Background

Structures of Alcohols and Phenol

Specific groups of atoms in an organic molecule can determine that molecule's physical and chemical properties. These groups are referred to as functional groups. You may have already learned about several different functional groups for hydrocarbons: alkanes, alkenes, alkynes and arenes. Organic compounds which contain the functional group –OH, the hydroxyl group, are called alcohols.

Alcohols are important commercially and include uses as solvents, drugs, and disinfectants. The most widely used alcohols are methanol or methyl alcohol, CH_3OH, ethanol or ethyl alcohol, CH_3CH_2OH, and 2–propanol or isopropyl alcohol or isopropanol, $(CH_3)_2CHOH$ (see structures below). Methyl alcohol is found in automotive products such as antifreeze and "dry gas." Ethyl alcohol is used as a solvent for drugs and chemicals, but is more popularly known for its effects as an alcoholic beverage. Isopropyl alcohol, also known as "rubbing alcohol," is an antiseptic.

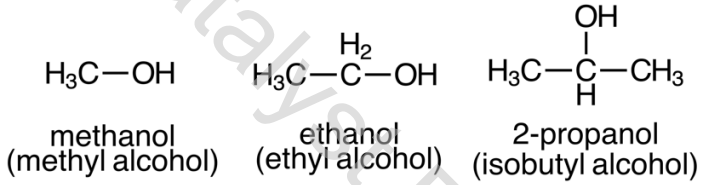


Figure 1 Structures of Alcohols

The classification of alcohols depends on the number of carbon-containing groups, R (alkyl or aromatic), attached to the carbon bearing the hydroxyl group. Note that ethanol is a primary alcohol, the carbon atom attached to the —OH group is bonded to one other carbon atom and 2-propanol is a secondary alcohol, the carbon atom attached to the —OH group is bonded to two other carbon atoms. In a tertiary alcohol, the carbon atom attached to the —OH group is bonded to three carbon atoms.

Phenols bear a close resemblance to alcohols structurally since the hydroxyl group is present. However, since the hydroxyl group is bonded directly to a carbon that is part of an aromatic ring, the chemistry is quite different from that of alcohols. Phenols are more acidic than alcohols; concentrated solutions of the compound phenol are quite toxic and can cause severe skin burns. Phenol derivatives are found in medicines; for example, thymol is used to kill fungi and hookworms.

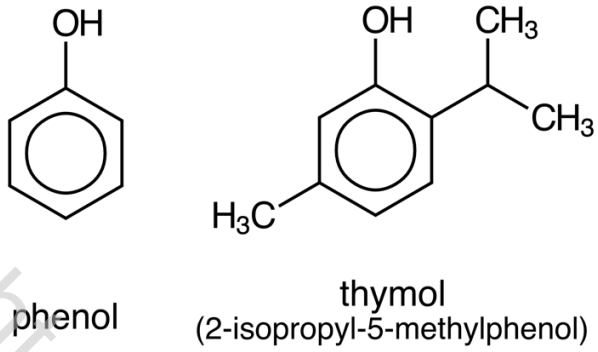


Figure 2 Structure of Phenols

Properties of Alcohols and Phenols

Physical Properties

Since the hydroxyl group is present in alcohols and phenols, these compounds are polar. The polarity of the hydroxyl group, coupled with its ability to form hydrogen bonds, enables many alcohols and phenols to mix with water. Since these compounds also contain nonpolar portions, they show additional solubility in many organic solvents, such as dichloromethane and diethyl ether.

