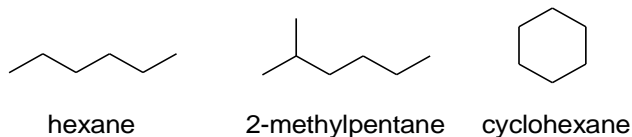

Experiment 12 – Identification of Hydrocarbons

Discussion

The number of known organic compounds totals into the millions. Of these compounds, the simplest types are those that contain only hydrogen and carbon atoms. These are known as *hydrocarbons*. Because of the number and variety of hydrocarbons that can exist, some means of classification is necessary.

One means of classification depends on the way in which carbon atoms are connected. *Chain* aliphatic hydrocarbons are compounds consisting of carbons linked either in a single chain or in a branched chain. *Cyclic* hydrocarbons are aliphatic compounds that have carbon atoms linked in a closed polygon (also referred to as a *ring*). For example, hexane (single) and 2-methylpentane (branched) are chain aliphatic molecules, while cyclohexane is a cyclic aliphatic compound.

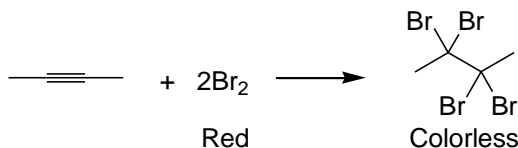
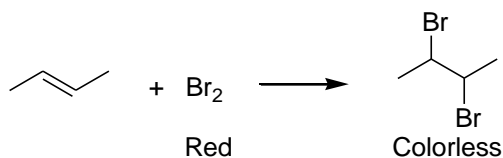


Another means of classification depends on the type of bonding that exists between carbons. Hydrocarbons that contain only carbon-to-carbon single bonds are called *alkanes*. These are also referred to as *saturated* molecules. Hydrocarbons containing at least one carbon-to-carbon double bond are called *alkenes*, and compounds with at least one carbon-to-carbon triple bond are called *alkynes*. Alkenes and alkynes are referred to as *unsaturated* molecules. Finally, a class of cyclic hydrocarbons that contain a closed loop (sextet) of electrons is called *aromatic*. With so many compounds possible, identification of the bond type is an important step in establishing the molecular structure. Quick, simple tests on small samples can establish the physical and chemical properties of the compounds by class.

Some of the observed physical properties of hydrocarbons result from the nonpolar character of the compounds. In general, hydrocarbons do not mix with polar solvents such as water or ethanol (ethyl alcohol). On the other hand, hydrocarbons mix with relatively nonpolar solvents such as ligroin (a mixture of alkanes), carbon tetrachloride (CCl₄), or dichloromethane (CH₂Cl₂). Because the density of most hydrocarbons is less than that of water, they will float. Crude oil and crude oil products (home heating oil and gasoline) are mixtures of hydrocarbons; when spilled on water, these substances spread quickly along the surface because they are insoluble in water.

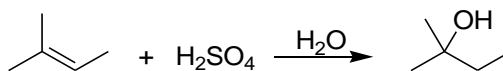
The chemical reactivity of hydrocarbons is determined by the type of bond in the compound. Unsaturated hydrocarbons (i.e., alkenes and alkynes) react by *addition* of reagents to the double or triple bonds. The addition products become saturated, with fragments of the reagent becoming attached the carbons of the multiple bond. Aromatic compounds, with a higher carbon-to-hydrogen ratio than nonaromatic compounds, undergo *substitution* in the presence of catalysts rather than an addition reaction.

1. *Reaction with bromine.* Unsaturated hydrocarbons react rapidly with bromine in a solution of carbon tetrachloride or cyclohexane. The reaction is the addition of the elements of bromine to the carbons of the multiple bonds.



