Organic Chemistry

Hydrocarbons

Saturated — Alkanes (C_nH_{2n+2})

Unsaturated — Alkynes (C_nH_{2n-2}), Alkenes (C_nH_{2n})

Isomers

structural

cis & trans

Functional Groups

Alcohols (-OH)

Carboxylic Acids (-COOH)

Esters (-COO-)

Chemical Reactions

Addition

Esterification

Catalytic Cracking

Combustion

Organic vs. Inorganic Compounds

ATTACHMENT 8

Sort and Predict Frame

Unit ____________________ Topic ____________________

Directions:

Read the list of words on the left and sort them into four different categories by placing them in the boxes. For the words that you are unsure of, predict which category each would belong to. When selecting categories, try to make the fourth category different than any category that the rest of the class would think of. Use your creativity; be original! You may use **one** word in more than one category.

	1. ____________________	2. ____________________
	3. ____________________	4. ____________________

Sort and Predict Frame: Used by permission of Lynda Matchullis and Bette Mueller, Nellie McClung Collegiate, Pembina Valley S.D. No. 27.

Plastic Identification Lab

Name: ______________________

Plastics belong to a class of chemical compounds called *polymers*. There are many different types of plastics, each made from a different polymer. A milk jug is a different type of plastic than a yogurt container. Not all plastics can be recycled the same way. Just like not all metals can be recycled the same way: aluminum recycling centers can't recycle steel or lead. Plastic recycling centers must separate the different types of plastics and recycle them differently. One way of distinguishing the different types of plastic is with the Resin Identification Code. Six of the more common are listed here: ***fig 1:***

Polymer Name	Resin Code	Common Packaging Application
polyethylene terephthalate	1 PETE	Plastic soft drink bottles, mouthwash bottles, peanut butter and salad dressing containers
high-density polyethylene	2 HDPE	Milk, water and juice containers, grocery bags, toys, liquid detergent bottles
polyvinyl chloride	3 V	Clear food packaging, shampoo bottles
low-density polyethylene	4 LDPE	Bread bags, frozen food bags, grocery bags
polypropylene	5 PP	Ketchup bottles, yogurt containers, margarine tubs, and medicine bottles
polystyrene	6 PS	Videocassette cases, compact disc jackets, coffee cups; knives, spoons and forks; cafeteria trays, grocery store meat trays and fast-food sandwich containers

You will be using a **flow chart** to help separate and identify these 6 different plastics. A flow chart is a graphic representation of a sequence of operations (often used by computer programmers).

Pre-Lab Questions:

Use your flow chart (fig 2) to answer the following questions by placing the correct resin codes in the blanks:

1. Which plastic(s) will burn with a green flame? __________

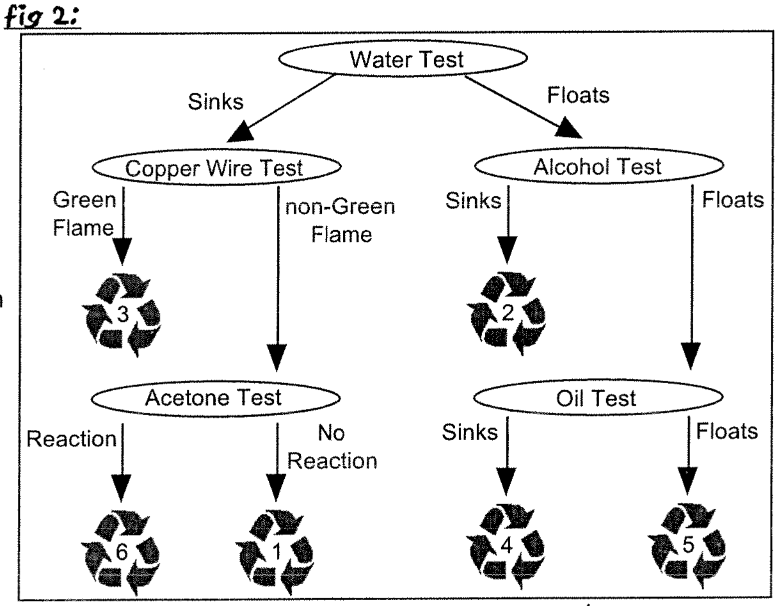
2. Which plastic(s) sink in alcohol? ______

3. Which plastic(s) float in water? __________

4. Which plastic(s) are more dense than water? ________

5. Which plastic(s) require the minimum number of tests in order to determine their identity? _________

fig 2:



Procedure:

At the front desk are cups labeled "A" -- "F", each containing samples of the plastics.

1. Obtain about 5 pieces of one type of plastic (you choose -- **just remember which unknown you're working with!!!**)

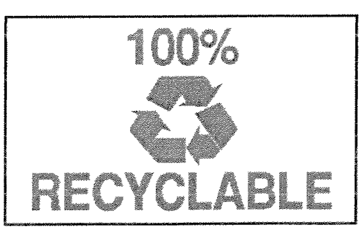
2. Take your unknown sample to your lab station. Perform the flow chart tests, according to the instructions on the back, until you've determined which plastic you have. Record your results in the results table.

3. Repeat steps 1 and 2 until you've discovered the identity of each unknown!

Results Table

unknown letter	color	resin ID Code
A		
B		
C		
D		
E		
F		

THIS LAB IS...



plastic ID lab (side 2)

Flow Chart Tests:

Water Test

At this lab station, you have a plastic cup filled 1/2 way with water. Place about 3 of your plastic pellets in the water, and poke the pellets with your finger to knock off any adhering bubbles & to overcome any surface tension. Note if they sink or float. Remove the plastic pellets with your fingers and save them (the pellets and your fingers) for later use. *Do not throw pellets down the sink - they are not water soluble!*

Copper Wire Test

Carefully hold the copper wire in a Bunsen burner flame until the wire is hot. Remove the wire from the flame and touch it to a plastic pellet. Place the wire back into the flame and observe its color. Dispose of pellet in recovery bin after testing. *Do not burn the pellet in the flame!*

Acetone Test

At this lab station, you have a small bottle of acetone and a watch glass. Place one plastic pellet on the watch glass, and a squirt (about 15 drops) of acetone. Let it soak for 30 seconds. Remove the pellet and scratch it with your fingernail. If the pellet is "gooey" this means that the acetone has reacted with the plastic my "loosening up" the polymer chains. If the pellet is unchanged, this means no reaction has taken place. Dispose of pellets in recovery bin after testing.

Alcohol Test

At this lab station, you have a 100 mL beaker of an alcohol solution covered with a watch glass. Uncover the beaker and place 2 clean plastic pellets in the beaker. Poke them with a stirring rod to knock off any adhering bubbles & to overcome any surface tension. Note whether most the pellets float or sink. Scoop the pellets out with a clean plastic spoon and dry them. They can be reused.

Oil Test

At this lab station, you have a 50 mL beaker with oil. Place 2 clean plastic pellets in the beaker. Poke them with a stirring rod to knock off any adhering bubbles. If the pellet hovers in the middle, consider it a "sinker". Scoop the pellets out with a clean spoon & dispose of pellets in the trash can.

fig 3:

DENSITY RANGES (in g/mL) for #1-#6	
#1 PET 1.38 - 1.39	#4 LDPE 0.92 - 0.94
#2 HDPE 0.95 - 0.97	#5 PP 0.90 - 0.91
#3 PVC 1.16 - 1.35	#6 PS 1.05 - 1.07
(water = 1.00)	

Questions:

