Experiment 23
Alkanes, Alkenes, Alkynes and Aromatics

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Name:

Date:

Key Objectives

1. Structure of alkanes, alkenes and alkynes
2. Solubility properties in polar (water) and nonpolar (hexane) solvents
3. Diagnostic chemical reactions with bromine (Br_2), Potassium Permanganate ($KMnO_4$)
4. Combustion reactions
5. Write complete chemical reactions.

Discussion

A. Classes of Hydrocarbons

Hydrocarbons can be divided into several different classes or depending on the functional group present. The following four classes of compounds will be explored.

Alkanes

Are composed of hydrocarbons having only single bonds between carbon (C−C) atoms. They are often referred to as **saturated** hydrocarbons because the molecule contains the maximum number of hydrogen atoms attached to each carbon. They have a generic formula given by C_nH_{2n+2}. Alkanes generally react via a **substitution** mechanism where two molecules exchange atoms, as illustrated in Figure 23.1 where X = any halogen.

$$R{-}CH_2{-}H + X{-}X \longrightarrow R{-}CH_2{-}X + HX$$

swap

Figure 23.1: Alkanes react by a substitution mechanism. credit: author

One half of the added molecule generally displaces a hydrogen atom (located anywhere on the alkane chain) and the resulting hydrogen radical (from the alkane) reacts immediately with the remaining half of the molecule. More than one product can be produced in a substitution reactions, as a general rule in class only give the monosubstituted products. One product is generally more stable than the others and the swapped atom preferentially goes on the carbon with the least number of hydrogen. In substitution reactions we will list all possible products and circle the favored product.

Alkenes

Are composed of hydrocarbons containing at least one carbon-carbon double bond (C=C). They are unsaturated in that the have two less hydrogens then the corresponding Alkane. They have a generic formula given by C_nH_{2n}. The carbon-carbon double bond is a point of high reactivity, and most chemical reactions of Alkenes occur by the **addition** mechanism where the carbon-carbon double bond is broken and the reacting molecules are added to the Alkene. An example is in Figure 23.2.

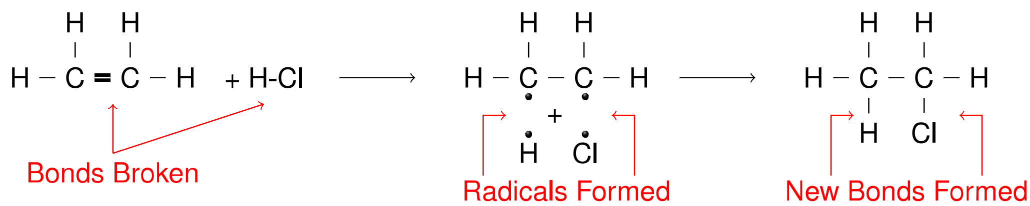

Figure 23.2: Alkenes react by an addition mechanism. credit: author

If the molecule being added to the alkene is unsymmetrical then more then one product can be produced.

Alkynes

Are composed of hydrocarbons containing at least one carbon-carbon triple (C≡C)bond. They are considered unsaturated and have a generic formula given by C_nH_{2n-2}. The carbon-carbon triple bond is a point of high reactivity and Alkynes tend to react in similar manner to Alkenes.

Aromatics

Are composed of hydrocarbons based on the benzene ring (C_6H_6) Benzene is composed of a 6-member ring containing alternating carbon-carbon double bonds as shown in Figure 23.3. From its formula benzene appears to be a highly unsaturated molecule, however, the benzene ring itself is unusually stable and it chemically reacts more like a saturated hydrocarbon in many respects and generally by **substitution** reactions.

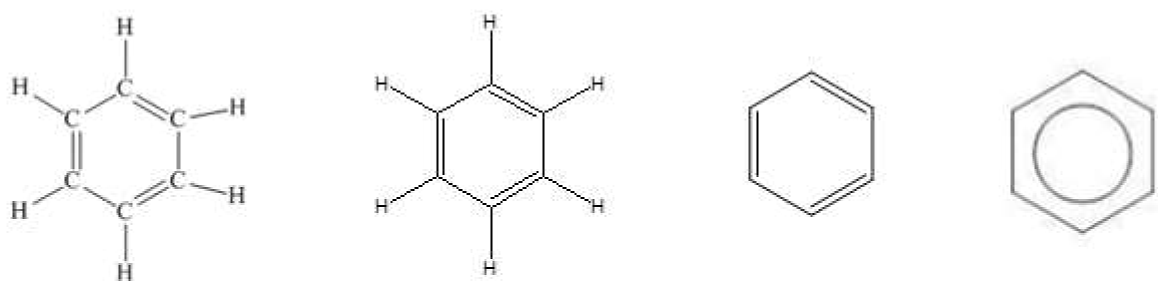

Figure 23.3: Benzene rings can be represented in a variety of different ways. All the pictures shown here are the same molecule. The picture on the right side is the most commonly used representation. credit: author