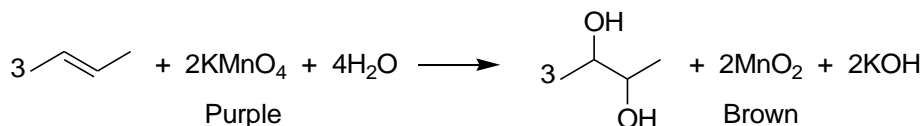
The bromine solution is red; the product that has the bromine atoms attached to carbon is colorless. Thus, a reaction has taken place when there is a loss of color from the bromine solution and a colorless solution remains. Because alkanes have only single C–C bonds present, no reaction with bromine is observed; the red color of the reagent would persist when added. Aromatic compounds resist addition reactions because of their “aromaticity”: *the possession of a closed loop (sextet) of electrons which imparts extreme stability.* These compounds can react with bromine but require the presence of a catalyst such as iron fillings or aluminum chloride.

2. *Reaction with concentrated sulfuric acid.* Alkenes react with cold concentrated sulfuric acid by addition. Alkyl sulfonic acids form as products and are soluble in H₂SO₄; subsequent water work-up results in an “–OH” on the more substituted carbon (as demonstrated in lecture).



Saturated hydrocarbons are unreactive (additions are not possible); alkynes react slowly and require a catalyst (H₂SO₄); due to their inherent stability, aromatic compounds are also unreactive.

3. *Reaction with potassium permanganate.* Dilute or alkaline solutions of KMnO₄ oxidize unsaturated compounds. Alkanes and aromatic compounds are generally unreactive. Evidence that a reaction has occurred is observed by the loss of the purple color of KMnO₄ and the formation of the brown precipitate manganese dioxide, MnO₂.



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Note that the product formed (which contains two “-OH” groups) is called a glycol.

Procedure

Assume the organic compounds are highly flammable. Use only small quantities. Keep away from open flames. Assume the organic compounds are toxic and can be absorbed through the skin. Avoid contact; wash if any chemical spills on your person. Handle concentrated sulfuric acid carefully. Flush with water if any spills on your person. Potassium permanganate and bromine are toxic; bromine solutions are also corrosive. Although the solutions are diluted, they may cause burns to the skin. Wear gloves when working with these chemicals. Also consider the following:

1. The hydrocarbons hexane, cyclohexene, and toluene (alkane, alkene and aromatic, respectively) are available in dropper bottles.
2. The reagents 1% Br₂ in cyclohexane, 1% aqueous KMnO₄, and concentrated H₂SO₄ are available in dropper bottles.
3. Unknowns are in dropper bottles labeled A, B, and C. They may include an alkane, an alkene, and/or an aromatic compound.
4. Test tubes will be suitable for all the tests; mix thoroughly.
5. Dispose of all organic wastes as directed by the instructor. *Do not pour them into the sink!*

Physical Properties of Hydrocarbons

1. *Water solubility of hydrocarbons.* Label six test tubes with the name of the substance to be tested. Place into each test tube 5 drops of the appropriate hydrocarbon: hexane, cyclohexene, toluene, unknown A, unknown B, and unknown C. Add about 5 drops of water dropwise into each test tube. Water is a polar solvent. Is there any separation of components? Which component is on the bottom; which component is on the top? Mix the contents. What happens when the contents are allowed to settle? What do you conclude about the density of the hydrocarbon? Is the hydrocarbon *more* dense than water or *less* dense than water? Record your observations. Save these solutions for comparison with the next part.
2. *Solubility of hydrocarbons in ligroin.* Label six test tubes with the name of the substance to be tested. Place into each test tube 5 drops of the appropriate hydrocarbons: hexane, cyclohexene, toluene, unknown A, unknown B, and unknown C. Add about 5 drops of ligroin dropwise into each test tube. Ligroin is a nonpolar solvent. Is there a separation of components? Is there a bottom layer and a top layer? Mix the contents. Is there any change in the appearance of the contents before and after mixing? Compare these test tubes with those from the previous part. Record your observations. Can you make any conclusion about the density of the hydrocarbons from what you actually see?