1. Using fig. 3, approximate the density of the alcohol solution, and explain your reasoning.

2. Why was it important to dislodge any adhering bubbles & overcome surface tension in the density tests?

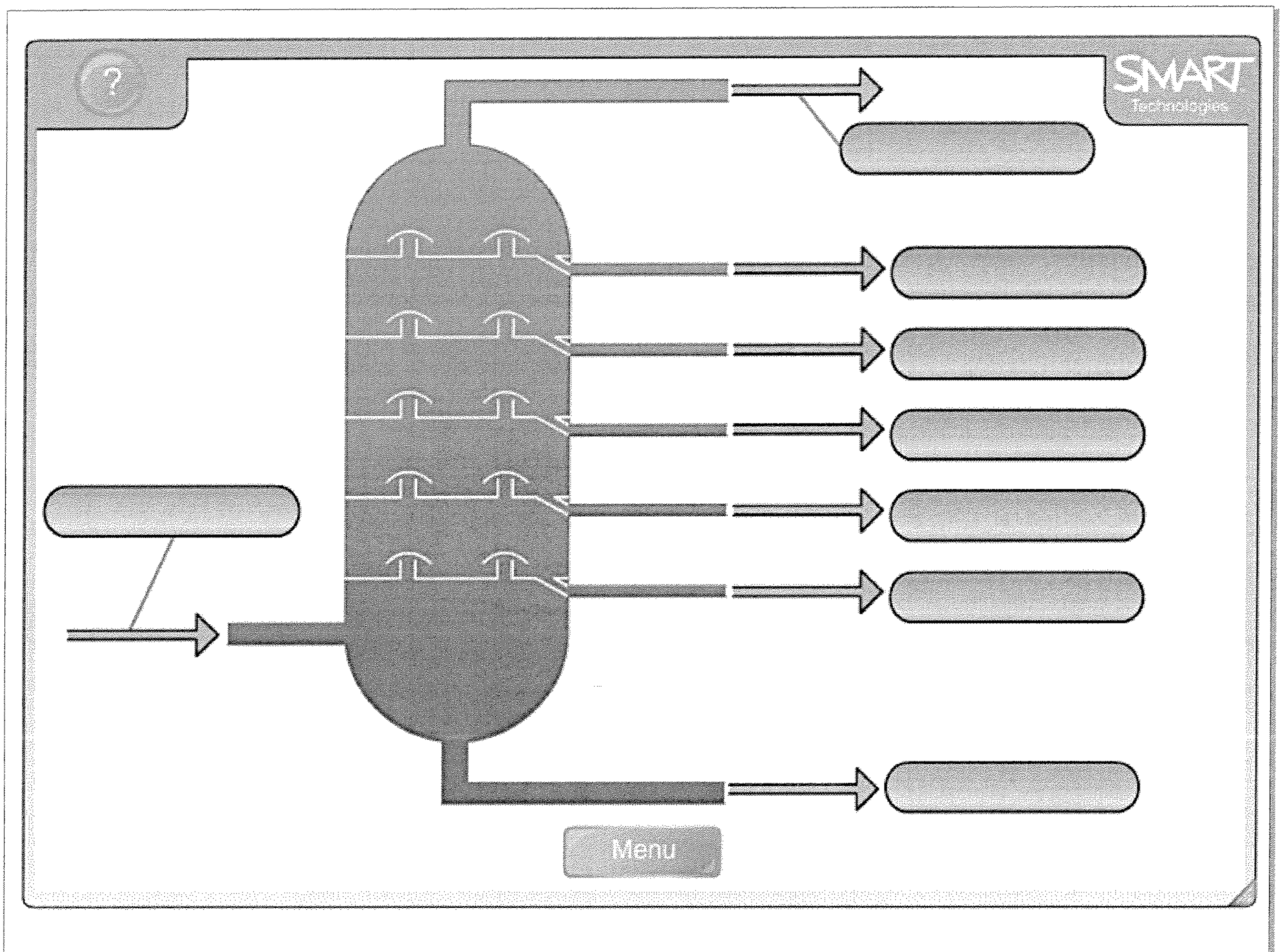
3. Why would it not be wise to make a canoe paddle out of PVC? What might you use instead?

4. You decide to jazz up your bathroom cabinet by transferring your fingernail polish remover into a more stylish plastic bottle. The next day, reaching for the bottle, you find a messy blob of goo. What was the bottle probably made of? And what is the active ingredient in the polish remover?

HELP PRESERVE OUR ENVIRONMENT

PLACE RECYCLABLE PRODUCTS IN THEIR APPROPRIATE CONTAINER

5. Two different samples (Y & Z) are placed in concentrated salt water; Y sinks. When more water is mixed in, Z sinks. Given the density of NaCl water = 1.10, what is the identity of Z? _____ What are the possible identies of Y? ____ / ____



Sep 22-6:06 AM

Petroleum

The organic compounds found in petroleum, or crude oil, are more complex than those in natural gas. Most of the hydrocarbons in petroleum are straight-chain and branched-chain alkanes. Petroleum also contains small amounts of aromatic compounds and sulfur-, oxygen-, and nitrogen-containing organic compounds.

Humans have known about petroleum for centuries; ancient peoples found it seeping from the ground in certain areas. In the late 1850s, a vast deposit of petroleum was discovered in Pennsylvania when a well was drilled to obtain petroleum for use as a fuel. Within decades, petroleum deposits had also been found in the Middle East, Europe, and the East Indies. Petroleum has since been found in other parts of the world as well.

Petroleum is a mixture of hydrocarbons having from one to more than 40 carbon atoms. Without further treatment, petroleum is not very useful. The mixture must be separated, or refined, into parts called fractions, which have many commercial uses. **The refining process starts with the distillation of petroleum (crude oil) into fractions according to boiling point.** A schematic of a petroleum refining distillation tower is shown in Figure 22.14. Each distillation fraction contains several different hydrocarbons. The fractions and their composition are listed in Table 22.4.

The amounts of products obtained by fractional distillation are not in proportion to the demand of the market. Gasoline is by far the most commonly used product, so other processes are used to make the supply meet the demand. **Cracking** is a controlled process by which hydrocarbons are broken down or rearranged into smaller, more useful molecules. For example, fractions containing compounds of higher molar mass are "cracked" to produce the more useful short-chain components of gasoline and kerosene. Hydrocarbons are cracked with the aid of a catalyst and with heat. This process also produces low-molar-mass alkanes, which are used to manufacture paints and plastics. Other catalytic processes besides cracking are used to increase the amounts of components that improve the performance of gasoline.

Checkpoint ***When and where was the first petroleum well drilled?***

Fractionating Column

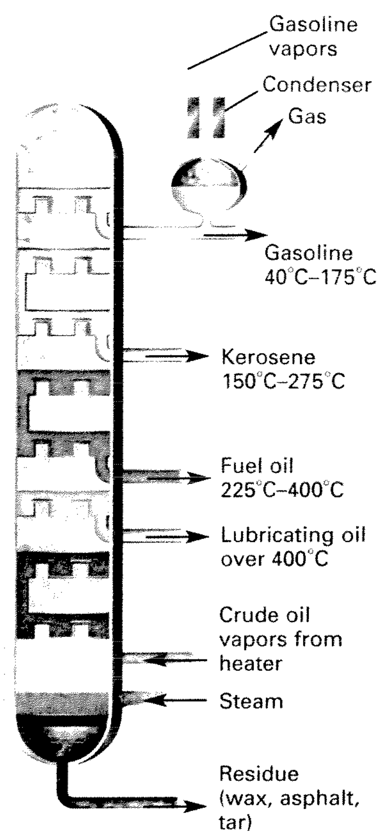


Figure 22.14 In fractional distillation, the crude oil is heated so that it vaporizes and rises through the fractionating column. The column is hotter at the bottom and cooler at the top. Compounds with the highest boiling points condense near the bottom. Compounds with the lowest boiling points condense near the top.

Table 22.4

Fractions Obtained from Crude Oils

Fraction	Composition of carbon chains	Boiling range (°C)	Percent of crude oil
Natural gas	C_1 to C_4	Below 20	10%
Petroleum ether (solvent)	C_5 to C_6	30 to 60	
Naphtha (solvent)	C_7 to C_8	60 to 90	
Gasoline	C_5 to C_{12}	40 to 175	40%
Kerosene	C_{12} to C_{15}	150 to 275	10%
Fuel oils, mineral oil	C_{15} to C_{18}	225 to 400	30%
Lubricating oil, petroleum jelly greases, paraffin wax, asphalt	C_{16} to C_{24}	Over 400	10%

6

Naming Saturated Aliphatic Hydrocarbons

Naming Aliphatic Hydrocarbons_Handout

The Carbon Atom

atomic mass n e^-
atomic number p^+

Carbon can form compounds composed of...

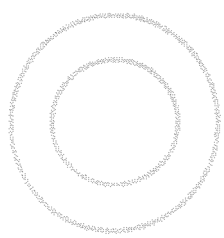
4 single bonds

2 double bonds

1 double & two single bonds

1 triple bond & a single bond

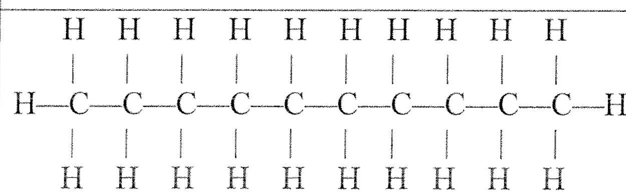
Bohr Diagram



8

Naming Straight Chain Alkanes

Each straight chain alkane is named according to the **stem** plus the ending *ane*. Names of the first ten straight chain alkanes are in the chart below.

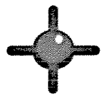
Name	Molecular Formula	Structural Formula	Boiling Point °C	Melting Point °C
Meth*ane*				
Non*ane*				
				

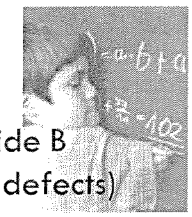
Date: ___________

Assignment: ____

From: _____ To: _____ Page No.: ___________

Alkane Isomers





Thalidamide A
(no morning sickness)

Thalidamide B
(severe birth defects)

Make butane

Make an isomer of butane

11

Go Online
NSTA SCi LINKS
For: Links on Alkanes
Visit: www.SciLinks.org
Web Code: cdn-1221

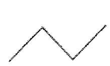
The names of the alkanes listed in Table 22.1 follow rules established by the International Union of Pure and Applied Chemistry (IUPAC). Every alkane has a name that ends with the suffix *-ane*. For the straight-chain alkanes with one to four carbon atoms, the official names and the common names are the same. They are methane, ethane, propane, and butane, respectively. A mixture of Latin and Greek prefixes are used to name the hydrocarbons having straight chains longer than four carbon atoms. The prefixes are *pent-* for 5, *hex-* for 6, *hept-* for 7, *oct-* for 8, and so on.

