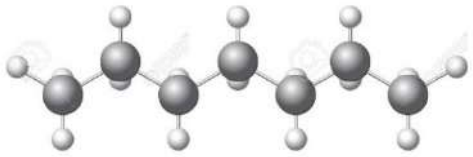
Molecular Formula	Molecular Formula	Molecular Formula
IUPAC Name	**IUPAC Name**	**IUPAC Name**

3. Consider the **normal alkane** shown here, built with a **molecular model set**.

   a. What is its **molecular formula**?

   b. What is its **IUPAC name**?

   c. Write a balanced equation for its **combustion**.



4. Consider the "ball and stick" representation of a normal alkane above.

   a. Write its molecular formula.

   b. What is its IUPAC name?

   c. Draw its "**bond-line formula"**.

5. A normal alkane is represented below by its bond-line formula.

   a. What is its **molecular formula**?

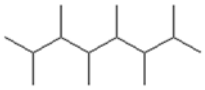
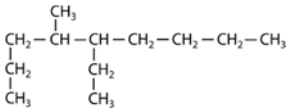
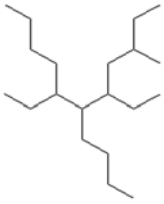
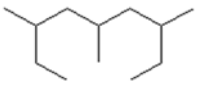
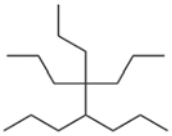
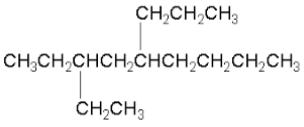
   b. What is its **IUPAC name**?

   c. Sketch its **structural formula**.

   d. Write a balanced equation for the **combustion** of this hydrocarbon.

   e. If 2.0 g of the hydrocarbon was burned completely, how many moles of CO_2 would be produced?

6. For each branched alkane below, **circle the parent chain**. Then identify the different types of **branches** that are present – **select all that apply**.

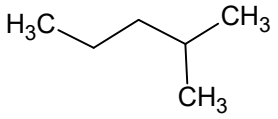
Branched Alkane		Branches
a.		O Methyl O Ethyl O Propyl O Butyl
b.		O Methyl O Ethyl O Propyl O Butyl
c.		O Methyl O Ethyl O Propyl O Butyl
d.		O Methyl O Ethyl O Propyl O Butyl
e.		O Methyl O Ethyl O Propyl O Butyl
f.		O Methyl O Ethyl O Propyl O Butyl

7. For each hydrocarbon in the previous question, give the NAME of its **parent chain**.

a.	
b.	
c.	
d.	
e.	
f.	

8. For each molecule below, provide its **IUPAC na**me and write its **molecular formula**. Recall that the general formula for an alkane is $\mathbf{C_nH_{2n+2}}$. So if an alkane has 6 carbons it will have 14 hydrogens (2x6 + 2 = 14).

a.



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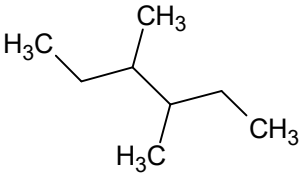

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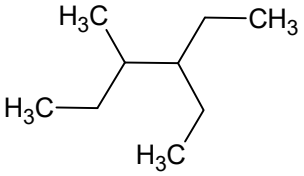

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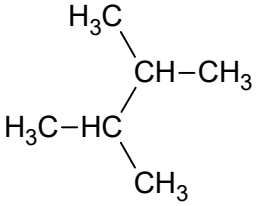

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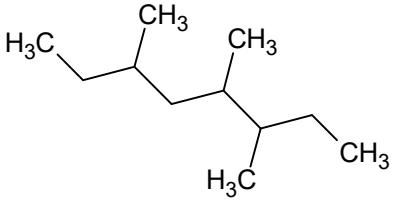

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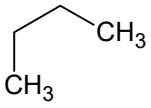

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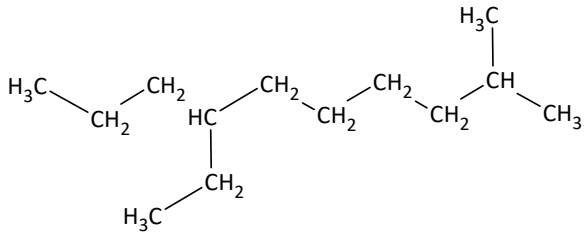

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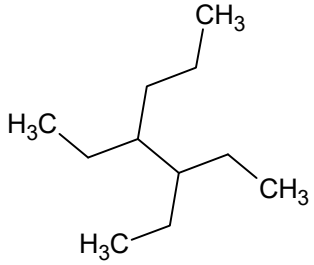
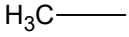


i.



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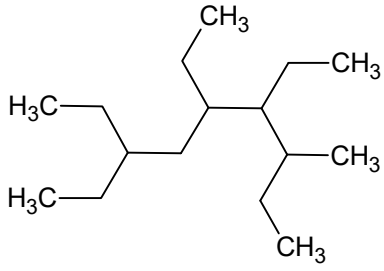
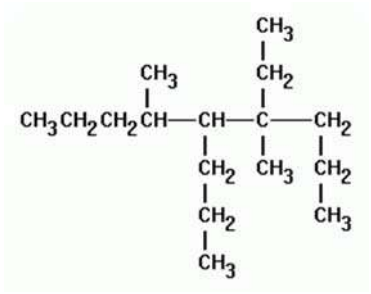
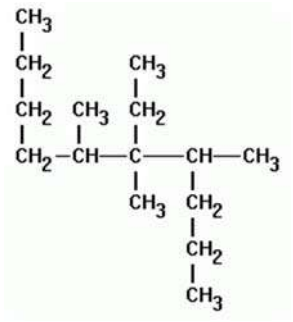
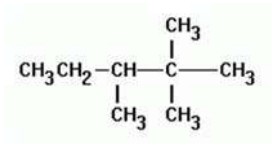


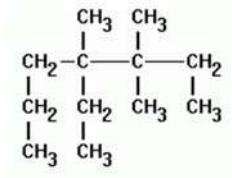
9. Write a balanced equation for the **combustion** of 2-methylhexane.

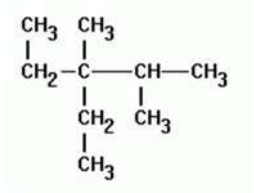
10. Provide the **IUPAC name** for each of the following branched alkanes.

a. 

b. 

c. 

d. 

e. 

