Reactions of Hydrocarbons

Objectives

- Investigate reactivity of hydrocarbons
- Distinguish saturated, unsaturated, and aromatic hydrocarbons

Background

Properties of Hydrocarbons

Hydrocarbons are a class of organic compounds containing only carbon and hydrogen. Hydrocarbons make up the bulk of fossil fuels, which are burned for energy. Hydrocarbons are generally flammable and therefore should not be handled near open flames. Hydrocarbons are also non-polar compounds and therefore should not mix readily with water.

Saturation

Hydrocarbons exist in two overall classes, saturated and unsaturated, as shown in Figure 1. In saturated hydrocarbons, all carbons in the compound contain four different bonds. Unsaturated hydrocarbons have at least two carbons with double or triple bonds. Saturated hydrocarbons are called alkanes while unsaturated hydrocarbons have different names depending on the type of multiple bond present. Hydrocarbons based around a double bond are called alkenes, and hydrocarbons with a triple bond are called alkynes.

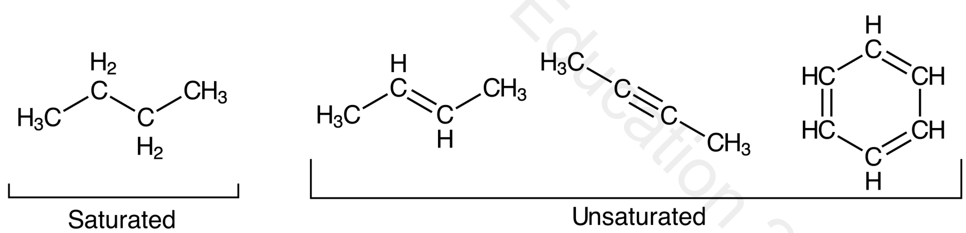


Figure 1 Examples of saturated and unsaturated hydrocarbons

In general, alkanes are relatively unreactive as there are few substitution reactions occur with them. However, alkenes and alkynes are much more reactive as a pi bond can more easily be broken to add new bonds to the carbons. New bonds added to both carbons that were in the double or triple bond are considered addition reactions.

Aromaticity

There is another type of unsaturated hydrocarbon that behaves differently than alkenes or alkynes. Aromatics are rings that have alternating double bonds stabilized due to resonance, which delocalizes the electrons in the pi bonds around the ring. As you look at the simplest aromatic, benzene, in Figure 2, note that the double bonds have resonant positions at the other carbon-carbon bonds, spreading the electron density from the double bonds around the whole ring as often represented by the circle. The representations in Figure 2 are interchangeable. The resonance of double bonds in aromatics prevents them from undergoing simple addition reactions like alkenes. Instead, aromatics are more likely to undergo substitution reactions.

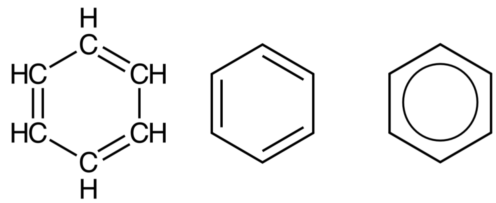


Figure 2 Different representations of the aromatic compound benzene

Sources of Hydrocarbons

Most hydrocarbons are obtained from fossil fuels, oils, or other natural sources. For example, long chain alkanes in oil are often broken up into smaller hydrocarbons, usually other alkanes or alkenes. Although alkynes can also be retrieved from natural sources, they are also often prepared synthetically. In this experiment, ethyne, commonly known as acetylene, will be made from calcium carbide (CaC_2).

Acetylene, the simplest alkyne, is used as a fuel for welding and cutting metals and therefore is still commonly used today. Calcium carbide was used as a fuel source for lamps by way of a chemical reaction with water; the reaction gave off acetylene that was then burned in the lamp.

Qualitative Tests of Hydrocarbons

Functional groups with different reactivity, like the different classes of hydrocarbons, can be distinguished by qualitative tests. In general, qualitative tests have some apparent visual change indicating when a reaction has occurred. To best understand qualitative tests, it is important to identify positive and negative results by testing with known compounds. Control tests ensure that the reagents are working properly and that you know what the different results look like.