To draw a structural formula for a straight-chain alkane, write the symbol for carbon as many times as necessary to get the proper chain length. Then complete the formula with hydrogens and lines representing covalent bonds. Complete structural formulas show all the atoms and bonds in a molecule. Sometimes, however, shorthand or condensed structural formulas work just as well. In a **condensed structural formula,** some bonds and/or atoms are left out of the structural formula. Although the bonds and atoms do not appear, you must understand that they are there. Table 22.2 shows several ways to draw condensed structural formulas for butane.

Checkpoint ***What suffix is used in the name of an alkane?***

Table 22.2

Formulas for Butane

Formula	**Description**
C_4H_{10}	Molecular formula
$\begin{array}{ccccccccc} & & H & & H & & H & & H & & \\ & & \vert & & \vert & & \vert & & \vert & & \\ H & - & C & - & C & - & C & - & C & - & H \\ & & \vert & & \vert & & \vert & & \vert & & \\ & & H & & H & & H & & H & & \end{array}$	Complete structural formula
$CH_3 - CH_2 - CH_2 - CH_3$	Condensed structural formula; C — H bonds understood
$CH_3CH_2CH_2CH_3$	Condensed structural formula; C — H and — C — C — bonds understood
$CH_3(CH_2)_2CH_3$ Subscript Methylene unit	Condensed structural formula; all bonds understood; parentheses indicate CH_2 units are linked together in a continuous chain (the — CH_2 — unit is called a methylene group); subscript 2 to the right of parenthesis indicates two methylene groups are linked together
$C - C - C - C$	Carbon skeleton; all hydrogens and C — H bonds understood
	Line-angle formula; all carbons and hydrogens understood; carbon atoms are located at each intersection and at the ends of lines

Discovery Activity: Molecular Modelling
Structural Formulas and Alkane Isomers

Introduction

Chemical formulas do not tell you the actual structural arrangement of atoms in a molecule. As a result, there may be more than one way to represent the actual molecule's structure.

Compounds that have the same molecular composition but different structures are called **isomers**. Stated otherwise, compounds that have the same *molecular formulas* but different *structural formulas* are isomers.

Purpose

Investigate isomers and construct all of the possible isomers of the molecules with the following molecular formulas.

I.	C_4H_{10}	III.	C_6H_{14}
II.	C_5H_{12}	IV.	C_7H_{16}

Procedure

1. Construct models of four alkanes listed in the table in the **Purpose** using the molecular modelling kit.
2. Fill in the table on the opposite page. Once the table is complete, answer the following questions.

Questions

1. What do you notice about the number of carbon atoms compared to the number of hydrogen atoms in an alkane?

2. Use subscript numbers and variables to write a general formula for this trend when C and H form alkanes.

3. What do you notice about the number of isomers as the size of the hydrocarbon increases?

4. Is there a mathematical formula that you can use to determine the number of isomers?

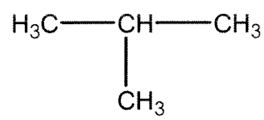
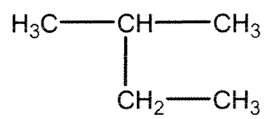
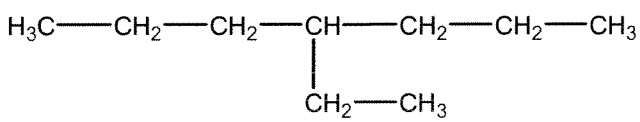
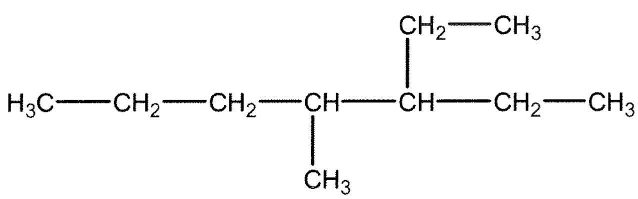
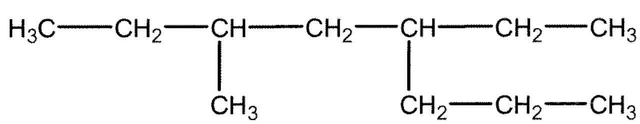
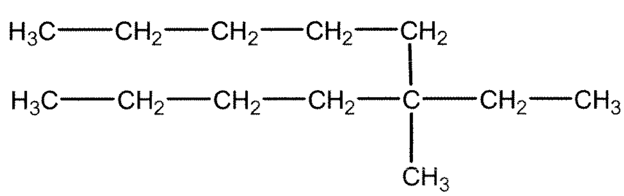
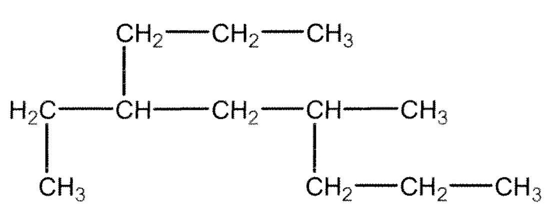
Discovery Activity: Molecular Modelling
Structural Formulas and Alkane Isomers

Chemical Formula	Two Structural Formulas		Total Number of Isomers
C_4H_{10}	Condensed Structural Formula	Condensed Structural Formula	
C_5H_{12}	Condensed Structural Formula	Condensed Structural Formula	
C_6H_{14}	Condensed Structural Formula	Condensed Structural Formula	
C_7H_{16}	Condensed Structural Formula	Condensed Structural Formula	

Name ________________________________ Period _______

Naming Alkanes – Worksheet #1

Name the following branched alkanes:

1.		
2.		
3.		
4.		
5.		
6.		
7.		

(over)

Draw structural formulas for the following molecules. Remember the following:

- Carbons on the end of a chain are attached to three hydrogens
- Carbons in the middle of a chain are attached to two hydrogens
- Carbons that have one branch attached are also attached to one hydrogen
- Carbons that have two branches attached are not attached to any hydrogens.

8. 4-ethyl-octane

9. 2-methyl-nonane

10. 2-methyl-2-ethyl-butane

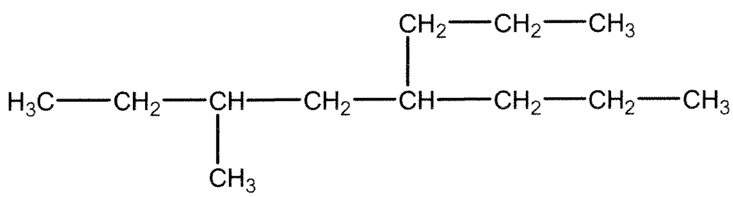
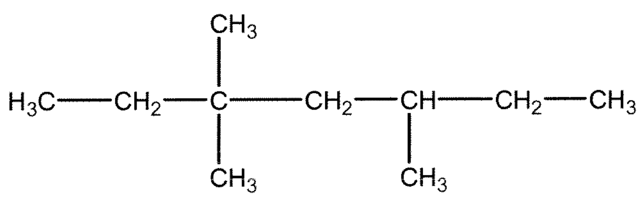
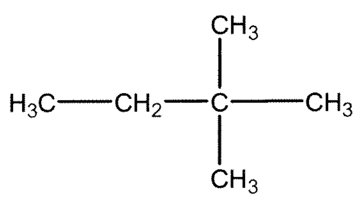
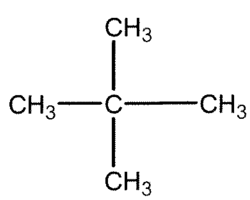
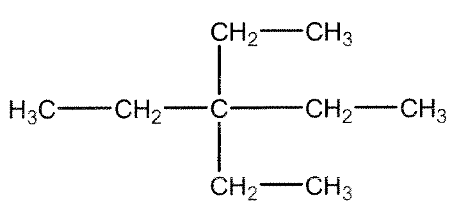
11. 3-ethyl-pentane

12. 2-methyl-3-ethyl-heptane

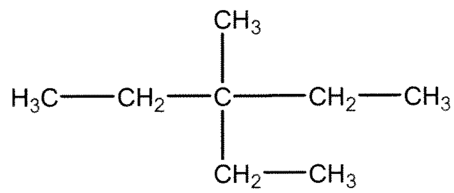
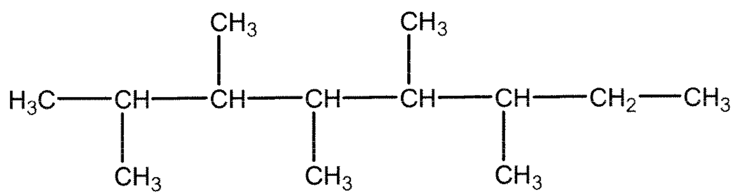
Name ______________________________ Period _______

Naming Alkanes – Worksheet #2

Name the following branched alkanes:

1.		
2.		
3.		
4.		
5.		

(over)

6.		
7.		