11. Draw a **bond-line formula** for each of the following alkanes.

a. methylbutane

b. 3,3-dimethyloctane

c. 3-ethyl-2-methylheptane

d. 2,3,4-trimethylpentane

e. 3-ethyl-2,5-dimethylhexane

f. n-propane

12. The molecule, 2-ethyl-3-methylpentane, has been named incorrectly. Draw it and provide its correct IUPAC name.

13. A 10.0-L gas cylinder contains 2.00 kg of **methylpropane** gas at 25°C.

a. Draw a **structural formula** for methylpropane and write its **molecular formula**.

b. Calculate the **pressure** (in kPa) in the gas cylinder.

14. Draw the **bond-line formula**, write the **molecular formula** and calculate the **percent composition** of each hydrocarbon below.

2,3-dimethylbutane	
Bond-line formula	Chemical Formula
% Carbon	% Hydrogen

3-ethylhexane	
Bond-line formula	Chemical Formula
% Carbon	% Hydrogen

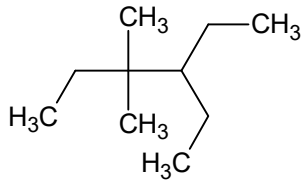
15. A **hydrocarbon** is found to be 83.6% carbon by mass. Its molar mass is 86 g/mol.

a. What is the **empirical formula** for the hydrocarbon?

b. What is the **molecular formula** for the hydrocarbon?

c. Could this hydrocarbon be an **alkane**? Explain briefly.

d. There are several different **structural isomers** with this molecular formula. **Draw** and **name** three different molecules with this formula.



16. Consider the **branched alkane** shown here.

a. What is its **IUPAC name** and molecular formula?

b. Would this compound likely dissolve in water? Explain briefly.

c. Write a balanced equation for the **combustion** of this alkane.

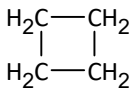
d. What volume of oxygen (at **STP**) would be needed for the combustion of a 50.0-g sample of the alkane?

e. Draw and name an **isomer** of this alkane whose **parent chain** has 8 carbons.

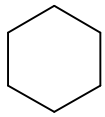
17. When a chain of carbon atoms forms a closed "**ring**" with only **carbon-carbon single bonds**, the compound is called a **cycloalkane**.

Give the **IUPAC name** for each cycloalkane below and write its **molecular formula**.

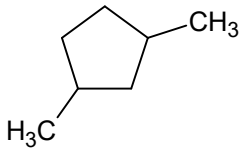
a.



b.



c.



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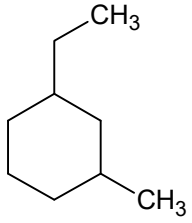

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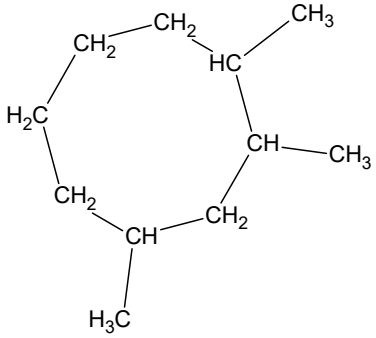

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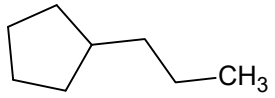
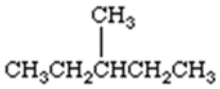
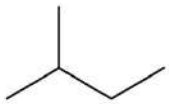
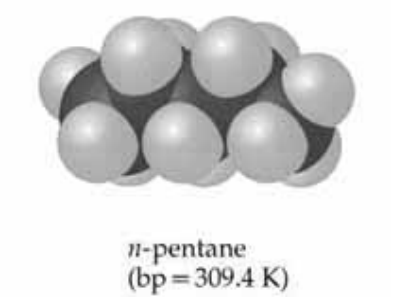


18. Match the terms on the left with the descriptions on the right.

Normal alkane	Substances with the same molecular formula but different structural formulas
Parent Chain	
C_nH_{2n+2}	An alkane with no branches or rings
Methane	The general formula of a cycloalkane with one ring
Structural Isomers	An alkane that is gaseous at room temperature, used as fuel for heating homes.
Condensed Structural Formula	
C_nH_{2n}	The general formula of an alkane with no rings
Bond-Line Formula	An alkane that is liquid at room temperature, a component of gasoline
Octane	A hydrocarbon where all the carbon-carbon bonds are "single bonds".
Alkane	The longest continuous chain of carbons in a hydrocarbon

19. The **space-filling diagram** for normal **pentane** is shown here.



n-pentane
(bp = 309.4 K)

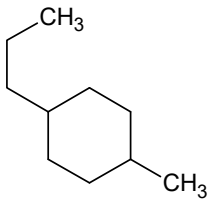
a. What is the **boiling point** of pentane, expressed in °C? What **phase** would it be at room temperature?

b. Draw the **condensed structural formula** for pentane.

c. Draw and give the IUPAC name for two **structural isomers** for normal pentane.

20. Give the IUPAC names for these alkanes & cycloalkanes.

a.



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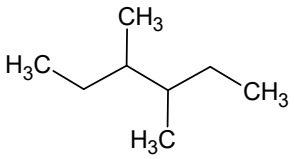
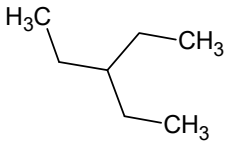


c.



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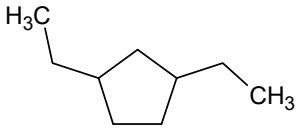

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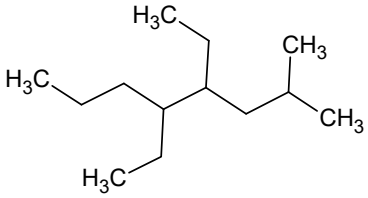

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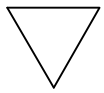

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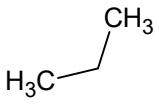

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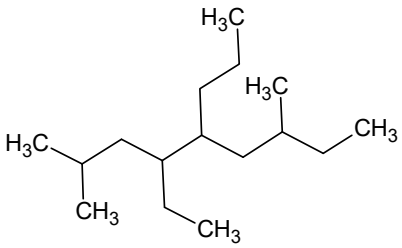


21. Butane is used as **lighter fluid**. Write a balanced equation for its **combustion**.

22. **Gasoline** contains a complex mixture of hydrocarbons – mainly alkanes with 4 to 12 carbon atoms. Draw each of the following components of gasoline.

a. 2,3,3-trimethylhexane

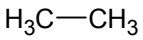
b. 3-ethyl-3,4-dimethylheptane

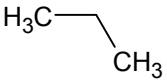
23. Hydrocarbons in diesel fuel have higher boiling points, with between 8 and 21 carbon atoms. Draw each of the following components from **diesel fuel**.