Bromine Test for Unsaturation

The addition of bromine is a common test for unsaturated hydrocarbons. For alkenes and alkynes, the reaction appears as an addition across the double or triple bond, creating a new bond to bromine on each carbon, as seen in Figure 3. When bromine is added to a sample with an alkene or alkyne, the prominent orangish-brown color of the bromine disappears. Make sure not to add too much bromine or the positive test with not be easily discernible.

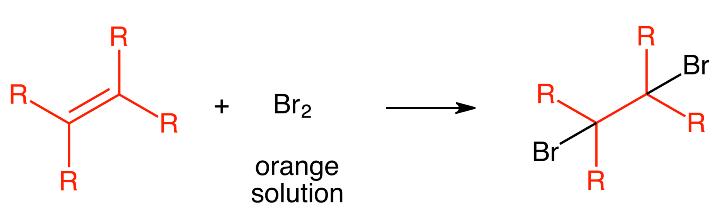


Figure 3 Reaction observed in a positive bromine test with an alkene

Bromine can also react with aromatic compounds, but the reaction follows a different pathway. Instead of both bromine atoms attaching on either side of the multiple bond, only one bromine attaches, as the substitution reaction shown in Figure 4. The other bromine is left in solution with the hydrogen removed from the ring. The test has the same general appearance as the alkene or alkyne; if the bromine reacts, the orangish-brown color of the bromine disappears.

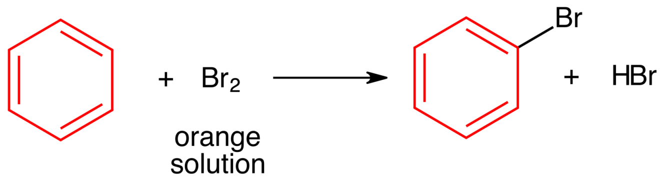


Figure 4 Reaction observed in a positive bromine test with an aromatic compound

Potassium Permanganate Test for Alkenes and Alkynes

Adding potassium permanganate, $KMnO_4$, to a sample can also indicate the presence of alkenes and alkynes. Potassium permanganate is a purple solution. When it is added to an alkene or alkyne, hydroxyl groups are added across the multiple bond, leaving behind the insoluble brown MnO_2, as shown in Figure 5. Therefore, a positive potassium permanganate test, also known as the Baeyer's test, corresponds to the decrease in the purple solution and the appearance of the brown solid. Note that alkanes and aromatics can also react, following a different substitution pathway, but are much slower.

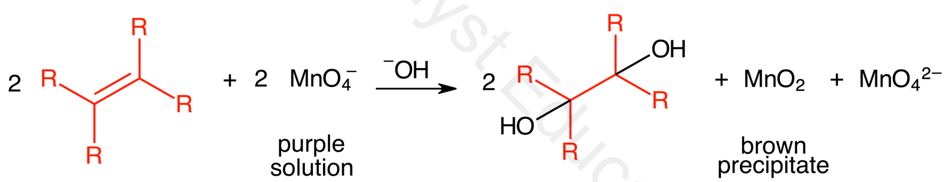


Figure 5 Reaction observed in a positive permanganate test with an alkene

Materials

- Alkane example
- Alkene example
- Aromatic example
- Unknown hydrocarbon
- Red food coloring
- Bromine
- $KMnO_4$ solution
- Calcium carbide
- Test tubes
- Small beaker
- Watch glass

Safety goggles are required!

All work should be performed in the fume hood.

Hydrocarbons are flammable and should be handled with care and disposed of properly.

Bromine can cause serious burns if contact with the skin is made. Sodium thiosulfate is provided to neutralize any spill or if skin contact is made.

Procedure

Qualitative Tests of Hydrocarbons

Solubility Tests

1. Write the identification code for your unknown on the space provided on the data sheet.
2. Place 20 drops (about 1 mL) of the alkane in a small test tube and add 20 drops of deionized water to it. Shake the contents of the tube well to see if they mix. It may be hard to see the two layers so look carefully. Remember to record your observations on the data sheet.
3. Dump the contents of the tube in the non-halogenated waste container and wash the test tube.
4. Add red food coloring to about 5 mL of water in a small beaker.
5. Place 20 drops of each known hydrocarbon (alkane, alkene, and aromatic) in separate small test tubes and add 1 mL of the colored water to it. Shake the contents of the tube well and then determine which layer is on top.
6. Dump the contents of each tube in the non-halogenated waste container and wash the test tubes.
7. Add 20 drops of the alkane to a clean dry test tube and add 20 drops of alkene to the same tube. Shake well and record your observations about whether they mix on the data sheet.
8. Dump the contents of the tube in the non-halogenated waste container and wash the test tube.
9. Add 20 drops of the alkane to a clean dry test tube and add 20 drops of aromatic to the same tube. Shake well and record your observations about whether they mix on the data sheet.