Draw structural formulas for the following molecules:

8. 2,2,3-trimethyl-butane

9. 3-ethyl-2,2-dimethyl-hexane

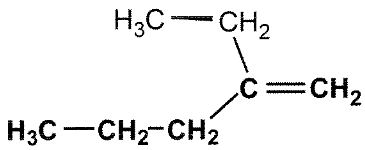
10. 2,3,4,5,6,7-hexamethyl-octane

Naming Alkenes

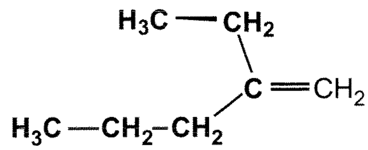
Suffix: -ene

Many of the same rules for alkanes apply to alkenes

1. Name the parent hydrocarbon by locating the longest carbon chain that contains the double bond and name it according to the number of carbons with the suffix -ene.



Parent = pentene



not hexene
(does not contain double bond)

2. a. Number the carbons of the parent chain so the double bond carbons have the lowest possible numbers.

$$\underset{6}{H_3C}-\underset{5}{CH_2}-\underset{4}{CH_2}-\underset{3}{CH}=\underset{2}{CH}-\underset{1}{CH_3}$$

2-hexene

b. If the double bond is equidistant from each end, number so the first substituent has the lowest number.

$$\underset{1}{H_3C}-\underset{2}{\overset{\overset{\displaystyle CH_3}{|}}{CH}}-\underset{3}{CH}=\underset{4}{CH}-\underset{5}{CH_2}-\underset{6}{CH_3}$$

2-methyl-3-hexene

3. Write out the full name, numbering the substituents according to their position in the chain and list them in alphabetical order.

4. Indicate the double bond by the number of the first alkene carbon.

$$\underset{6}{H_3C}-\underset{5}{CH_2}-\underset{4}{CH_2}-\underset{3}{CH}=\underset{2}{CH}-\underset{1}{CH_3}$$

2-hexene

5. If more than one double bond is present, indicate their position by using the number of the first carbon of each double bond and use the suffix -diene (for 2 double bonds), -triene (for 3 double bonds), -tetraene (for 4 double bonds), etc.

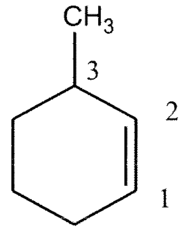
$$\underset{1}{H_2C}=\underset{2}{CH}-\underset{3}{CH_2}-\underset{4}{CH}=\underset{5}{CH_2}$$

1,4-pentadiene

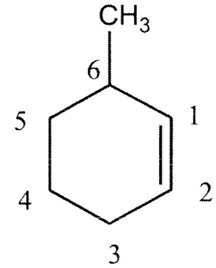
$$\underset{1}{H_2C}=\underset{2}{CH}-\underset{3}{CH}=\underset{4}{CH}-\underset{5}{CH_3}$$

1,3-pentadiene

6. a. Cycloalkenes are named in a similar way. Number the cycloalkene so the double bond carbons get numbers 1 and 2, and the first substituent is the lowest possible number.

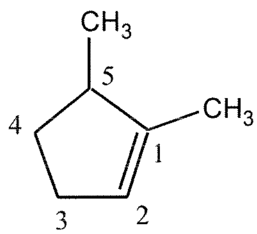


3-methylcyclohexene

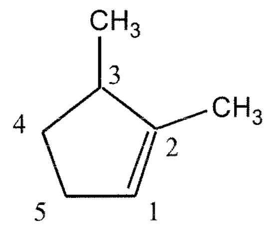


NOT
6-methylcyclohexene

b. If there is a substituent on one of the double bond carbons, it gets number 1.

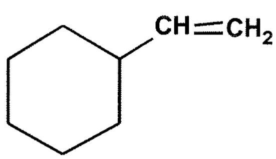


1,5-dimethylcyclopentene

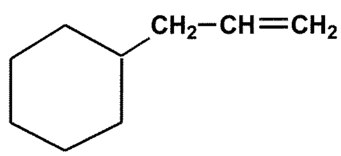


NOT
2,3-dimethylcyclopentene

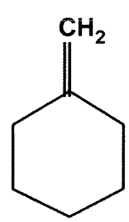
Alkenes as Substituents:



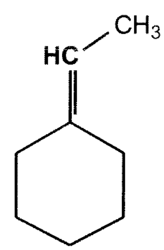
ethenyl or vinyl
(vinylcyclohexane)



2-propenyl or allyl
(allylcyclohexane)



methylene
(methylenecyclohexane)



ethylidene
(ethylidenecyclohexane)

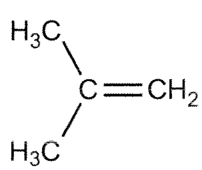
Non-IUPAC Alkenes (Table 6.1, pg. 184)

$H_2C{=}CH_2$

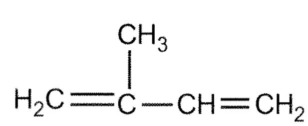
ethylene
(ethene)

$H_3C{-}CH{=}CH_2$

propylene
(propene)



isobutylene
(2-methylpropene)



isoprene
(2-methyl-1,3-butadiene)

Alkene Worksheet

Molecular formula	Structural formula	Name
C_2H_4		ethene
C_3H_6		propene
C_4H_8		1-butene
C_4H_8		cis-2-butene
C_4H_8		trans-2-butene
C_5H_{10}		1-pentene
C_5H_{10}		cis-2-pentene

Alkene Worksheet

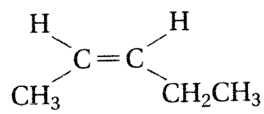
C_5H_{10}		trans-2-pentene
C_5H_{10}		2-methyl-1-butene
C_8H_{16}		cis-3,4-dimethyl-3-hexene

Name ______________________ Date ________________ Class ________________

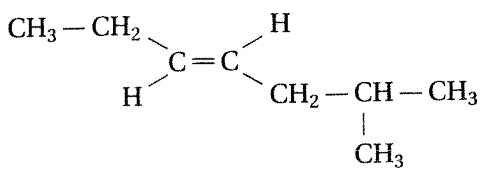
3. Name and draw all of the alkynes with the molecular formula C_5H_8.
4. Write structural formulas for the following hydrocarbons.
   a. 3,5-dimethyl-1-hexene
   b. 4-methyl-1-pentene
   c. 3,3-dimethyl-1-butyne

SECTION 22.3 ISOMERS

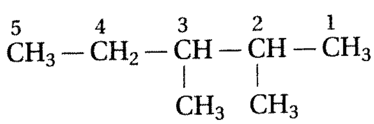
1. Name this compound, according to the IUPAC system.



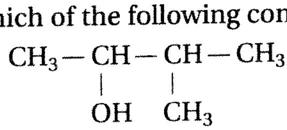
2. Name this compound, according to the IUPAC system.

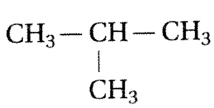


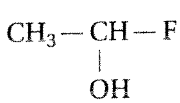
3. Write the structural formula for *trans*–2–heptene.
4. Which of the following can exist as *cis, trans* isomers?
   a. 2-butene
   b. 1-butene
   c. 2-methyl-2-butene
   d. 3-hexene
5. Identify the asymmetric carbon in the following compound.



6. Which of the following compounds have an asymmetric carbon?

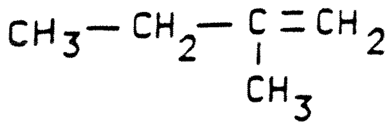
a. 

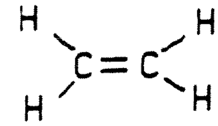
b. 

c. 

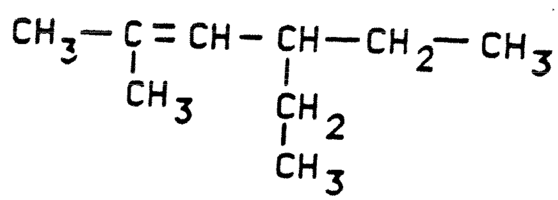
23

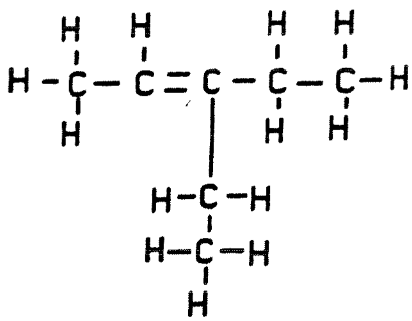
Name each of the following compounds.

1. 

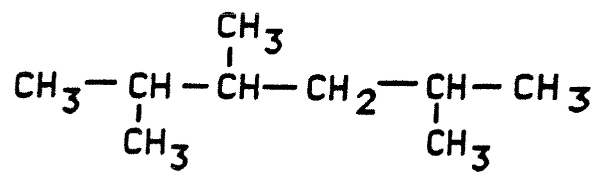
2. 

3. $CH_3-CH_2-CH_2-CH=CH-CH_3$

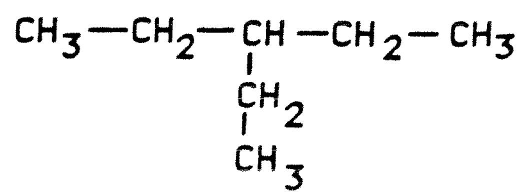
4. 

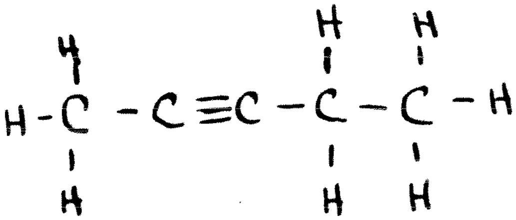
5. 