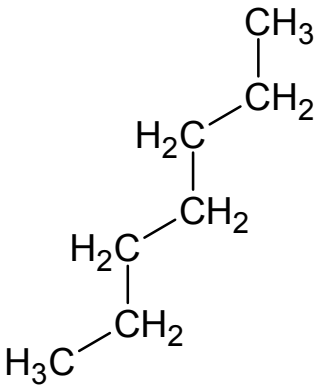
a. 3,5,5-triethyl-4,6-dipropyloctane

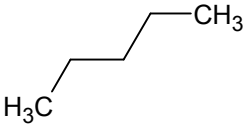
b. 5,6-dibutyldecane

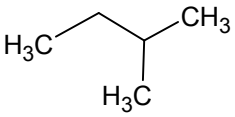
Alkanes Nomenclature

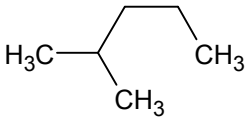


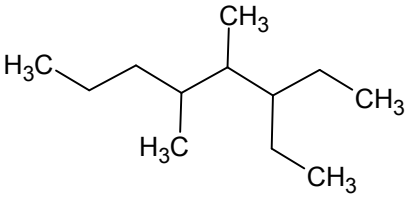


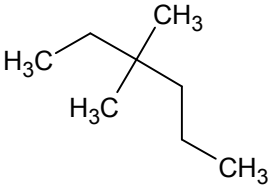


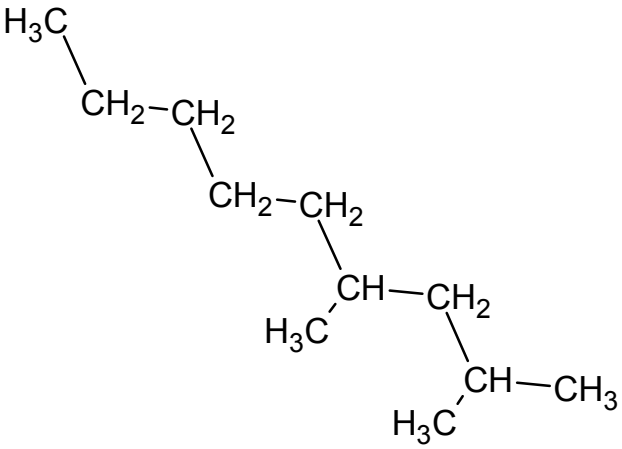


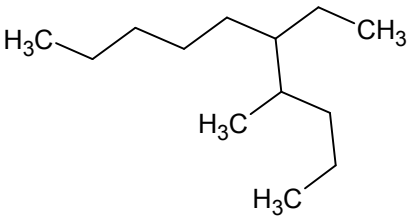


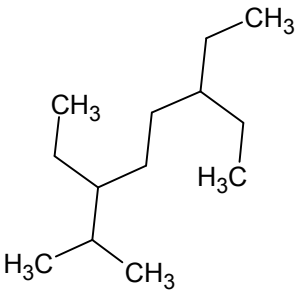


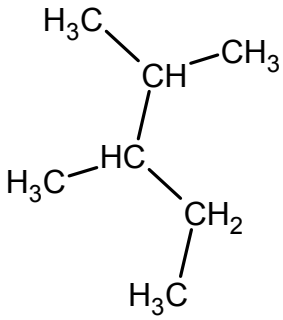












3,3-dimethyloctane

3-methylhexane

6-methyl-4-propyldecane

2-chlorobutane

3,3-diethylheptane

2,3,3,4-tetramethylpentane

1,2-dibromoethane

1,1-dibromopropane

1-bromo-1,2,2-trichloroethane

Organic Chemistry – Alkenes & Alkynes

1. Fill in the blanks.

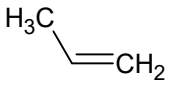
   _____ hydrocarbons include both alkanes and _____, which have only carbon-carbon "single bonds". They have the maximum possible number of _____ atoms attached to the carbon backbone of the molecule.

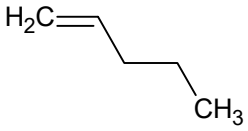
   _____ hydrocarbons have fewer than the maximum number of hydrogen atoms because they have carbon-carbon _____-bonds and/or _____-bonds.

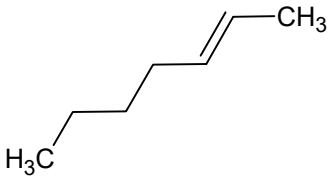
   An _____ is a hydrocarbon with one or more double bonds. An _____ is a hydrocarbon with one or more triple bonds.

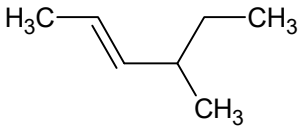
   When large alkane molecules are heated to very high _____ at very high pressures, the molecules break apart into a smaller alkane and ethene gas. This is known as thermal _____ and is used to produce smaller alkanes from large ones. A similar process can be done at lower temperatures and pressures, if a _____ is used.

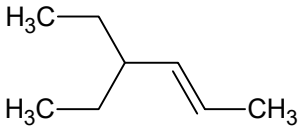
2. Give the IUPAC name and the molecular formula for each **alkene** below.

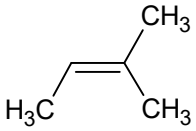
a. 

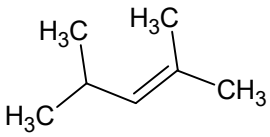
b. 

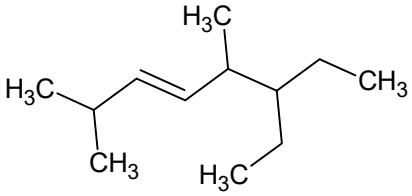
c. 

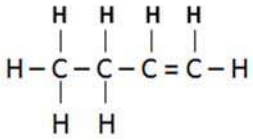
d. 

e. 

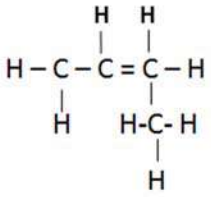
f. 

g. 

h. 



Butene



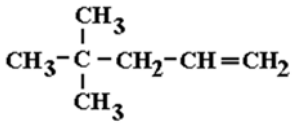
Methyl Propene

3. Consider the alkenes shown above. Each of the names is incorrect.

   a. Give the correct IUPAC name & formula for the molecule on the left.

   b. Give the correct IUPAC name & formula for the molecule on the right.

   c. Are these two molecules **isomers**? Explain.



4. Consider the **condensed structural formula** shown above.
   a. What is its IUPAC name?

   b. Draw its bond-line formula.