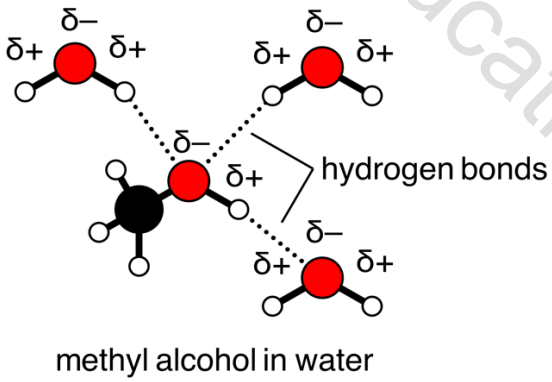


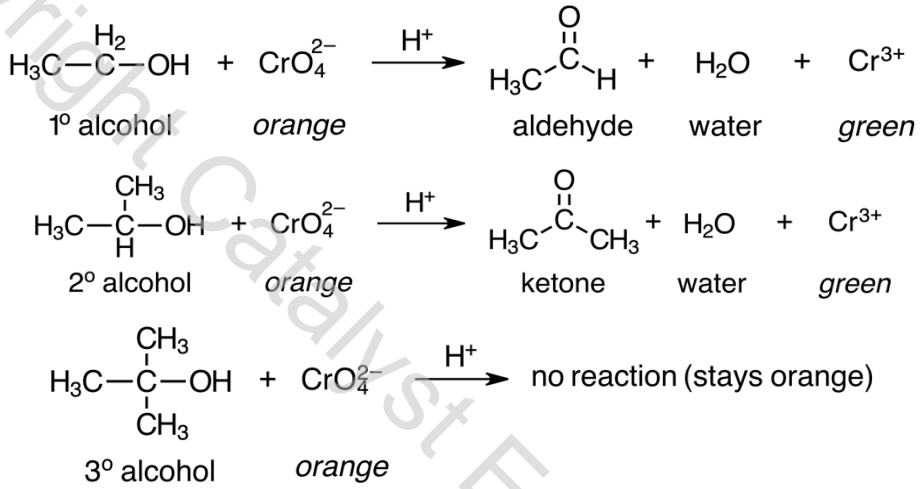
Figure 3 Hydrogen Bonding: Methyl Alcohol and Water

Chemical Properties

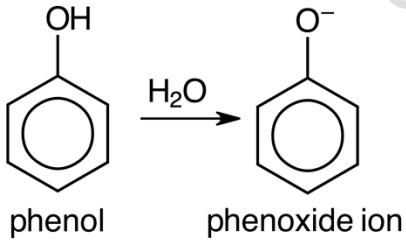
The chemical behavior of the different classes of alcohols and of phenols can be used as a means of identification.

Quick, simple tests that can be carried out in test tubes will be performed.

1. **Chromic acid test** - This test is able to distinguish primary and secondary alcohols from tertiary alcohols. Using acidified dichromate solution, primary alcohols are oxidized to carboxylic acids; secondary alcohols are oxidized to ketones; tertiary alcohols are not oxidized. (Note that in those alcohols which are oxidized, the carbon that has the hydroxyl group loses a hydrogen.) In the oxidation, the brown-red color of the chromic acid changes to a blue-green solution. Phenols are oxidized to nondescript brown tarry masses.



2. **Acidity of phenol** - Phenol is also called carbolic acid. Phenol is an acid and will react with base; thus, phenols readily dissolve in basic solutions. In contrast, alcohols are not acidic.



3. **Iron(lll)chloride test** - Addition of aqueous iron(lll) chloride to a phenol gives a colored solution. Depending on the structure of the phenol, the color can vary from green to purple.

$$\text{Phenol} + Fe^{3+} \longrightarrow Fe^{3+}(\text{phenol complex})$$

In this experiment, you will examine physical and chemical properties of representative alcohols and phenol. You will be able to compare the differences in chemical behavior between these compounds and use this information to identify an unknown.

Objectives

- Learn characteristic reactions of alcohols and phenols
- Use physical and chemical characteristics for identification of an organic compound

Materials

- Model displays
- ethanol
- 2-propanol
- 2-methyl-2-propanol (*t*-butyl alcohol)
- cyclohexanol
- 20% phenol
- 2% chromate solution
- 1% $FeCl_3$
- Test tubes and rack
- pH paper

> ***Wear appropriate attire for lab. Goggles should be worn at all times when chemicals and/or glassware are in use anywhere in the lab. Food, beverages, gum, etc. may not be in the lab.***
>
> ***Phenol is toxic**. Solid phenol should be handled only with a spatula or forceps. Contact with the solid will cause burns to skin; any contact should be thoroughly washed with large quantities of water. For 15 minutes. Many of the other reagents for the tests you will perform contain strong acids or bases. Wear gloves when working with these chemicals. If any chemicals are spilled on your skin, clothing or get into your eyes, immediately wash the affected area(s) with running water for 15 minutes and notify your TA. Large spills may require use of the safety shower. Dispose of all waste in the appropriate labeled container in the hood. Do not pour anything into the sink!*
>
> ***Chromate solution contains H_2SO_4 is very corrosive**, and it is also classified as a carcinogen.*

Check with TA or Instructor for any other supplies you may need.