Chemical Properties of Hydrocarbons

1. *Reaction with bromine.* Results provided on data sheet.
2. *Reaction with $KMnO_4$.* Label six clean, dry test tubes with the name of the substance to be tested. Place into each test tube 5 drops of the appropriate hydrocarbon: hexane, cyclohexene, toluene, unknown A, unknown B, and unknown C. Carefully add (dropwise) 1% aqueous $KMnO_4$ solution; after each drop, shake to mix the solutions. Keep count of the number of the drops needed to have the color of the permanganate solution persist; do not add more than 10 drops. Record your observations.
3. *Reaction with concentrated H_2SO_4 .* Label six clean, dry test tubes with the name of the substance to be tested. Place into each test tube 5 drops of the appropriate hydrocarbon: hexane, cyclohexene, toluene, unknown A, unknown B, and unknown C. Place all of the test tubes in an ice bath. Wear gloves and carefully add (with shaking) 3 drops of cold, concentrated sulfuric acid to each test tube. Note whether the solution has become homogeneous or whether a color is produced. (The evolution of heat, the formation of a homogeneous solution, or the appearance of a color is evidence that a reaction has occurred.) Record your observations.
4. *Unknowns:* By comparing the observations you made for your unknowns with that of the known hydrocarbons, you can identify unknowns A, B, and C. Record their identities on your data sheet.

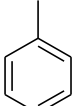
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Data and Calculations for Experiment 12**Physical Properties of Hydrocarbons**

Solubility: Does the hydrocarbon mix with the solvent, *soluble*, or not mix with solvent, *insoluble*? Use the observations you make for the solubility tests and determine whether the hydrocarbons are polar or nonpolar substances.

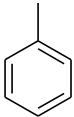
Density: For water, is the density *greater* than water (sinks) or *less* than water (floats)? For ligroin, can you tell anything about the relative densities?

| <i>Hydrocarbon</i> | H₂O | | Ligroin | |
|---|-----------------------|----------------|-------------------|----------------|
| | <i>Solubility</i> | <i>Density</i> | <i>Solubility</i> | <i>Density</i> |
| Hexane | | | | |
| Cyclohexene | | | | |
| Toluene,  | | | | |
| Unknown A | | | | |
| Unknown B | | | | |
| Unknown C | | | | |

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Chemical Properties of Hydrocarbons

| <i>Hydrocarbon</i> | <i>Bromine Test*</i> | <i>KMnO₄ Test</i> | <i>H₂SO₄ Test</i> |
|---|----------------------|------------------------------|---|
| Hexane | Red | | |
| Cyclohexene | Colorless | | |
| Toluene,  | Red | | |
| Unknown A | Red | | |
| Unknown B | Colorless | | |
| Unknown C | Red | | |

**The results of the bromine test have been provided for you.*

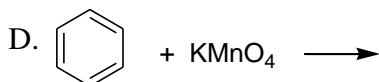
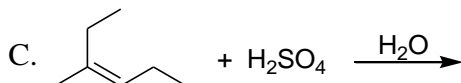
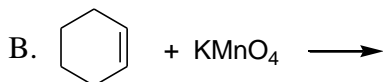
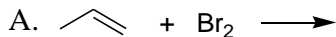
Unknown A is _____.

Unknown B is _____.

Unknown C is _____.

Questions

1. Below are four organic compounds. The reagent shown is added to the compound. Based on your studies in this lab, determine the products (if any) that you should observe when the reactants below are mixed together:

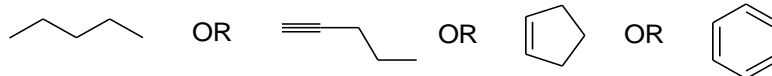


2. A student has two compounds in two separate bottles but with no labels on either one. One is an alkane, octane (C₈H₁₈); the other is 1-hexene (C₆H₁₂), an alkene. Based on your observations in this experiment, what should you see in the following tests?

Octane

1-Hexene

- A. Water solubility
- B. Ligroin solubility
- C. Density versus water
- D. Bromine test
- E. Permanganate test
3. An unknown compound, believed to be a hydrocarbon, showed the following behavior: no heat or color appeared when sulfuric acid was added; permanganate solution remained purple; and the red color of bromine solution was lost only after a catalyst was added. From the compounds below, circle the ONE that fits the observations.



4. In your own words, write a one-half page, well-written abstract of the entire experiment, making sure to briefly state the overall purpose or goal as well as any conclusions. (For additional guidelines on writing this abstract, please refer to the **Moorpark College Chemistry Department Laboratory Report Rubric** found in the lab manual and department website.)