5. Draw a **condensed structural formula** for each of the following **alkenes**.

   a. 3-methyl-2-pentene

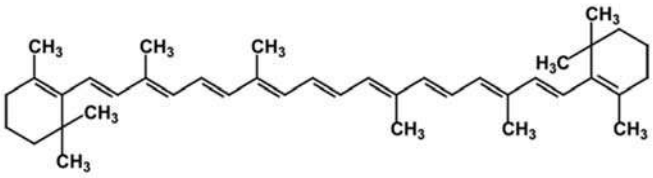
   b. 2,5-dimethyl-3-hexene

   c. 2-bromopropene

   d. 2-chloro-3-methyl-2-butene

   e. 2,2-dichloro-5-ethyl-6-fluoro-3-octene

   f. 1,1-dichloroethene

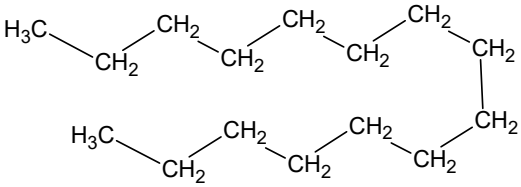


6. β-carotene is the orange pigment found in carrots and other vegetables. As you can see, there are many carbon-carbon double bonds in the molecule as well as two rings.

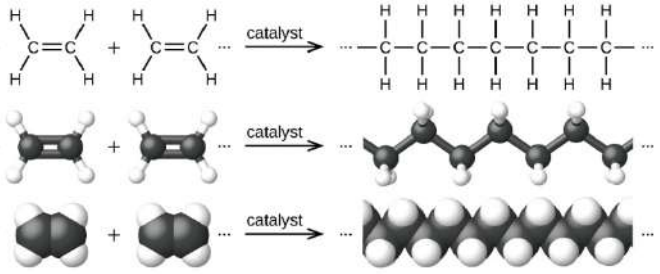
   a. Based on its chemical structure, would you predict β-carotene to be soluble in water? Explain.

   b. With the addition of each double bond or ring, two hydrogens are lost from the molecule. With this in mind, what is the molecular formula for β-carotene?

7. Recall that large alkanes can undergo **thermal cracking** to produce alkenes and smaller alkanes. When the alkane below is cracked, it forms 2 ethene molecules, a propene molecule and an octane molecule.



   Draw **ethene** and **propene**, the two alkene products of this cracking process.



Ethylene **Polyethylene**

8. **Plastics** are also known as **polymers**. A polymer is a very long chain of repeating simple units called **monomers**.

   The monomers are simple **alkenes**. When joined in a **polymerization reaction**, their double bonds are converted to single bonds.

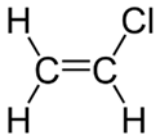
   Two simple monomers that are used to make plastics are **ethylene** and **propylene**.

   a. What is the IUPAC name for ethylene? Hint: Its structure is shown above.

   b. What is the IUPAC name for propylene?

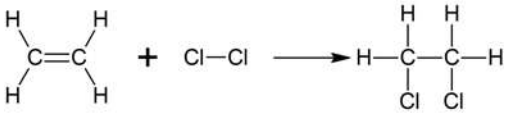
   c. Give an everyday example of a plastic that is made from each polymer below.

Polymer		Everyday Example
2 HDPE	High-Density Polyethylene	
3 V	Polyvinyl Chloride (PVC)	
4 LDPE	Low-Density Polyethylene	
5 PP	Polypropylene	



9. The alkene shown above is the **monomer** used to create the polymer **polyvinyl chloride** (PVC). Its common name is "vinyl chloride". What is its correct IUPAC name?

10. In a **halogenation reaction**, an alkene reacts with chlorine or bromine molecules to create chloroalkanes and bromoalkanes.



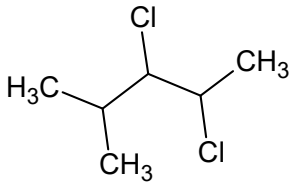
The two halogen atoms are added across the double bond in the alkene. **One halogen atom ends up on each of the carbons in the original double bond**. In the example above, ethene reacted with chlorine gas and the product is 1,2-dichloroethane.

Write a reaction with bond-line formulas or condensed structural formulas for each reaction below. Give the IUPAC name for the product.

a. Propene reacts with chlorine

b. 2-butene reacts with bromine

11. Draw and name the starting reagent that you would react with chlorine gas to produce the following molecule in the **halogenation of an alkene**.

Desired Product

2,3-dichloro-4-methylpentane

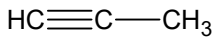
Starting Reagent

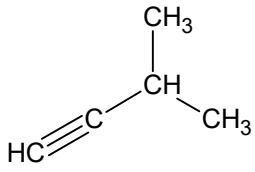
12. Write a balanced equation for **combustion reactions** of each alkene below.

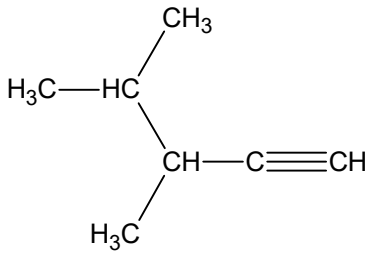
a. 2-pentene

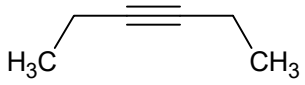
b. 2,3-dimethyl-1-hexene

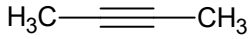
13. Give the IUPAC name and molecular formula for each alkyne below.

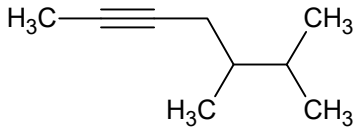
a. 

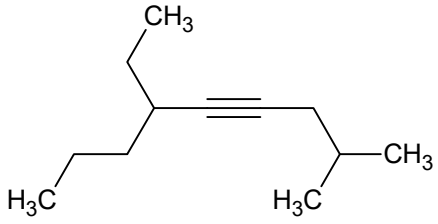
b. 

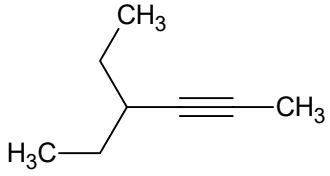
c. 

d. 

e. 

f. 

g. 

h. 

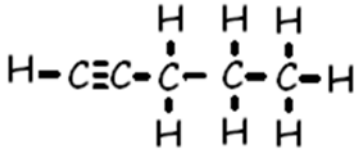
14. The simplest **alkyne** is **ethyne**. Its older more common name is **acetylene** and it's a fuel used in welding torches.