B. Physical Properties

Different functional groups result in different physical properties for organic compounds. Physical properties do not change the chemical structure of the compounds tested and are generally nondestructive. They include things like Boiling Points, Melting Points, Solubility, Color, Appearance, Texture, Odor, Density, Solubility and many others.

C. Chemical Properties

Chemical properties are those observed when a compound undergoes a chemical reaction. These can include flammability, chemical stability, toxicity and many others.

We will be examining how various hydrocarbons react with several standard reagents. Chemical properties are important from both a chemical reaction perspective and also how they function biologically.

Chemically we can differentiate between saturated hydrocarbons (alkanes) and unsaturated hydrocarbons (alkenes/alkynes) using several standard chemical tests. These tests are sometimes called **Diagnostic Tests** or **Identification Tests**. These tests generally incorporate a color change, formation of a precipitate or gas, or the rate at which a reaction occurs to indicate what type of compound is being tested. When performing tests there are several things to consider when interpreting your results.

Term	Definition
Control	A compound which is known to provide a positive or negative result to determine if the test is working correctly.
Positive Result	Indicates that a specific functional group is present.
Negative Result	Indicates that a specific functional group is **NOT** present.
False Positive	A compound which provides a positive result but should not. (ie it should test negative)
False Negative	A compound which provides a negative result but should not (ie it should test positive).

Combustion

Combustion is not considered a diagnostic test because most substances will burn if enough heat is applied. However, how easily something combusts, the color of the flame, whether complete or incomplete combustion occurs can give some insight into a compounds structure.

When a compound burns in the presence of oxygen the reaction is called a combustion. Like most organic substances, hydrocarbons are combustible. The general reaction is given below.

$$\_\_\_\mathrm{C, H, O} + \_\_\_\mathrm{O_2(g)} \longrightarrow \_\_\_\mathrm{CO_2(g)} + \_\_\_\mathrm{H_2O(g)} + \mathrm{Heat/Energy} \qquad (1)$$

Complete combustion occurs when there is enough oxygen to fully convert all the carbon atoms in the organic compound to carbon dioxide and the hydrogen atoms to water. Incomplete combustion occurs when there is insufficient oxygen to react with carbon, resulting in some carbon atoms not reacting and forming a black residue.

We will explore the solubility of hydrocarbons in water and with respect to each other in a future lab.

Reaction with Bromine

Each hydrocarbon will be reacted with a bromine solution. Bromine reacts with carbon-carbon double and triple bonds by **addition** across the double bond. Disappearance of the characteristic bromine color (reddish/orange) within 10 seconds indicates that it has reacted with a double or triple bond of a hydrocarbon.

$$\underset{\text{Colorless}}{\mathrm{CH_3{-}CH{=}CH{-}CH_3}} + \underset{\text{Red/Orange}}{\mathrm{Br_2}} \xrightarrow[\text{Fast}]{} \underset{\text{Colorless}}{\mathrm{CH_3{-}CHBr{-}CHBr{-}CH_3}} \tag{2}$$

Bromine will react with carbon-carbon single bonds in alkanes by replacing a H with Br by **substitution**, however, the reaction is generally slow and requires UV light to act as a catalyst.

$$\underset{\text{Colorless}}{\mathrm{CH_3CH_3}} + \underset{\text{Red/Orange}}{\mathrm{Br_2}} \xrightarrow[\text{Slow}]{\text{Light}} \underset{\text{Colorless}}{\mathrm{CH_3CH_2Br}} + \underset{\text{PungentOdor}}{\mathrm{HBr}} \tag{3}$$

Bromine does not react with benzene (aromatic rings) due to the stable resonance structure, but can react with functional groups attached to it.