6. $CH_3-CH=CH-CH_3$

8. 

7. $CH_2=CH-CH_2-CH_3$

10. 

9. 

ALKYNES WORKSHEET

1. Write the structural formulas for each of the following.

   a) 3-methyl-1-pentyne

   b) 1-hexyne

   c) 2,5-dimethyl-3-heptyne

   d) 2- methyl-3-hexyne

   e) 4-chloro-2-pentyne

2. Name each of the following alkynes by the IUPAC system.

   a) $CH_3-C \equiv C-CH_2-CH_3$

   b) $HC \equiv C-\underset{\underset{\displaystyle CH_3}{|}}{CH}-CH_3$

3. Write the all alkyne isomers of C_4H_6. Name each compound.

Summary of the Rules for IUPAC of Organic Nomenclature

1. Choose the **longest continuous** chain that includes the
   a. functional group*, **or**
   b. multiple bond, **or**
   c. side chain.

2. Number the carbon atoms in the **longest continuous** chain starting at the end closest to the
   a. functional group*, **or**
   b. multiple bond, **or**
   c. side chain.

3. Give the compound the name of the **alkane** that has the same number of carbon atoms as the **longest continuous** chain.

4. Change the **suffix** of the alkane to indicate the functional group* or **multiple bond** present.

5. Locate the functional group* or side chain by stating the **number** of the carbon atom to which the functional group* or side chain is **attached.**

   Always start from the **end** of the longest chain that will locate the functional groups* and side chains using the **lowest** numbers possible.

6. Functional groups* and side chains are identified by giving the **name** of each functional group* and side chain. State the number of the carbon atom in the **longest continuous** chain to which the functional group* or side chain is **attached.**

   List the functional groups* or side chains either
   a. alphabetically, **or**
   b. in order of complexity - from **least** to **most** complex

* Functional groups have **not** been covered in the unit as yet but **will be** covered in later material so are included to make this summary more **complete** so it can be used by the student as a review for tests.

Organic Reactions

Organic compounds have many different uses. Depending on what is available, different organic compounds can be manufactured through specific types of chemical reactions.

Here we will focus on 3 types of organic reactions:

A. Addition B. Combustion C. Catalytic Cracking

A. Addition Reactions

Catalytic Hydrogenation occurs when hydrogen is added to an alkene or an alkyne in the presence of a nickel, platinum, or palladium catalyst. Depending on the number of moles of hydrogen that react, either an alkene or an alkane may be produced.

Sample Catalytic Hydrogenation Addition Reactions

1. Production of an alkane from an alkene.

2. Production of an alkene from an alkyne and one mole of hydrogen gas.

3. Production of an alkane from an alkyne and two moles of hydrogen gas.

B. Combustion Reactions

Many organic compounds readily react in the presence of oxygen to produce carbon dioxide gas and water vapour. Heat is also given off as a byproduct. This is why many hydrocarbons are burned to heat homes, offices, and industrial complexes. Hydrocarbons that are not used to produce heat are used to fuel automobiles. All of the organic compounds we have studied so far may be combusted.

Sample Combustion Reaction

1. Write the balanced chemical equation for the combustion of ethanol.

2. According to its Material Safety Data Sheet (MSDS), glacial acetic acid is flammable. Write the balanced chemical equation for the combustion of ethanoic acid.

C. Catalytic Cracking

Catalytic cracking occurs when large chain alkanes are passed through a high temperature reaction chamber (approximately 700°C to 900°C), producing smaller chain alkanes, alkenes (mainly ethylene), and hydrogen gas. Another name for this type of reaction is dehydrogenation because of the hydrogen molecules that are removed from the organic compounds.

Sample Catalytic Cracking Reactions

1. *n*-butane is cracked to produce 1—butene and 2—butene.

2. Decane is cracked to produce ethylene and octane.

3. Heptane undergoes catalytic cracking. Two different alkane products are produced, one of which is butane.

It is important to note that the conversion of alkanes to alkenes is a complex process that often produces multiple different products. Don't worry; you will always be given sufficient information so that you can write the complete balanced equation for dehydrogenation reactions.

Concept Reinforcement

1. Write the balanced addition reaction showing all atoms when 1 mole of hydrogen gas are added to 3 - methyl -1- butyne in the presence of a nickel catalyst. Name the alkene product.

2. Draw the structural formula and name the product if two moles of hydrogen are added to the reaction described above.

3. Write the balanced addition reaction showing all atoms for the hydrogenation of 2 - pentene. Name the alkane product.

4. Complete question 1 on sheet entitled "Organic Reactions Worksheet."

Organic Reactions Worksheet

For each of the following chemical reactions:

a) state the type of reaction (esterification, catalytic cracking, addition, combustion)
b) write the complete structural formulas for all reactants and products
c) write the IUPAC names for all reactants and products.
d) write the balanced chemical equation.

1. Propene reacts with hydrogen gas.

2. Ethanol and butanoic acid are heated in the presence of a sulfuric acid catalyst.

3. Nonane is heated to high temperature in the presence of a catalyst producing hexane and propene.

4. 1, 3 – hexadiene is combusted in the presence of oxygen gas.

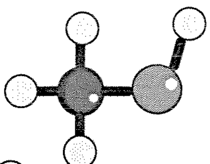
5. 2 – methyl – 1 – pentanol reacts with methanoic acid in the presence of an acid catalyst.

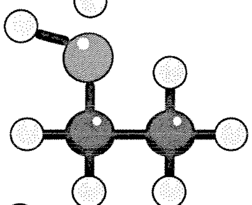
6. 4 – methyl – 2 – hexyne reacts with 2 moles of hydrogen gas.

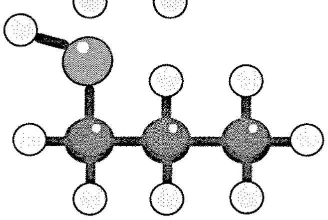
Alcohols

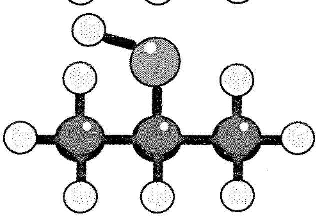
Match the IUPAC names with their corresponding structural formulas

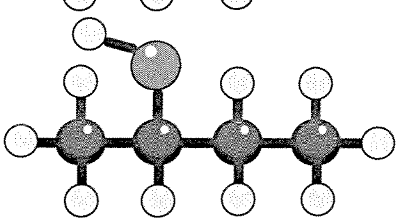
Chemical Formula	IUPAC Name	General Formula



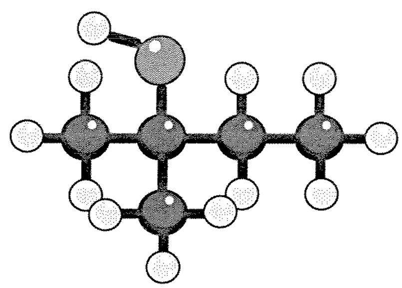








Name the following molecule



Alcohols

Make a minium of four statements about alcohols after examining the handout.

1. Alcohols are...

2. Alcohols are named by...

3. A primary alcohol (symbol 1°) is described as...

4. A secondary alcohol is described as...

5. A ternary alcohol would be an alcohol that...

Conclusions About Alcohols

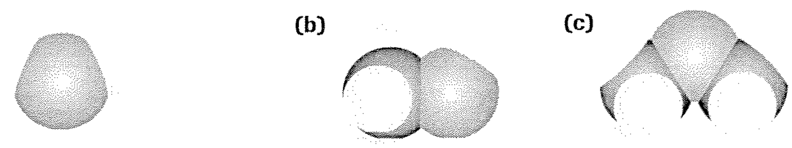
1.5 Alcohols and Ethers

alcohol an organic compound characterized by the presence of a hydroxyl functional group; R—OH

hydroxyl group an —OH functional group characteristic of alcohols

Alcohols and ethers are structurally similar in that they are essentially water molecules with substituted alkyl groups. In **alcohols**, one of the two H atoms in H_2O is replaced by an alkyl group; in ethers, both H atoms are replaced by alkyl groups. The molecular models in **Figure 1** show water, the simplest alcohol, and the simplest ether. The properties of these compounds are related to the effects of the polar **hydroxyl groups** (—OH) and the nonpolar alkyl groups.

(a) (b) (c)



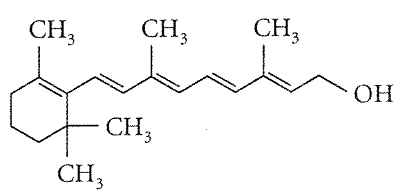
H—O—H R—O—H R—O—R

Figure 1
Molecular models and general formulas of **(a)** water, H—O—H, **(b)** the simplest alcohol, CH_3—OH, methanol and **(c)** the simplest ether, H_3C—O—CH_3, methoxymethane (dimethyl ether)

Alcohols

The "alcohol" in wine and beer is more correctly called ethanol. It is formed by yeast, a fungus that derives its energy from breaking down sugars, producing carbon dioxide and ethanol as waste products. Once the concentration of ethanol reaches a critical level, the yeast cannot survive and fermentation ceases. The alcohol content in wine is therefore limited to about 13% (26 proof).

