VANISHING VAPORS

Working with organic solvent liquids like acetone, benzene, or toluene can be dangerous, because they easily vaporize into toxic fumes. But why do these chemicals evaporate so quickly? In this activity, students will conduct an experiment that helps them visualize the different evaporation rates of ethanol (as an example of an oxygenated solvent) and water. They will compare the chemical structures of water, ethanol, acetone, benzene, and toluene, and learn how structure relates to evaporation characteristics. Finally, students will explain the high evaporation rates of acetone, toluene, and benzene by looking at their chemical structure.

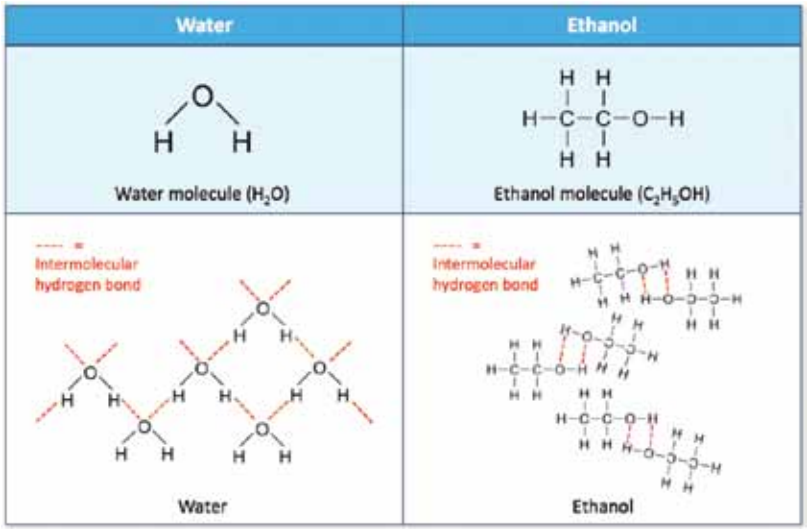
BACKGROUND

In *Uncommon Scents*, students learn that organic solvents can be liquids or gases, and that the liquids can easily evaporate. Students may not be familiar with the molecular reasons for these high evaporation rates.

> See PowerPoint "Uncommon Scents01_Activity02"

In this activity, students will compare the evaporation rate of water and ethanol. They will observe that the end of the ruler that holds the alcohol strip goes up and the end that holds the water strip goes down (see procedure below), because alcohol evaporates faster than water. As the alcohol changes its state from a liquid to a gas, the alcohol side of the ruler gets lighter.

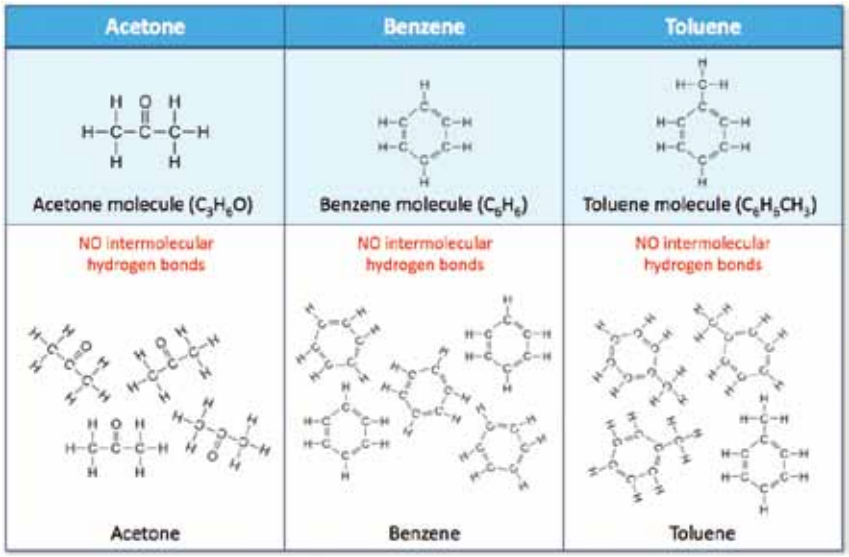
Water evaporates slower because its hydrogen bonds build an extensive network (intermolecular hydrogen-bonding). Because of these intermolecular forces, the water molecules do not easily escape from the liquid (evaporate). Like water, ethanol can build intermolecular hydrogen bonds using its hydroxyl group (the -OH group), but the network is much weaker, making it easier for the ethanol molecules to escape from the fluid (evaporate). In other words, the evaporation of water requires more energy than the evaporation of ethanol. In fact, the "heat of vaporization" (the



PowerPoint "Uncommon Scents01_Activity02", slide 7

energy required to transform a given quantity of a substance into a gas) of water is 2,257 J/g, versus 839.31 J/g for ethanol.