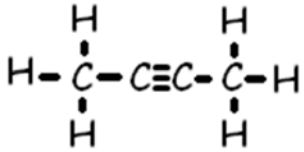
a. Draw the **condensed molecular formula** for ethyne and write its **molecular formula**.

b. A full 20.0-L acetylene tank has a pressure of 1725 kPa at 20°C. What **mass** of acetylene (ethyne) is in the tank?

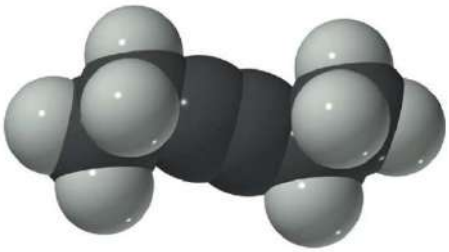
c. If a welder burns 250. g of acetylene, what **volume of CO_2** would be produced, measured at **STP**?

15. Draw the **bond-line formula**, give the **molecular formula** and write the **IUPAC name** for the alkynes here.



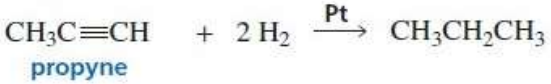


16. The space-filling model of 3-hexyne is shown here.



How many moles of oxygen gas are required for the combustion of 5.0 g of 3-hexyne?

17. Both alkenes and alkynes can undergo hydrogenation reactions, where they react with hydrogen gas in the presence of a catalyst like platinum metal.



What **volume** of hydrogen gas, measured at 200°C and 1.50 atm, would be required to convert 40.0 g of propyne gas to propane gas?

18. Draw a **condensed molecular formula** for each alkyne below.

a. 3-methyl-1-butyne

b. 2-hexyne

c. 1-chloro-4-methyl-1-pentyne

19. Each of the following names is **incorrect**! Draw the **bond-line formula** for each molecule and then give its correct IUPAC name.

a. 3-pentyne

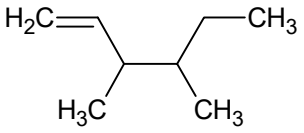
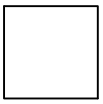
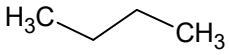
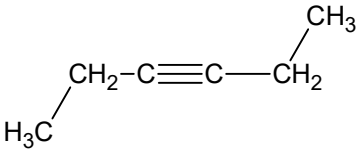
b. 4-ethyl-2-pentyne

c. 3-methylpropyne

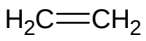
d. 3,7-dimethyl-5-heptyne

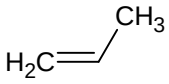
e. 1,1,4-trimethyl-2-butyne

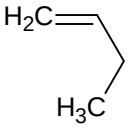
20. Match each item from the left column with something in the right column.

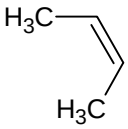
A cycloalkane	The general molecular formula for an alkyne
Parent Chain	Different chemicals that have the same molecular formulas
C_nH_{2n-2}	
Isomers	Teflon
A normal alkane	The longest continuous chain of carbons in a hydrocarbon
An example of polymer	The monomer used as the basis of many common plastics
C_nH_{2n}	
Ethylene	
An alkene	The repeating unit in a polymer
Hydrocarbons	The general molecular formula of an alkene or a cycloalkane
Monomer	
An alkyne	Alkanes, cycloalkanes, alkenes, alkynes

