EXPERIMENT 28

Hydrocarbons and Alcohols

Performance Goals

28–1 Perform various tests on an alkane to determine whether it is saturated or unsaturated.

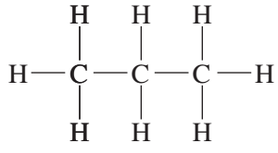
28–2 Perform tests on an alcohol to determine if it is a primary, secondary, or tertiary alcohol.

CHEMICAL OVERVIEW

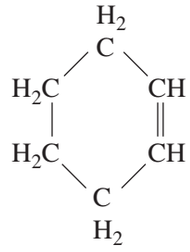
Organic chemistry is the study of the compounds of carbon other than the carbonates, cyanides, carbon monoxide, and carbon dioxide. All organic molecules contain carbon and hydrogen; many of them also contain oxygen. Organic compounds are divided into subgroups based on common ''functional groups.'' These subgroups have similar chemical properties and can be identified by laboratory tests.

Hydrocarbons

The simplest types of organic compounds are the *hydrocarbons,* which are composed of carbon and hydrogen only. In these compounds, carbon atoms may join in an open chain or form ring structures:



Propane (an alkane)

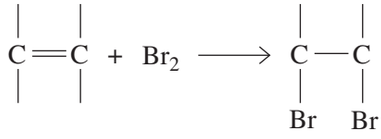


Cyclohexene (an alkene)

Saturated hydrocarbons are those in which each carbon is bonded to four other atoms, either hydrogens or other carbon atoms. Hydrocarbons in this class are named **alkanes** or **paraffins.** The first few members of alkanes, such as methane and propane, are gases; the higher-molar-mass alkanes, such as those found in paraffin wax, are solids.

Unsaturated hydrocarbons contain one or more double or triple bonds. Those with double bonds are **alkenes**, and those with triple bonds are

alkynes. Addition to a double or triple bond characterizes these compounds:



(28.1)

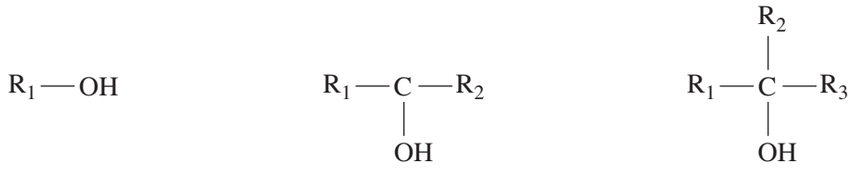
In general, alkenes and alkynes are much more reactive than alkanes are.

The reaction in Equation 28.1 is used to detect unsaturation. Bromine imparts a brownish color to a liquid. The disappearance of that color is a positive test for a multiple bond.

Unsaturated hydrocarbons can be oxidized by strong oxidizing agents, such as potassium permanganate, $KMnO_4$. Evidence of the reaction is the rapid disappearance of the purple color of the permanganate ion. Alcohols also react with $KMnO_4$.

Alcohols

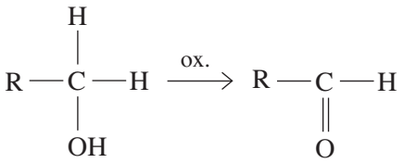
Alcohols contain carbon, hydrogen, and oxygen, with the common functional group, —OH. This is known as the **hydroxyl group.** Depending on where the hydroxyl group is attached in a molecule, the alcohol is classified as primary (1°), secondary (2°), or tertiary (3°). In a primary alcohol the —OH group is connected to a carbon that is joined to only one other carbon atom. In a secondary alcohol the carbon that has the —OH group is joined to two other carbons, and in a tertiary alcohol the carbon is bonded to three other carbons.



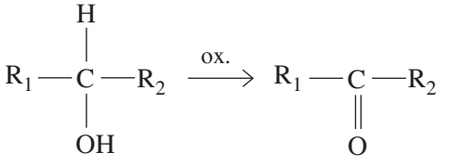
Primary *Secondary* *Tertiary*

In these diagrams, R_1, R_2, and R_3 represent alkyl groups. They may or may not be the same.