Other alcohols that are produced by living organisms include cholesterol and retinol, commonly known as vitamin A.



retinol
(vitamin A)

While ethanol is not as toxic as other alcohols, it is recognized as a central nervous system depressant and a narcotic poison. Ethanol can be purchased in alcoholic beverages, the only "safe" form to consume. The ethanol commonly used in science laboratories is not intended for drinking and is purposely mixed with methanol, benzene, or other toxic materials in order to make it unpalatable.

Naming Alcohols

In the IUPAC system of naming alcohols, the —OH functional group is named *-ol*, and is added to the prefix of the parent alkane. As before, the parent alkane is the longest carbon chain to which an —OH group is attached. For example, the simplest alcohol, with one —OH group attached to methane, is named "methan*ol*." It is highly toxic and ingesting even small quantities can lead to blindness and death. The alcohol with two carbon atoms is ethan*ol*, the active ingredient in alcoholic beverages. It is an important synthetic organic chemical, used also as a solvent in lacquers, varnishes, perfumes, and flavourings, and is a raw material in the synthesis of other organic compounds.

DID YOU KNOW ?

Alcohol Toxicity
It may be argued that all chemicals are toxic, to widely varying degrees. Some substances, such as methanol, are toxic in very small amounts, while others, such as NaCl, are generally harmless in moderate quantities. Toxicity is expressed by an LD_{50} rating, found in Material Safety Data Sheets (MSDS). It is the quantity of a substance, in grams per kilogram of body weight, that researchers estimate would be a lethal dose for 50% of a particular species exposed to that quantity of the substance. The LD_{50} values for several alcohols in human beings are shown below.

Alcohol	LD_{50} (g/kg body weight)
methanol	0.07
ethanol	13.7
1-propanol	1.87
2-propanol (rubbing alcohol)	5.8
glycerol (glycerine)	31.5
ethylene glycol (car antifreeze)	<1.45
propylene glycol (plumber's antifreeze)	30

Table 1 Boiling Points for Some Short-Chain Alcohols

Name	Formula	Boiling point (°C)
methanol	CH_3OH	65
ethanol	C_2H_5OH	78
1-propanol	C_3H_7OH	97
1-butanol	C_4H_9OH	117

INVESTIGATION 1.5.2

Trends in Properties of Alcohols **(p. 86)**

Is there a link between the molecular size of alcohols and their properties? Predict a trend, and then see if your evidence supports your prediction.

DID YOU KNOW ?

Fill up with Methanol

Alcohols have many uses, one of the more recent being a fuel for motor vehicles. The problem with methanol as a fuel for cars is its hydroxyl group. This functional group makes it less volatile than the hydrocarbons that make up gasoline, and the low volatility makes it difficult to ignite. In our cold Canadian winters, there is little methanol vapour in the engine and an electrical spark is insufficient to start the car. Canadian scientists are investigating a variety of dual ignition systems, one of which is a plasma jet igniter that is 100 times more energetic than conventional ignition systems.

hydration reaction a reaction that results in the addition of a water molecule

Properties of Alcohols

Alcohols have certain characteristic properties, including boiling points that are much higher than those of their parent alkanes. For example, ethanol boils at 78°C, compared with ethane, which boils at −89°C (**Table 1**). This property can be explained by the presence of a hydroxyl group, −OH, attached to a hydrocarbon chain. This functional group not only makes alcohol molecules polar, it also gives them the capacity to form hydrogen bonds.

Furthermore, simple alcohols are much more soluble in polar solvents such as water than are their parent alkanes. This can also be explained by the presence of the polar O−H bond.

In long-chain alcohols, the hydrocarbon portion of the molecule is nonpolar, making larger alcohols good solvents for nonpolar molecular compounds as well. Thus, alcohols are frequently used as solvents in organic reactions because they will dissolve both polar and nonpolar compounds.

When one of the H atoms in water is replaced by an alkyl group, the resulting alcohol, R−O−H, is less polar than water, with accompanying differences in physical properties. We will see later that when both H atoms in water are replaced by alkyl groups, we get another group of organic compounds named ethers, R−O−R. Perhaps you can predict now what their physical properties will be.

Practice

Understanding Concepts

4. Explain briefly why methanol has a higher boiling point than methane.
5. Arrange the following compounds in order of increasing boiling point, and give reasons for your answer.
   (a) butane
   (b) 1-butanol
   (c) octane
   (d) 1-octanol

Making Connections

6. Glycerol is more viscous than water, and can lower the freezing point of water; when added to biological samples, it helps to keep the tissues from freezing, thereby reducing damage. From your knowledge of the molecular structure of glycerol, suggest reasons to account for these properties of glycerol.

Reactions Involving Alcohols

Preparing Alcohols: Hydration Reactions

If you recall the reactions of alkenes, the double bonds readily undergo addition reactions. If we start with an alkene, we can introduce the −OH functional group by adding HOH, water. Indeed, many alcohols are prepared industrially by addition reactions of water to unsaturated hydrocarbons. For example, 2-butanol is formed by the reaction between water and butene, using sulfuric acid as a catalyst. Since the overall result is the addition of a water molecule, this type of addition reaction is also referred to as a **hydration reaction**. This reaction follows Markovnikov's rule: The hydrogen attaches to the carbon atom that already has more hydrogen atoms; the −OH group attaches to the other carbon atom in the double bond.

$$\underset{\text{1-butene}}{CH_3CH_2CH{=}CH_2} + \underset{\text{water}}{HOH} \xrightarrow{\text{acid}} \underset{\text{2-butanol}}{CH_3CH_2-\underset{\displaystyle OH}{\underset{|}{CH}}-\underset{\displaystyle H}{\underset{|}{CH_2}}}$$

Naming Alcohols

Draw the structural and condensed structural formula's for each of the following compounds.

1. 1 - butanol

2. 1,2- ethanediol

3. methanol

4. 2-methyl-1-pentanol

5. 2,3-dimethyl-2-hexanol

6. 1,3- butanediol

7. 3-ethyl-2-pentanol

8. 1,2,4-heptanetriol

Name, draw the structural formula and state the uses for the following compounds.

1. CH_3OH

2. CH_3CH_2OH

3. $CH_3CH_1OH\ CH_3$

4. $CH_3CH_2\ CH_2\ CH_2OH$

5. $CH_3CH_2\ COH(CH_3)\ CH_3$

6. $CH_2\ OH\ CH_2OH$

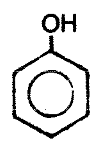
7. $CH_2\ OH\ CHOH\ CH_2OH$

Alcohols

Nomenclature and Uses of Some Common Alcohols

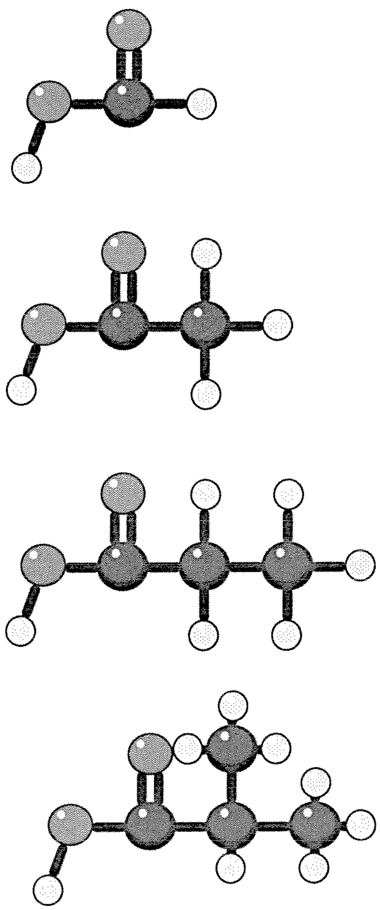
Complete the following table.