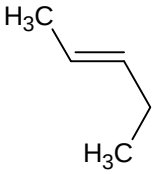
Alkenes Nomenclature

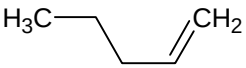


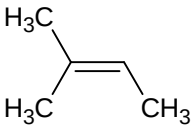


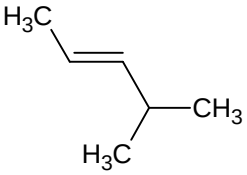


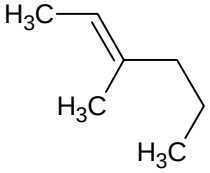


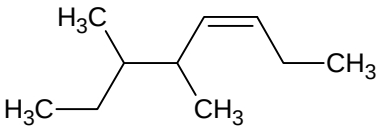


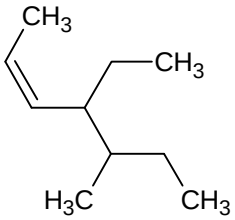


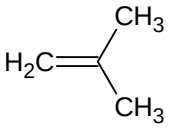


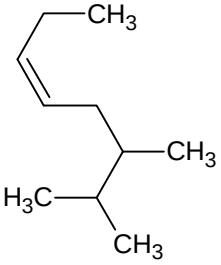


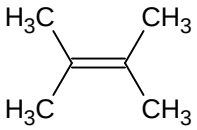


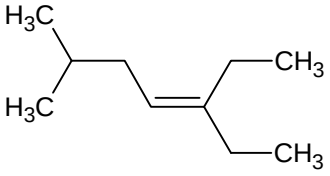




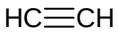


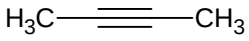


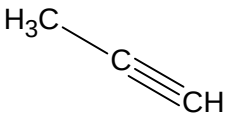


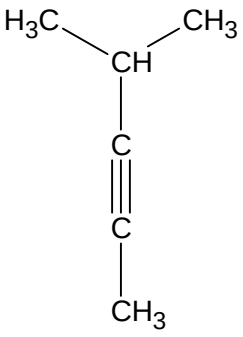


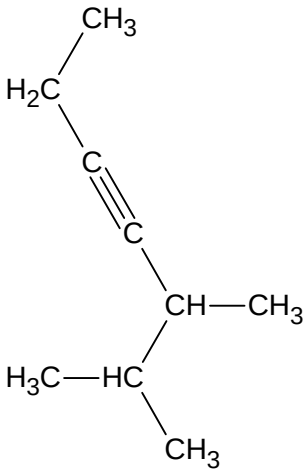
Alkynes Nomenclature

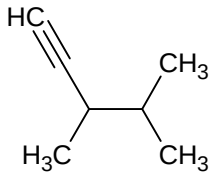


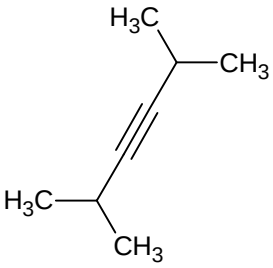


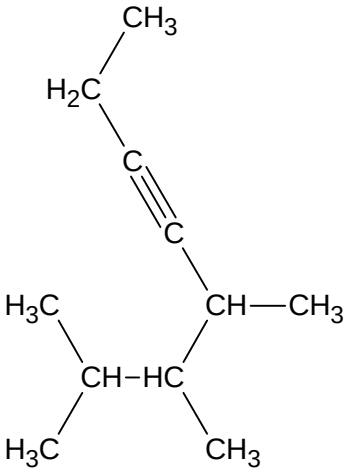


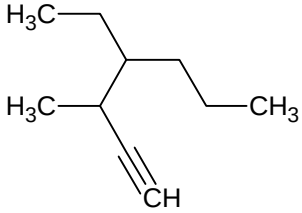








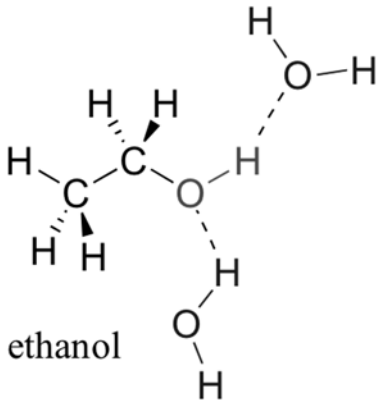




Organic Chemistry – Alcohols, Carboxylic Acids and Esters

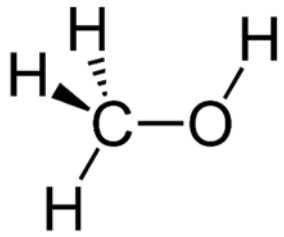
1. An **alcohol** is an organic molecule where a hydrocarbon has a **hydroxyl functional group** (-OH) attached. The **C-H bonds in hydrocarbons are non-polar**, but the **O-H bond is polar**, just like in water.

   The diagram below shows two water molecules **hydrating** an ethanol molecule.

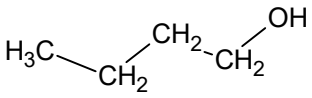


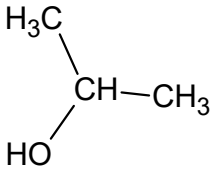
   a. Label the **partial charges** (δ+ and δ-) in the water molecules and the alcohol molecule above to explain the attractive forces between them.

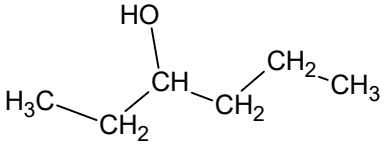
   b. Draw two water molecules showing the **hydration** of the methanol molecule below when it is dissolved in water.

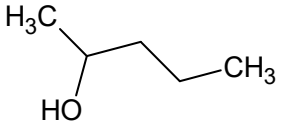


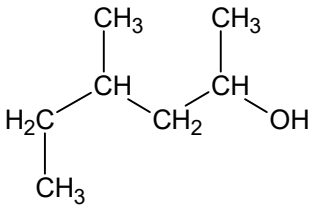
2. Give the IUPAC name for each **alcohol** below.

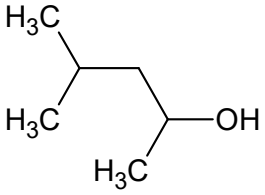
a. 

b. 

c. 

d. 

e. 

f. 

3. Draw each of the following **alcohols** using either a **bond-line formula** or a **condensed molecular formula**.

   a. 2-butanol

   b. 3-methyl-1-hexanol

   c. 2,2-dimethyl-3-octanol

   d. 4-ethyl-3-methyl-3-decanol

   e. 2,4-dimethyl-3-pentanol

   f. 3-chloro-2-methyl-2-heptanol

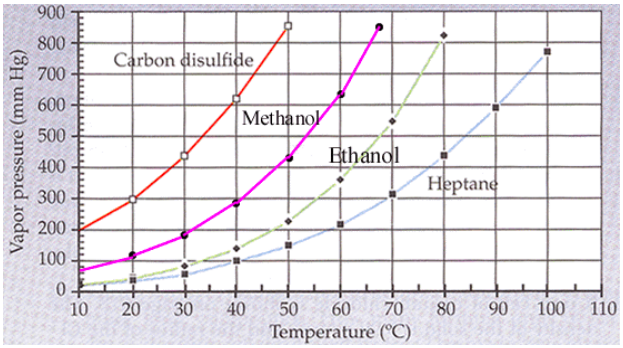
4. All **alcohols** are toxic, however humans have evolved the ability to digest small amounts of ethanol. Ethanol is the alcohol that is present an any alcoholic beverage. The **density** of pure ethanol is 0.789 g/mL.

   a. Draw a condensed molecular formula for ethanol.

   b. How many **molecules** of ethanol are present in a 10.0-mL sample?

   c. A student needs 0.200 mol of ethanol for an experiment. What **volume** (in mL) should she use?

5. Calculate the **percent oxygen** by mass in 2-pentanol.



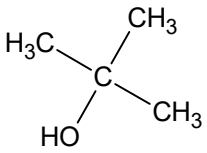
6. The vapor curves for four substances are shown above.
   a. Give the **molecular formula** for each of these compounds:
      i. Methanol
      ii. Ethanol
      iii. Heptane
   b. From the graph, estimate the **normal boiling point** for:
      i. Methanol
      ii. Ethanol
      iii. Heptane

7. **Alcohols** are highly flammable. How many moles of carbon dioxide would be produced by the combustion of 25.0 g of rubbing alcohol (2-propanol)?

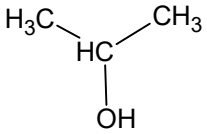
8. **Alcohols** are commonly used as **solvents**. They are less **polar** than water. The larger the **hydrocarbon chain**, the less polar the molecule will be.

   Many of these alcohol solvents have commonly used older names. For each alcohol below, give its proper **IUPAC name**.

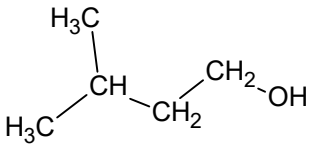
   a. Tert-butyl alcohol



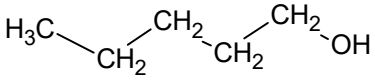
   b. Isopropyl alcohol



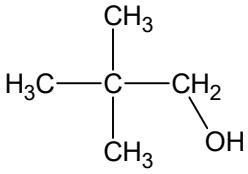
   c. Isopentyl alcohol



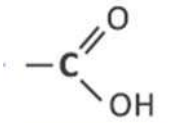
   d. Amyl alcohol



   e. Neopentyl alcohol

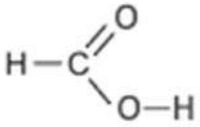


9. **Organic acids** have a **carboxyl functional group**. The acids are called **carboxylic acids**. Their names are based on the names of the parent chains, with the endings changed to "**-oic acid**".