Alcohols are easily oxidized to either aldehydes or ketones:



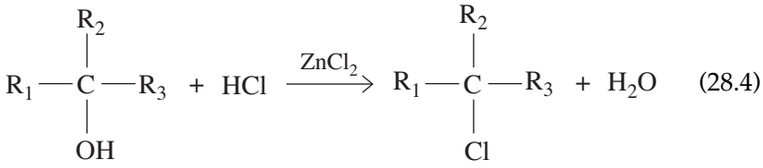
(an aldehyde) (28.2)



(a ketone) (28.3)

Tertiary alcohols resist oxidation, even by strong oxidizing agents.

By oxidation and subsequent testing of the oxidation product, an alcohol can be classified as primary, secondary, or tertiary. The Lucas test will be used in this experiment to classify alcohols. Tertiary alcohols are converted to alkyl halides very rapidly, secondary alcohols take a few minutes, while primary alcohols react very slowly, with no observable change in 10 minutes.



(Insoluble in water)

Liquids of similar polarity tend to be miscible. Alcohols have —OH groups, which impart polar characteristics and the ability to hydrogen bond with water. As a result, most lower molar mass alcohols are water soluble.

Alkanes and alkenes are nonpolar so they are soluble in nonpolar or weakly polar organic solvents. Water is a polar solvent and is not miscible with any hydrocarbon.

SAFETY PRECAUTIONS AND DISPOSAL METHODS

The organic chemicals you will use in this experiment are highly volatile and flammable. Do not breathe the vapors and be sure not to use them near flames. Bromine, Br_2, causes severe burns on contact with the skin. Handle this reagent very carefully and only in the fume hood. Avoid breathing the vapors, which are also very harmful. Be sure to wear eye protection while performing this experiment, and wash your hands when you are finished.

Dispose of the organic liquids in a special container provided or as directed by your instructor. *Do not pour organic liquids down the sinks in the open laboratory!*

PROCEDURE

1. Solubility of Alcohols and Hydrocarbons

Add 5 mL of water to five dry, labeled test tubes. Now pour 1 mL of each of the following liquids into separate test tubes and shake. Observe if the substance dissolves and record your observations on the work page.

Test tube No. 1: ethanol (CH_3CH_2OH)

Test tube No. 2: 2-propanol ($CH_3CHOHCH_3$)

Test tube No. 3: *t*-butanol ($(CH_3)_3COH$)

Test tube No. 4: cyclohexene (C_6H_{10})

Test tube No. 5: hexane (C_6H_{14})

2. Reactions of Alcohols and Hydrocarbons

A. Reaction with Br_2. Add 1 mL hexane (an alkane) and 1 mL cyclohexene (an alkene) to two separate, dry, labeled test tubes. Add 2 to 3 drops of bromine solution to each and shake. The disappearance of a brownish color is indicative of an alkene. Record your results on the work page.

B. Reaction with $KMnO_4$. Add 1 mL hexane and 1 mL cyclohexene to two separate, dry, labeled test tubes. Add 2 to 3 drops of $KMnO_4$ solution to each and shake. The disappearance of the purple color of $KMnO_4$ with the appearance of a brown precipitate (MnO_2) is a positive test for unsaturated hydrocarbons. Record your results on the work page.

C. Lucas test. Add 1 mL of ethanol, 1 mL 2-propanol, and 1 mL *t*-butyl alcohol to three separate, dry, labeled test tubes. Pour 3 mL of Lucas reagent into each, insert stopper, and shake to mix. Allow the solutions to stand at room temperature for up to 15 minutes. The appearance of cloudiness indicates a reaction. If no change is visible, immerse the test tube(s) into a water bath maintained at approximately 60°C, and observe whether any change occurs. Discontinue heating after 15 minutes. Record your observations on the work page.

3. Identification of an Unknown

A. Solubility. Obtain an unknown from your instructor and record the unknown number. Add 5 mL of water to a dry test tube. Pour 1 mL of the unknown into the test tube and shake. Observe if the substance dissolves and record your observations. If the unknown is insoluble, go to part B. If it is soluble, go to part C.