$$\text{Benzene } + \mathrm{Br_2} \longrightarrow \text{ No Reaction} \tag{4}$$

Potassium Permanganate

Each hydrocarbon will also be reacted with potassium permanganate, a strong **oxidizing** agent. This test is commonly known as the **Baeyer** test for unsaturation. The carbon-carbon double and triple bonds are oxidized to form alcohols with both sides of the carbon-carbon double bond gaining an -OH group (sometimes referred to as diols) More information on the reaction is in Hein Chapter 22. Evidence that the reaction has occurred is the rapid disappearance (within a few seconds) of the purple permanganate color. The resulting reaction products will generally be colored, typically a brown solid, but varies with reaction conditions.

$$\underset{\text{Colorless}}{\text{Alkene/Alkyne}} + \underset{\text{Purple}}{\mathrm{KMnO_4}} \longrightarrow \text{Diol} + \mathrm{KOH} + \underset{\text{Coloredppt}}{\mathrm{MnO_2(s)}} \tag{5}$$

$$\text{Example :} \qquad \mathrm{CH_3{-}CH{=}CH{-}CH_3 + KMnO_4 \longrightarrow CH_3{-}CHOH{-}CHOH{-}CH_3 + KOH + MnO_2(s)}$$

$$\underset{\text{Colorless}}{\text{Alkane/Aromatic}} + \underset{\text{Purple}}{\mathrm{KMnO_4}} \longrightarrow \text{NR} \tag{6}$$

Procedure

A. Combustion

1. Perform the following test in the hood (be sure the hood is turned on).
2. Remember hot things are hot.
3. Place about 1 mL of the substance to be tested in an evaporating dish.
4. Ignite the liquid using a bunsen burner
5. Record your observations noting the characteristics (color, amount of smoke) of each flame along with any evidence of residue left behind in the evaporating dish.
6. Repeat for each of the substance to be tested.

B. Reaction with Bromine

1. Be especially careful with the bromine solution and if spilled notify your instructor immediately and wash your hands.
2. In a clean test tube place 1 mL of the solution to be tested.
3. To the solution add 3 drops of the 1% bromine solution in dichloromethane.
4. Swirl the tubes gently to mix them.
5. Note any results after 2 minutes. Record any color changes.
6. Any test tube that still shows the bromine color after 2 minutes, should be exposed to the ultraviolet light for an additional 5-10 minutes. Note any changes. Record any color changes.
7. Dispose of the contents of the test tubes in the waste bottle labeled "E21 Waste".

C. Reaction with Potassium Permanganate

1. In a clean test tube place 1 mL of the solution to be tested.
2. To the solution add 5 drops of the potassium permanganate solution.
3. Swirl the tubes gently to mix them.
4. Note any results after 1 minute. Record any color changes.
5. Dispose of the contents of the test tubes in the waste bottle labeled "E21 Waste".

D. Identity of an Unknown Hydrocarbon

1. You must complete the tests with bromine and potassium permanganate (parts B and C) above before doing an unknown.

2. Determine which class of hydrocarbons (alkane, alkene, or alkyne) that your unknown belongs to by reacting it with both bromine and potassium permanganate as described in the last two sections.

E. Acetylene

1. Reference Figure 23.4 for the experimental setup.

2. Fill a 1000 mL beaker 75% full with tap water.

3. Fill 4 large test tubes (25 $\times$ 200 mm) with water as follows: Tube (1) completely full, Tube (2) 75% full, Tube (3) 50% full, and Tube (4) 25% full.

4. Obtain 4 corks to seal each test tube with.

5. Obtain a small lump of calcium carbide from the reagent bottle. Drop it in the beaker of water as shown in the Figure.

6. Using your finger or tongs to hold the cork in, invert the test tube and lower it into the beaker of water.

7. Remove the cork (using the tongs).

8. Hold the test tube over the bubbling acetylene gas to collect the gas.

9. When the test tube is full of gas, remove it from the water and quickly stopper it.

10. Repeat the above procedure until all 4 test tubes are filled.

11. Test the contents of the tube for combustibility.

12. Wrap each test tube in paper towels.

13. Bring the mouth of the test tube to a Bunsen burner, as you remove the stopper.

14. After the acetylene ignites, tilt the mouth of the tube up and down several times.

15. Record your observations.

16. Dispose of the solution in the beaker in the sink.

Figure 23.4: Experimental setup for collecting acetylene gas. credit: http://fon10.weebly.com/uploads/1/3/4/7/13472506/2_5_activity_ethynecombustion.pdf

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Name: ________________________________ Date: ____________________ Score: _____/80

Results

A. Combustion

	Compound	Observations	Complete Chemical Reaction
[4 pt]	Heptane		$\_\_\_C_7H_{16}(l) + \_\_\_O_2(g) \longrightarrow$
[4 pt]	1-Hexene		$\_\_\_C_6H_{12}(l) + \_\_\_O_2(g) \longrightarrow$
[4 pt]	Toluene		$\_\_\_C_7H_8(l) + \_\_\_O_2(g) \longrightarrow$

Table 23.1: Results - Combustion

[3 pt] 1. Which compounds showed complete combustion, incomplete combustion? Explain.