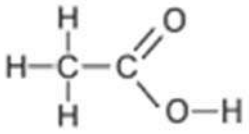


Carboxyl Group

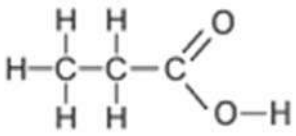
   a. The simplest example has only one carbon atom and used to be called **formic acid**, from the Latin for "ant". This acid is used as a defense mechanism by fire ants. What is its correct IUPAC name?



   b. The next is an acid with two carbon atoms. Its common name is **acetic acid**, from the Latin for "vinegar". White vinegar is a 5% solution of this acid. What is its correct IUPAC name?

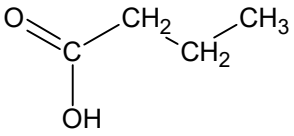


   c. The third carboxylic acid was once called **propionic acid**, from the Latin meaning "first fat". It got this name because it was the first carboxylic acid to share some properties with much larger "fatty acids". What is its correct IUPAC name?



10. Give the **IUPAC name** for each of the following **carboxylic acids**.

a.



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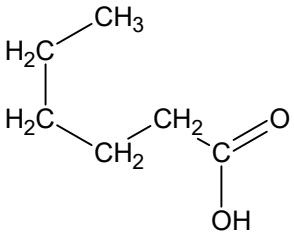
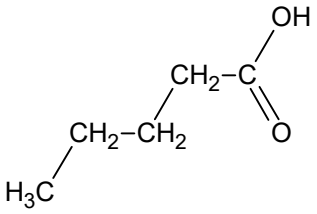
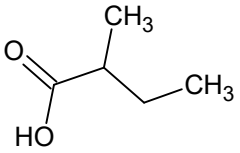


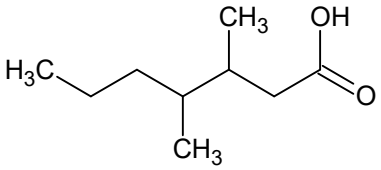
c.



d.



e.



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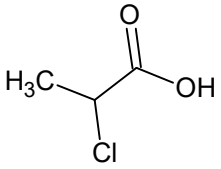


11. Draw a **bond-line formula** for each of the following **carboxylic acids**.

a. 3-methylbutanoic acid

b. 2,3-dichloroheptanoic acid

c. 3-ethylpentanoic acid

d. 2-bromopropanoic acid

e. 2,3.4-trimethylhexanoic acid

f. 3-ethyl-6-propyldecanoic acid

12. Carboxylic acids, like any other acid, can be neutralized by a reaction with a base. A student decided to neutralize a 5.0-g sample of propanoic acid using sodium hydroxide. What **mass** of NaOH will be needed?

$C_2H_5COOH + NaOH \rightarrow NaC_2H_5COO + H_2O$

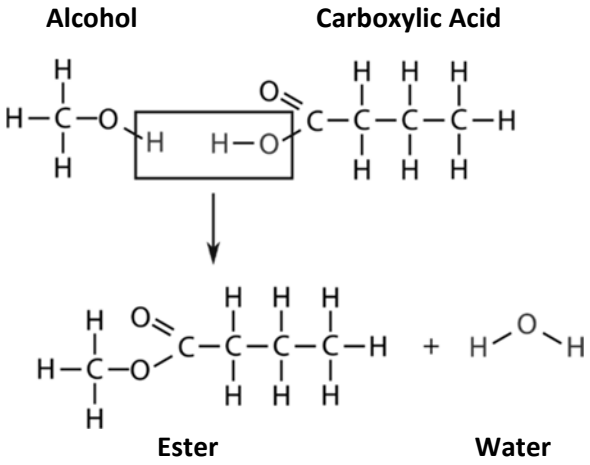
13. Carboxylic acids will react with sodium bicarbonate and produce carbon dioxide gas. The most common example of this is adding baking soda to vinegar. If an excess of sodium bicarbonate is added to 10.0 g of butanoic acid, **what volume of CO_2 will be produced**, measured at 20°C and 96.5 kPa?

$+ NaHCO_3 \rightarrow NaC_3H_7COO + CO_2 + H_2O$

Butanoic acid

14. What is the percent by mass of oxygen in hexanoic acid?

15. An **ester** is the product of the reaction between an **alcohol** and a **carboxylic** acid. The reaction is called an **esterification reaction**.



In the reaction, the **H** in the **alcohol hydroxyl group** combines with the **OH** in the **acid carboxyl group** to make **water**. Then the remainder of the alcohol attaches to the carboxylic acid to create the **ester** as shown above.

In the example above, give the names of …

The alcohol:

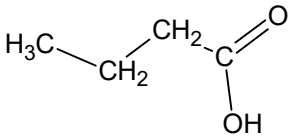
The carboxylic acid:

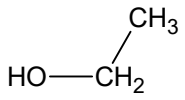
The ester:

16. Consider the **esterification reaction** shown below. Write the names of the **carboxylic acid** and the **alcohol** being used. Then write the **IUPAC name** and draw the **condensed molecular formula** for the **ester** that would form.

Carboxylic Acid

Alcohol



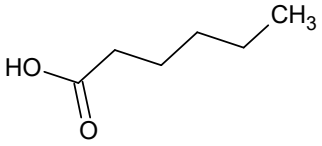


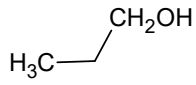
Ester

17. Consider the **esterification** reaction shown below. Write the names of the **carboxylic acid** and the **alcohol** being used. Then write the **IUPAC name** and draw the **condensed molecular formula** for the **ester** that would form.

Carboxylic Acid

Alcohol



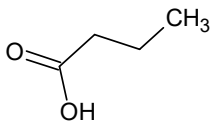


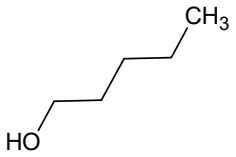
Ester

18. Consider the **esterification** reaction shown below. Write the names of the **carboxylic acid** and the **alcohol** being used. Then write the **IUPAC name** and draw the **condensed molecular formula** for the **ester** that would form.

Carboxylic Acid

Alcohol



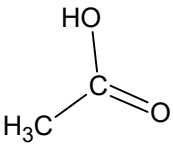


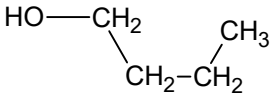
Ester

19. Consider the **esterification** reaction shown below. Write the names of the **carboxylic acid** and the **alcohol** being used. Then write the name and draw the **condensed molecular formula** for the **ester** that would form.

Carboxylic Acid

Alcohol





Ester

20. **Esters** are famous for their **smells** and **flavors**. They are found naturally in many fruits, vegetables and flowers and are added to many processed foods as **artificial flavors** and to **perfumes** for their odours. For each ester below, draw its structure and then give the name of both the **alcohol** and **carboxylic acid** that would be used to create the ester.