Table H5
Common Alcohols

1. (methyl alcohol or wood alcohol)		gas line and windshield washer antifreeze; solvent for varnishes and shellacs; denaturant for ethanol
2. (ethyl alcohol or grain alcohol)		alcoholic beverages; in pharmaceutical industry as solvent and medicinal ingredients; in industry as solvent and antifreeze
3.	$CH_3 - CH - CH_3$ | OH	rubbing alcohol; solvent
4. 1-butanol		solvent; hydraulic fluid
5.	CH_3 | $CH_3 - CH_2 - C - CH_3$ | OH	solvent
6. phenol (carbolic acid)		germicide; ingredients of some plastics
7. 1,2-ethanediol (ethylene glycol)		permanent radiator antifreeze
8. (glycerin or glycerol)	$CH_2 - OH$ | $CH - OH$ | $CH_2 - OH$	making synthetic resins for paints; manufacture of cellophane; cosmetics and toilet soap; pharmaceutical ingredient; making of nitroglycerin explosives; in foods and beverages
9. 2,2,2-trichloro-1,1-ethanediol (chloral hydrate)		a sedative (note similarity to chloroform)
10. pentachlorophenol (PCP)		a fungicide and wood preservative

37

Carboxylic Acids



38

Nomenclature of Carboxylic Acids

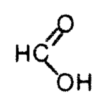
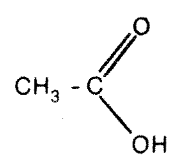
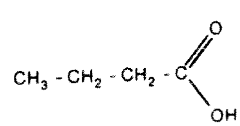
Carboxylic acids are named in the IUPAC system by dropping the *e* and adding the suffix *oic* to the name of the parent hydrocarbon (containing the *same total number* of carbon atoms). The resulting name is then followed by the word *acid*. Many carboxylic acids are naturally occurring and have common or trivial names that reflect their natural source. The IUPAC and common names are given in the examples in Table 6. Additional names are given in Table 7 in the section *Sources and Uses of Some Common Organic Acids.*

Sources and Uses of Carboxylic Acids

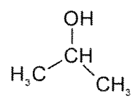
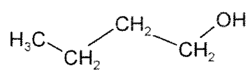
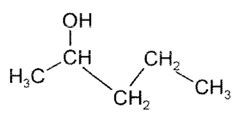
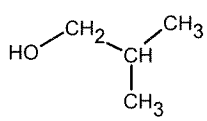
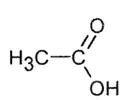
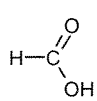
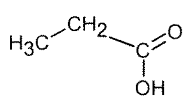
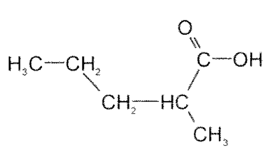
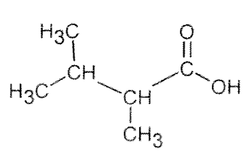
Complete the following table.

Table 6

Sources and Uses of Some Carboxylic Acids

	Name (Common Name in Brackets)	Formula	Sources and Typical Uses
e.g.	methanoic acid (formic acid)		responsible for sensation caused by nettle, bee and ant stings; used in medicine and food preservations; used commercially in the textile industry
1.	(acetic acid)		component of vinegar; used as a solvent; salts of acid used as mordant and in insecticides and fungicides
2.	propanoic acid (propionic acid)		used as antifungal agents in the baking industry and ointments either in salt or acid form
3.	(butyric acid)		employed as flavoring agent; odor-causing component of rancid butter
4.	hexanoic acid (caproic acid)		employed as a flavoring agent; has odor characteristic of limberger cheese

Alcohols & Carboxylic Acids

Structure	IUPAC Name
1. 	
2. 	
3. 	
4. 	
5. 	
6. 	
7. 	
8. 	
9. 	
10. 	

Alcohols & Carboxylic Acids

IUPAC Name	Structural Formula	Chemical Formula
1. 2 – butanol		
2. 3 – methyl hexanoic acid		
3. 3,3 – dimethyl pentanoic acid		
4. 3,4 – heptandiol		
5. Ethanol		
6. 1 – butanol		
7. 1 – propanol		
8. 2 – hexanol		
9. 2 – ethyl – 3 – methyl butanoic acid		

Appendix 5.2: Preparation of Esters

Purpose

To study a method for the preparation of esters and to study some of their properties.

Substances Used

Complete the structural formulas for the following alcohols and carboxylic acids before starting the lab.

Alcohols	Carboxylic Acids
1. isopentyl alcohol (3–methyl–1–butanol)	2. acetic acid ethanoic acid
3. isobutyl alcohol (2–methyl–1–butanol)	4. propanoic acid
5. ethyl alcohol ethanol	6. butanoic acid butyric acid
7. methyl alcohol methanol	8. salicylic acid

Safety Precaution

In this lab activity, you will be adding a very small amount of concentrated sulphuric acid to four of the test tubes. **This acid is very corrosive.** Your teacher will show you the safe location of this acid and how to add the correct amount safely.

Ester Naming

Draw the structural formula for the following compounds

1. propyl butanoate
2. ethyl propanoate
3. methyl hexanoate
4. butyl methonoate

Name and draw the structural formula for the following esters.

1. $CH_3CH_2CH_2CH_2COOCH_2CH_2CH_3$

2. $CH_3CH_2COOCH_2CH_2CH_2CH_2CH_3$

3. $CH_3COOCH_2CH_2\ CH_2CH_2CH_2CH_3$

4. Esters 1,2 and 3 in this section are isomers draw, and name a 4th isomer of this ester.

Chemistry 30S Organic Chemistry Performance Task

Your Task
In groups of no more than two students, construct a bath bomb, prepare a product information label, and package your product for sale.

Part I. Making the Bath Bomb

Equipment
- 100 mL beaker
- 250 mL beaker
- 600 mL beaker
- Glass stir rod
- Plastic sandwich bag

Chemicals
- Citric acid, 18.0 g
- Cornstarch, 10.0 g
- Ester fragrance, 0.7 g
- Baking soda, 65.0 g
- Vegetable oil, 25.0 g

Data
Record the masses of each of the ingredients before making the bath bomb.

Ingredients	Mass (+/- 0.1 g)

Procedure
1. Mass each of the dry ingredients using the 250 mL beaker.
2. Mass the vegetable oil and the ester for fragrance using the small beaker.
3. Pour all ingredients into the large beaker and mix carefully with the glass stir rod. Take care not to break the stir rod!
4. Form the mixture into the shape of your choice. Place the bath bomb in a plastic sandwich bag and take home to dry and package. At home remove the bath bomb from the plastic and allow to dry for 24 to 48 hours before packaging.
5. Package the bath bomb as if it were a consumer product. Keep in mind that the bath bomb is brittle and an airtight seal will prevent the fragrance from escaping over time.

Part II. Preparing the Product Information Label
Prepare a product information label which lists all of the ingredients, from highest to lowest concentration by percent mass (%w/w). Use appropriate IUPAC naming systems for the baking soda and ester ingredients.

Part III. Package Your Product for Sale
This is your opportunity to create an attractive product as if it were to be available for sale. Be creative and consider who you may sell to, where your product may appear, how your product will be manufactured and shipped, and how you wish it to be displayed in a store.

Bath Bomb Assessment Rubric

Student 1		**Student 2**	
Criteria	**Novice (0 or 1)**	**Intermediate (2 marks)**	**Expert (3 marks)**
Group prepares a bath bomb	Bath bomb is not shaped **(1)** or no bath bomb present **(0)**	Shape of bath bomb is the same as another group and/or has no unique aesthetic aspect(s)	Bath bomb has a unique shape and/or has some unique aesthetic aspect(s)
Product information label present	Label is missing information from more than one of the expert level categories **(1)** or no label present **(0)**	Label is missing information from one of the expert level criteria or some information from expert level criteria is incorrect	Label includes the names of all ingredients, including the correct IUPAC names for baking soda and the ester, and the corresponding percent weights by mass ordered from highest to lowest percent concentration by mass
Bath bomb packaging	Only one or no criteria met	Only two criteria met	Packaging secures bath bomb, is airtight, and informs the reader of its contents in a unique way
Evidence of equitable participation	One student does most or all of the work	Evidence of one group member contributing more than another student or student does not submit statement of individual contribution	Evidence that all group members contributed equitably and each member submits a piece of writing listing their specific contribution(s) to the completion of the task
Student 1 Mark	**/12**	**Student 2 Mark**	**/12**

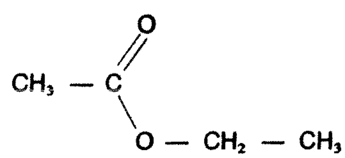
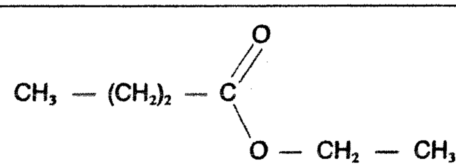
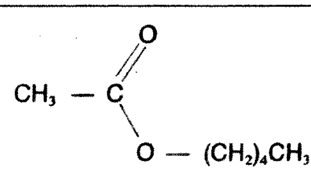
Esters

Sources and Uses of Some Common Esters

Esters are a common occurrence in nature and are abundant in animal fats and vegetable oils. (See the ALCHEM elective *Foods and their Analogs*.) Unlike the acids involved in their formation, simple esters usually have pleasant odors and constitute the odors and flavors of fruits. Table H8 gives some examples of esters.

Complete Table H8.

Table H8
Sources and Uses of Some Common Esters

Name (Common Name is Given in Brackets)	Structural Formula	Sources and Typical Uses
1. ethyl methanoate (ethyl formate)		rum flavor and odor
2. (ethyl acetate)		fingernail polish remover, solvent
3. pentyl propanoate (pentyl propionate)		apricot flavor and odor
4. (ethyl butyrate)		used in artificial peach, pineapple and apricot flavors
5. octyl ethanoate (octyl acetate)		orange flavor and odor
6. (n-amyl acetate)		pear flavor and odor
7. ethyl benzoate		cherry flavor and odor

Optional

8. 1-methylpropyl ethanoate		strawberry flavor and odor
9. 2-methylpropyl methanoate (isobutyl formate)		raspberry flavor and odor
10. (isoamyl acetate)	$CH_3 - COO - \overset{\overset{CH_3}{\vert}}{CH} - CH_2 - CH_2 - CH_3$	banana flavor and odor

Esters and Esterification

Write a structural equation to represent a reaction between each of the following. Name the ester product in each case. (An acid catalyst is employed for each reaction.)