Complete Combustion:

Incomplete Combustion:

[3 pt] 2. What is the chemical identity of the residue left behind after some combustions. What evidence do you have to support your conclusion? Explain.

B,C,D. Reaction with Bromine and Potassium Permanganate and Unknown

If "No Reaction" occurs write "NR" in the box.

	Compound	**Part B.** Br_2 (< 2 min)	**Part B.** Br_2 (5-10 min + UV light)	**Part C.** $KMnO_4$ - Initial	**Part C.** $KMnO_4$ - after mixing
[3 pt]	Heptane				
[3 pt]	1- Hexene				
[3 pt]	Toluene				
[3 pt]	Unknown ID: ______				

Table 23.2: Results - Reaction with Bromine and Potassium Permanganate and Unknown

[4 pt] 3. Based on your observations of the Bromine test. Which compounds reacted slow? Which reacted fast? Did the results match the expected results? Explain.

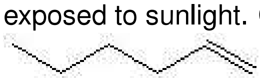
Slow:

Fast:

[3 pt] 4. Write a complete chemical reaction showing how heptane reacts with Br_2 after the reaction is exposed to sunlight. Circle the favored product.

 $+ Br_2 \longrightarrow$

[3 pt] 5. Write a complete chemical reaction showing how 1-hexene reacts with Br_2 after the reaction is exposed to sunlight. Circle the favored product.

 $+ Br_2 \longrightarrow$

[3 pt] 6. Based on chemical tests performed, to which class of hydrocarbons (Saturated or Unsaturated) does your unknown belong? Explain.

[3 pt] 7. Would you expect acetylene (ethyne) to react with bromine with or without exposure to light? Explain.

E. Acetylene (Ethyne)

Mixture	Observations
Tube 1	
Tube 2	
Tube 3	
Tube 4	

Table 23.3: Results - Acetylene

[2 pt] 8. What is required to be present in order for combustion to occur? Explain.

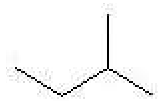
[2 pt] 9. What is being varied between each test tube/trial? Explain.

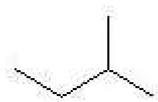
[2 pt] 10. Why did the tubes behave differently even though the chemicals reacted were the same? Explain.

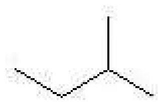
[2 pt] 11. Which tube best illustrates complete combustion? Explain.

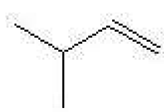
[4 pt] 12. Write a complete (balanced and including states) chemical equation for the complete combustion of acetylene (ethyne).

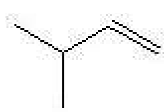
[15 pt] 13. Complete the following reaction. If multiple products exist circle the favored product.

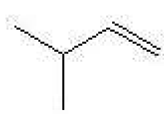
1.  $+ Br_2 \longrightarrow$

2.  $+ KMnO_4 \longrightarrow$

3.  $+ O_2 \longrightarrow$

4.  $+ Br_2 \longrightarrow$

5.  $+ KMnO_4 \longrightarrow$

6.  $+ O_2 \longrightarrow$

Name: ______________________________ Date: ________________ Score: _____/20

Prelab Questions

[4 pt] 1. What is meant by the terms complete combustion and incomplete combustion.

[4 pt] 2. What functional group does each reaction test for **AND** what is the visible evidence of a positive result.

Bromine Test:

Potassium Permanganate Test:

[12 pt] 3. Complete the table below listing all of the chemical compounds used in lab. For organic compounds use line drawing, and inorganic compounds simply write the chemical formula.

Name	**Structure**	**Name**	**Structure**
Bromine		Potassium Permanganate	
Benzene		Heptane	
1-hexene		Acetylene (Ethyne)	
dichloromethane		Toluene	
2,3-dibromobutane		2-bromobutane	

Hello!