Methyl Ethanoate – Pineapple Flavor

Alcohol | Carboxylic Acid

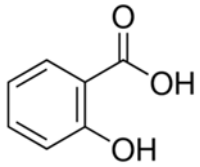
Butyl Methanoate – Raspberry Flavor

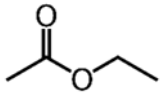
Alcohol | Carboxylic Acid

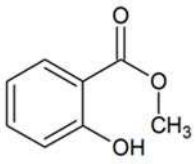
Ethyl Octanoate – Apple Flavor

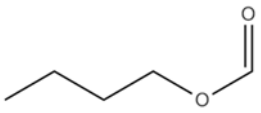
Alcohol | Carboxylic Acid

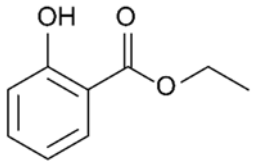
21. Give the IUPAC name for each **ester** below. Some are made using **salicylic acid**:

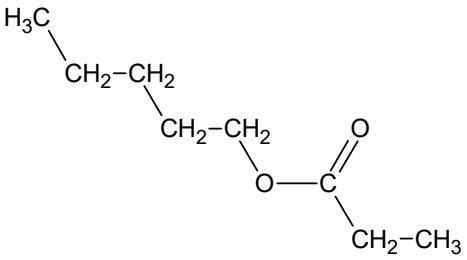


a. 

b. 

c. 

d. 

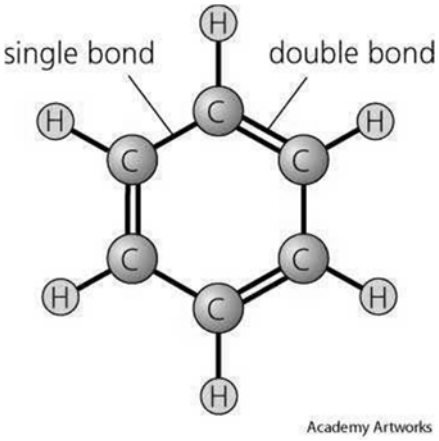
e. 

22. Methyl ethanoate is a very **volatile** – its **boiling point** is only 57°C. What **volume** would a 50.0-g sample of methyl acetate vapour occupy at 200.°C and 105 kPa?

23. Ethyl hexanoate is an oily liquid at room temperature, with a pleasant pineapple smell. It is the product of ethanol reacting with hexanoic acid. What **mass** of ethanol is required to make 10.0 g of ethyl hexanoate?

24. What is the percent oxygen by mass in butyl pentanoate?

Organic Chemistry – Aromatic Compounds

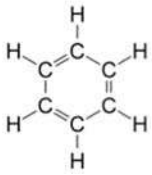


Aromatic compounds contain one or more "**benzene rings**", shown above. Benzene is made of 6 carbon atoms with a conjugated system of single and double bonds as shown above.

However, **one pair of electrons in each double bond is delocalized** and freely moves around the ring. The six carbon-carbon bonds are actually equivalent to each other. **Each bond is intermediate between a single and double bond**.

They were originally called **aromatic compounds** because of the pleasant odours associated with many of them.

Benzene has the molecular formula, $\mathbf{C_6H_6}$, and can be drawn in several different ways:



1. Sketch and give the molecular formula for each **aromatic compound** shown below.

   a. chlorobenzene

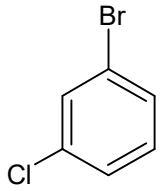
   b. 1,2-dibromobenzene

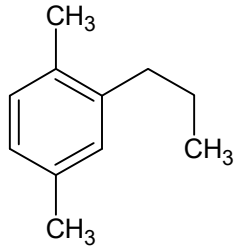
   c. 1,3-dimethylbenzene

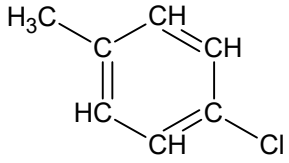
   d. ethylbenzene

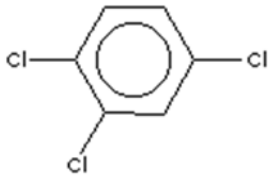
   e. 2-ethyl-1,3-dimethylbenzene

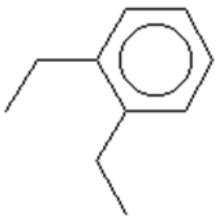
2. Give the IUPAC name for each **aromatic compound** below.

a. 

b. 

c. 

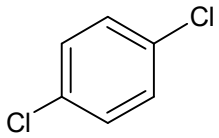
d. 

e. 

3. A common alternative to numbering when there are only two branches in an **aromatic compound** is to use the prefixes:

Ortho (o-) to mean 1,2 branching
Meta (m-) to mean 1,3 branching
Para (p-) to mean 1,4 branching

p-dichlorobenzene (PDB) is used in moth balls. You say "*para-dichlorobenzene*". It is really 1,4-dichlorobenzene.



Sketch each of these aromatic compounds:

a. Ortho-dimethylbenzene

b. Meta-ethylmethylbenzene

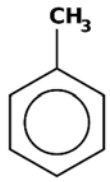
c. p-dibromobenzene

d. o-bromochlorobenzene

e. m-chloromethylbenzene

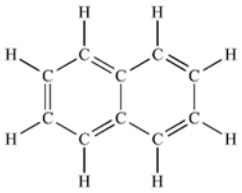
4. Many aromatic compounds have common older names. For each example below give its **molecular formula** and calculate the **percent carbon** by mass.

   a. Toluene

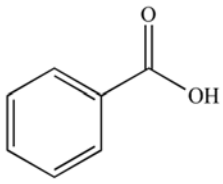


   b. Phenol

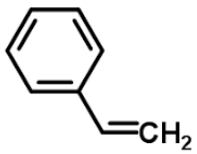
   c. Naphthalene



   d. Benzoic Acid



   e. Styrene



5. Like all hydrocarbons, aromatic compounds are flammable. If a 10.0-g sample of benzene burns completely, how many moles of carbon dioxide gas would be produced?

6. Benzene reacts with chlorine gas to form chlorobenzene. When a chemist added 20.0 g of benzene to a flask along with 50.0 g of chlorine gas, she was able to obtain 6.52 g of chlorobenzene.

   a. Write a balanced chemical equation for this synthesis reaction.

   b. Which reagent was the **limiting reagent**?

   c. What should have been the **theoretical yield** of chlorobenzene?

   d. What was the **percent yield** for the experiment?