Procedure

Structures of Alcohols and Phenol

1. Look at the display models of ethanol, 2-propanol, and 2-methyl-2-propanol and draw the condensed structural formula of each.
2. Classify each structure as primary, secondary, or tertiary.

Physical Properties of Alcohols and Phenols

pH

1. Obtain six test tubes, a test tube rack, and pH paper.
2. Into separate test tubes, add 10 drops of ethanol, 2-propanol, 2-methyl-2-propanol, cyclohexanol, and your unknown solution.

3. Test the pH of each solution by dipping a stirring rod into the solution and placing a drop of the solution onto the pH paper Be sure to clean the stirring rod between each solution.
4. Record the pH of each solution. Save your test tubes for the next part of the procedure.

Solubility in Water

5. Add 2-3 mL (~40 drops) of DI water to each test tube.
4. Shake gently to see if the compounds dissolve.
5. Record your observations. Soluble compounds will result in a clear solution with no separate layers. Insoluble compounds will result in a cloudy mixture or the solution will have separate layers.

Chemical Properties of Alcohols and Phenols

Chromic Acid Test – Oxidation

1. Obtain six test tubes and into separate tubes add 8 drops of ethanol, 2-propanol, 2-methyl-2-propanol, cyclohexanol, 20% phenol, and the unknown solution.
2. Obtain the 2% chromate solution and add 2 drops to each test tube.
3. Stir the solutions carefully and wait at least 2 minutes to allow the alcohol to react. Look for a color change in the chromate solution.
4. Record your observations. If a test tubes becomes hot, place it into a beaker of ice water. If the alcohol oxidized, the color will be green. If the color stayed orange, no reaction occurred.
5. Draw the condensed structural formula of each alcohol.
6. Classify each alcohol as primary, secondary, or tertiary.

Iron(III) Chloride Test

7. Obtain six test and into separate test tubes add 5 drops of ethanol, 2-propanol, 2-methyl-2-propanol, cyclohexanol, 20% phenol, and the unknown solution.
8. Obtain the 1% $FeCl_3$ solution and at 5 drops to each solution.
9. Stir each test tube and record your observations.

Identification of the Unknown

10. Use the results of the tests to identify the unknown as one of the five compounds used in this experiment.
11. Draw the condensed structural formula of the unknown.

Lab 6 Alcohols and Phenols

Team _____

Structures of Alcohols and Phenols

Fill in the table and upload an image.

Ethanol	2-propanol
Classification	
2-methyl-2-propanol (*t*-butyl alcohol)	phenol
Classification	

Physical Properties of Alcohols and Phenols

Unknown # _____

Alcohol	**pH**	**Soluble in Water?**
Ethanol		
2-Propanol		
2-Methyl-2-propanol		
Cyclohexanol		
Phenol		
Unknown		

Chemical Properties of Alcohols and Phenols

Chromic Acid Test – Oxidation of Alcohols

Fill in the table and upload an image.

Alcohol	**Color after 2 min**	**Condensed Structural Formula**	**Classification**	**Condensed Structural Formula of Product**
Ethanol				
2-Propanol				
2-Methyl-2-propanol				
Cyclohexanol				
Phenol				
Unknown				

Iron(III) chloride Test

Alcohol	**$FeCl_3$ Test Color**
Ethanol	
2-Propanol	
2-Methyl-2-propanol	
Cyclohexanol	
Phenol	
Unknown	

Identity of Unknown_____

Name of Unknown_____

Draw the condensed structural formula of your unknown and upload the image.

Give your feedback on what went well, what you learned, and what you could improve upon next time.