1. propanoic acid and 1-butanol

2. butanoic acid and 1-hexanol

3. pentanoic acid and 1-octanol

4. benzoic acid and methanol

Optional:

5. methanoic acid and 2-methyl-1-propanol

6. benzoic acid and 2-butanol

Esterification Lab

Purpose
Prepare an ester from an alcohol and a carboxylic acid.

Chemicals

- 5 mL of an alcohol
- 10 drops of concentrated sulfuric acid
- 5 mL of a carboxylic acid
- 1 boiling chip

Equipment & Setup

1. Large test tube & cork stopper
2. Utility stand
3. 250 mL beaker
4. Wire mesh
5. Utility clamp
6. Burner
7. Iron ring
8. Test tube holder
9. Flint striker
10. Boiling chip
11. One-hole cork stopper with a 50 cm length of 6 mm glass tubing (acts as a condenser tube)

Safety

1. Wear safety goggles over your eyes at all times when dealing with chemicals.
2. All chemicals have distinct and pervasive odours. Cap each container immediately after dispensing its chemical.
3. All chemicals are poisonous, many are corrosive and others will dehydrate your skin. Take appropriate precautions when dispensing all chemicals.
4. Rinse all affected areas with lots of running water.
5. Clean up all spills immediately.
6. Wash your hands with soap after completing the experiment.

Procedure

1. Set up a 250 mL beaker on a ring stand using an iron ring and a wire mesh. Leave about six inches of space between the top of the burner and the iron ring to accommodate the height of the flame. Fill the beaker about two-thirds full with tap water and place gently on the wire mesh. The beaker of water will serve as a hot water bath.

2. Attach a utility clamp to the iron rod and fit a large test tube inside the clamp so that it is suspended in the water bath and does NOT touch the bottom of the beaker. Tighten the clamp just enough so that the test tube just slides in and is safely supported by the clamp. Add a boiling chip to the test tube.

Esterification Lab

3. Bring your large test tube with the cork stopper to the fume hood and obtain 5 mL of the assigned carboxylic acid and 5 mL of the assigned alcohol using the appropriate plastic pipets. Ensure the caps are on all the chemicals so you don't get a headache from the odours.

4. Note the particular scent of each reactant as you are dispensing it. Do not waft or otherwise stick your nose in the chemicals. You will get a headache and irritate your respiratory tract.

5. Have your instructor add 10 drops of concentrated sulfuric acid to your test tube. Stopper your test tube, and return to your lab station.

6. First checking that the glass tubing is not plugged, remove the cork stopper and cover the test tube with the one-hole stopper containing the 50 cm long glass condenser rod. Make sure that the stopper is firmly inserted into the mouth of the test tube so that it will not fall over while heating. Follow the teacher's instructions on how this should be done.

7. Slide the test tube with the attached condenser tube through the utility clamp and into the water bath.

8. Heat the water bath until the reaction mixture in the test tube starts to boil. Turn off the burner. Do not boil the water bath. The boiling point of your reactants is lower than the boiling point of water! You may need to remove the test tube from the water bath now and again so that the mixture can reflux (bubble slowly) for about five minutes. Be careful that the boiling mixture does not travel up the condenser tube!

9. Allow the reaction mixture to cool for several minutes. Remove the condenser and check the odour of the ester formed in the test tube using the wafting technique.

10. Recap the test tube with the cork stopper and submit your ester to the instructor for inspection and disposal instructions.

11. Put all of the equipment away. If you need to, cool the iron ring by running it under tap water before handling it.

Esterification Lab

LABORATORY RUBRIC: SKILLS AND ATTITUDES

Name:			**Period:**
Criteria	**Novice**	**Intermediate**	**Expert**
Student observes proper safety precautions	Student does not wear their safety goggles or has a lab accident	Student is nagged once or more about not following proper safety precautions	All aspects of the lab are conducted in a safe manner
Student follows written and verbal instructions	Evidence that the student has not followed more than one written or verbal instruction	Evidence that the student has not followed one written or verbal instruction	Student follows all written or verbal instructions
Evidence of equitable participation	Little or no evidence of equitable participation by a group member	Some evidence that a group member participated more than another	Evidence that all group members participated equitably
Lab station is cleaned up after lab	More than one piece of evidence remains of chemicals or equipment after cleanup	Evidence of chemicals or a piece of equipment remains after cleanup	Entire station is cleaned up with no evidence remaining of equipment or chemicals

Discussion Questions

1.

a) Sketch the complete structural formulas (all individual atoms visible at 90°) for all reactants and products for your particular acid and carboxylic acid combination.

b) Write the appropriate IUPAC name below the structural formula of the ester product.

Esterification Lab

2. What is the role of sulfuric acid in these reactions?

3. How is the – OH functional group of an alcohol different from the hydroxide anion in an inorganic compound (A.K.A. an ionic salt)?

4. Compare and contrast the odours of the reactants and the products.

5. Of what use are esters?

Summary Table for Some Organic Compounds

Group	Structure (R Represents H or Carbon Chain)	Nomenclature	General Formula	1. Physical Properties 2. Chemical Properties	Uses and Occurrence
alkanes	R—C—C—R (with single bonds above and below each C)	—ane	C_nH_{2n+2}	1. nonpolar; insoluble; low melting and boiling points 2. substitution; combustion	fuels; petrochemical building blocks
alkenes	R — C = C — R (with single bonds above and below each C)	—ene	C_nH_{2n}	1. same as alkanes 2. addition, combustion	starting materials for many polymers
alkynes	R — C ≡ C — R	—yne	C_nH_{2n-2}	1. same as alkanes 2. addition of one or two molecules of adding reagent, combustion	first member of the series used in oxyacetylene welding
aromatics	 H or R on each of the six positions	—benzene or phenyl—	$C_6H_nR_{(6-n)}$ (variable)	1. nonpolar; insuluble in water 2. substitution; combustion	very diverse-solvents, foods, drugs, explosives, mothballs
alkyl halides	$R\text{-}X_n$ (X = F, Cl, Br, I)	fluoro— chloro— bromo— iodo—	$C_nH_{2n+1}X$ $C_nH_{2n-1}X$ C_6H_5X	1. variable boiling points; generally insoluble in water 2. intermediates in the preparation of many organic substances	solvents, insecticides, antiseptics, anaesthetics, refrigerants, insect repellants
alcohols	R - OH $R(\text{-}OH)_2$ $R(\text{-}OH)_3$	—ol —diol —triol	$C_nH_{2n+1}OH$ $C_nH_{2n}(OH)_2$ $C_nH_{2n-1}(OH)_3$	1. higher boiling; soluble because of hydrogen bonding 2. many reactions; e.g., esterification, combustion	very diverse - antifreeze, alcoholic drinks, cosmetics, foods
acids	R—C(=O)—OH	—oic acid	$C_nH_{2n+1}COOH$	1. high boiling; first four members soluble 2. all inorganic acid reactions; esterification	commonly occur in foods, waxes
esters	R—C(=O)—O—R′	R′ yl R oate	$C_nH_{2n+}COOC_mH_{2m+1}$	1. insoluble in water 2. can react with water to form a carboxylic acid and alcohol	used as solvents and artificial flavors; commonly occur in animal fats and vegetable oils

Common Types of Organic Chemical Reactions

Combustion of Organic Compounds

$$\left\{\begin{array}{l}\text{hydrocarbon}\\ \text{alcohol}\\ \text{carboxylic acid}\\ \text{ester}\end{array}\right\} + O_2(g) \longrightarrow CO_2(g) + H_2O(g)$$

Substitution Reaction

$$\begin{array}{l}\text{alkane}\\ \text{aromatic}\end{array} + X_2 \longrightarrow \left\{\begin{array}{l}\text{alkyl halide}\\ \text{aromatic halide}\end{array}\right\} + HX$$

Addition Reactions

$$\text{alkene} + \left\{\begin{array}{c}H_2\\ HX\\ X_2\\ HOH\end{array}\right\} \longrightarrow \left\{\begin{array}{l}\text{alkane}\\ \text{alkyl halide}\\ \text{alkyl dihalide}\\ \text{alcohol}\end{array}\right\}$$

$$\begin{array}{l}\text{1 mole of}\\ \text{alkyne}\end{array} + \text{1 mole of} \left\{\begin{array}{c}H_2\\ HX\\ X_2\\ HOH\end{array}\right\} \longrightarrow \left\{\begin{array}{l}\text{alkene}\\ \text{alkenyl halide}\\ \text{alkenyl dihalide}\\ \text{alcohol}\end{array}\right\}$$

$$\begin{array}{l}\text{1 mole of}\\ \text{alkyne}\end{array} + \text{2 moles of} \left\{\begin{array}{c}H_2\\ HX\\ X_2\\ HOH\end{array}\right\} \longrightarrow \left\{\begin{array}{l}\text{alkane}\\ \text{alkyl dihalide}\\ \text{aklyl tetrahalide}\\ \text{polyalcohol}\end{array}\right\}$$

Esterification

carboxylic acid + alcohol ⟶ ester + HOH