10. Dump the contents of the tube in the non-halogenated waste container and wash the test tube.
11. Repeat the tests on your unknown by mixing it with the colored water in one test tube and mixing it with the alkane in another test tube. Record your observations.

Bromine Test for Unsaturation

1. Place 20 drops of each listed hydrocarbon into separate clean, dry test tubes: alkane, alkene, aromatic, and unknown.
2. Add bromine dropwise to each tube, shaking between drops. Record your observations of the color behavior on your data sheet.
3. Dispose of the content of the tubes in the **halogenated waste** container. Wash the test tubes with soap and water.

Potassium Permanganate Test for Alkenes and Alkynes

1. Add 20 drops of water to a test tube labeled $KMnO_4$ solution and add 1 drop of potassium permanganate. Set it aside for comparison with the test solutions.
2. Place 20 drops of each listed hydrocarbon in separate clean small *labeled* test tubes: alkane, alkene, aromatic, and unknown.
3. Add 1 drop of $KMnO_4$ to each test tube and shake well. They will not mix into solution as the permanganate solution is in water.
4. Let the tubes set for 2 to 3 minutes for the reaction to occur. Record your observations on the data sheet, comparing them to the aqueous potassium permanganate solution that you prepared.
5. Take all of the tubes from this test and put the solutions in the non-halogenated waste container. Wash the test tubes with soap and water, then dry them.

Preparation of Ethyne

1. Take a spatula tip of calcium carbide and place it on a watch glass.
2. Add 1 drop of deionized water on top of the calcium carbide. Observe and record the results.
3. Once the reaction has stopped, add another drop of water to ensure that the reaction is complete.
4. Put the solid in the trash, and wash the spatula and watch glass with soap and water.

Pre-Lab Questions

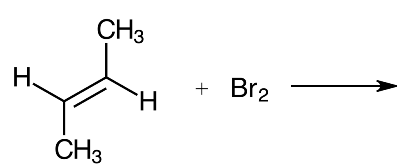
Prepare for lab by completing and understanding the answers to these questions. Refer to the Background or another resource, such as your textbook, if necessary.

1. What is the main safety concern about hydrocarbons?

2. Why should bromine be handled with care?

3. Where should all reactions for this lab take place?

4. Draw the product for the reaction of the given hydrocarbon and bromine.



5. What visual observation would you expect if you ran the reaction of the above hydrocarbon with bromine?

Lab 3: Reactions of Hydrocarbons Report Sheet

Name ____________________ Section ____________________

Date ____________________ Instructor ____________________

Qualitative Tests of Hydrocarbons

UNKNOWN CODE: _________________________

Solubility Tests

Compound	Water solubility	Top or bottom layer?	More or less dense than water?
alkane			
alkene			
aromatic			
unknown			

What was observed when mixing the alkanes, alkenes, and aromatics?

Bromine Test for Unsaturation

Compound	Observations and conclusions
alkane	
alkene	
aromatic	
unknown	

Potassium Permanganate Test for Alkenes and Alkynes

Compound	Observations and conclusions
alkane	____________________
alkene	____________________
aromatic	____________________
unknown	____________________

CLASS OF UNKNOWN COMPOUND: ______________________

Preparation of Ethyne

What did you observe that suggested a reaction with the formation of ethyne?

What is the common name for ethyne?

Draw the structure of ethyne.

Post-lab Questions

1. Are hydrocarbons soluble or insoluble in water? Include a brief explanation.

2. Which hydrocarbon group is the least reactive? Why?

3. Write the balanced equation for calcium carbide (CaC_2) reacting with water to give off ethyne when reacted with water. Make sure to include both products of the reaction.

4. How many grams of ethyne (molar mass=26.0 g/mol) would be given off if the limiting reagent in the reaction is calcium carbide (molar mass=64.1 g/mol) and you start with 2.00 g of it?