B. Reaction with Br_2 and $KMnO_4$. Add 1 mL of the unknown to two separate, dry, labeled test tubes. Add 2 to 3 drops of bromine solution to one test tube, and add 2 to 3 drops of $KMnO_4$ solution to the other test tube. Shake both test tubes and observe any color change.

C. Lucas test. Pour 1 mL of the unknown into a dry test tube and perform the Lucas test.

D. Identify the unknown as ethanol, 2-propanol, *t*-butanol, cyclohexene, or hexane.

Name _____ Date _____ Section _____

Experiment 28

Advance Study Assignment

1. Predict the solubility of the following compounds in the specified solvent by writing an M for miscible or NM for nonmiscible in the following table.

	$CH_3(CH_2)_4CH_3$ (**Hexane**) *Solvent*	H_2O (**Water**) *Solvent*
CH_3CH_2OH		
$CH_3CH_2CH_2CH_3$		
$CH_3CHOHCH_3$		

2. A. Write the equation for the reaction of cyclohexene with bromine.

B. Predict the color or appearance of a solution if two drops of bromine are added to cyclohexene.

3. Complete the table below using the information given in the Chemical Overview sections. In each blank space in the table write S (slow), F (fast), or NR (no reaction).

Lucas Test

Type of Alcohol	*Room Temp.*	*60°C*
1°		
2°		
3°		

Name _____ Date _____ Section _____

Experiment 28

Work Page

Part 1—Solubility of Alcohols and Hydrocarbons

Test Tube	*Substance*	*Solubility*
1		
2		
3		
4		
5		

Part 2—Reactions of Alcohols and Hydrocarbons

Step A—Reaction of Br_2 with Alkenes

Substance	*Yes*	*No*
Hexane		
Cyclohexene		

Step B—Reaction of $KMnO_4$ with Alkenes

Substance	*Yes*	*No*
Hexane		
Cyclohexene		

If the structure of acetylene is HC≡CH, would you predict that it gives a positive _____ or negative _____ test with $KMnO_4$?

Step C—Lucas Test

		Lucas Test		*Time (min)*	
Test Tube	*Substance*	*Yes*	*No*	*Room Temp.*	*60°C*
1					
2					
3					

Part 3—Identification of an Unknown

Unknown number _____

Step A—Solubility

Soluble in H_2O? Yes _____ No _____

If not soluble go to step B, if soluble go to step C.

Step B—Reactions of Alkenes

Reaction with Br_2? Yes _____ No _____

Reaction with $KMnO_4$? Yes _____ No _____

Step C—Lucas Test

Lucas test was positive at room temperature _____, or 60°C _____.

Identity of unknown _____

Name _____ Date _____ Section _____

Experiment 28

Report Sheet

Part 1—Solubility of Alcohols and Hydrocarbons

Test Tube	*Substance*	*Solubility*
1		
2		
3		
4		
5		

Part 2—Reactions of Alcohols and Hydrocarbons

Step A—Reaction of Br_2 with Alkenes

Substance	*Yes*	*No*
Hexane		
Cyclohexene		

Step B—Reaction of $KMnO_4$ with Alkenes

Substance	*Yes*	*No*
Hexane		
Cyclohexene		

If the structure of acetylene is HC≡CH, would you predict that it gives a positive _____ or negative _____ test with $KMnO_4$?

Step C—Lucas Test

		Lucas Test		*Time (min)*	
Test Tube	*Substance*	*Yes*	*No*	*Room Temp.*	*60°C*
1					
2					
3					

Part 3—Identification of an Unknown

Unknown number _____

Step A—Solubility

Soluble in H_2O? Yes _____ No _____

If not soluble go to step B, if soluble go to step C.

Step B—Reactions of Alkenes

Reaction with Br_2? Yes _____ No _____

Reaction with $KMnO_4$? Yes _____ No _____

Step C—Lucas Test

Lucas test was positive at room temperature _____, or 60°C _____.

Identity of unknown _____