Acetone, benzene, and toluene evaporate even faster than ethanol, because these molecules do not contain a hydroxyl (-OH) group. Acetone contains a ketone group (one oxygen atom tightly bound to a carbon atom with a double bond), whereas benzene and toluene form aromatic rings and do not contain oxygen atoms at all. Because acetone, benzene, or toluene molecules can't build intermolecular hydrogen bonds, the intermolecular forces between the molecules in the liquid are very weak. Therefore, the molecules can easily escape from the liquid into the gaseous state, resulting in



PowerPoint "Uncommon Scents01_Activity02", slide 8

a higher evaporation rate. In other words, the energy needed for the evaporation of these solvents is lower. The "heat of vaporization" values are 510.79 J/g (acetone), 433.11 J/g (benzene), and 412.52 J/g (toluene).

LEARNING OBJECTIVES

The students will:

- Observe the change of substances from liquid into gaseous state (evaporation).
- Realize that different substances have different evaporation rates.
- Learn that the differences in evaporation rates are caused by differences in chemical structure (specifically the presence or absence of hydroxyl groups).

STANDARDS

National Science Content Standards: 5-8

Standard A:

- Students should develop abilities necessary to do scientific inquiry.
- Students should develop understandings about scientific inquiry.

Standard B:

- Students should develop an understanding of properties and changes of properties in matter.

MATERIALS

- Water
- Alcohol (Ethanol; alternatively isopropyl alcohol. If isopropyl alcohol is used, provide students with the chemical formula.)
- Paper towel
- Scissors
- Pencil (round diameter)
- Ruler
- 2 paper or plastic cups (16 oz)
- 2 smaller paper or plastic cups
- Tape
- Tablespoon measure
- Student Activity Sheet: Directions (one reusable copy per group)
- Student Activity Sheet: Results (one copy per student)

PREPARATION

Make sure the classroom is well ventilated during and after the experiment (open windows or turn on a ventilation system).

> Show PowerPoint "Uncommon Scents01_Activity02"

PROCEDURE

1. Organize the class into groups of two students each. Each team needs a set of the materials.
2. Have student read the procedure and formulate a hypothesis. Remind students that a hypothesis is a statement that predicts the outcome of an experiment, and that a hypothesis is testable.
3. Have each group complete steps 2-9 on their student activity sheet.
4. Discuss the following and have students record the answers in their experiment sheet:

EXPLANATION:

Why did the _____ strip dry first?

Answer: See explanations given in the "Background" section; answers should include these key points:

- ◊ The intermolecular hydrogen bonds between ethanol molecules are weaker than between water molecules (alternatively: the intermolecular hydrogen bonds between water molecules are stronger than between ethanol molecules)
- ◊ The ethanol molecules can escape from the fluid more easily (alternatively: the water molecules can't escape from the fluid as easily as ethanol)

What happened as the strips dried?

- ◊ The ethanol/water molecules evaporate/change from liquid into gaseous state/ escape from the liquid into the air

Did the experiment confirm or reject your hypothesis?

TEACHER PAGES

5. Have students fill out the sheet "Where's the hydrogen bond?"
    - Discuss why acetone, benzene, and toluene evaporate quicker than ethanol. Answer: See explanations given in the "Background" section; answers should include these key points:
        - ◊ Acetone, benzene, and toluene do not contain a hydroxyl (-OH) group
        - ◊ The molecules can't build intermolecular hydrogen bonds
        - ◊ The molecules can easily escape from the fluid
    - Discuss why you didn't use these chemicals in your experiment. Answer: Because they are toxic.
    - Have students complete the sentence: When a substance consists of molecules that form intermolecular hydrogen bonds, the intermolecular forces are _____, (Answer: stronger) and the substance evaporates _____. (Answer: quicker/more easily/faster, etc.)

EXTENSION ACTIVITY

Have students brainstorm other things that could affect the evaporation rates.
Examples can be:

- Temperature of the substance: If the substance is hotter, then evaporation will be faster, because the molecules are in movement and intermolecular forces are reduced.
- Air movement: If fresh air is moving over the substance all the time, then the concentration of the substance in the air is less likely to go up with time, thus encouraging faster evaporation.
- Surface area: A substance with a larger surface area will evaporate faster as there are more surface molecules that can escape from the fluid.
- Concentration of the substance in the air: If the air already has a high concentration of the substance evaporating, then the given substance will evaporate more slowly.
- Concentration of other substances in the air: If the air is already saturated with other substances, it can have a lower capacity for the substance evaporating.
- Concentration of other substances in the liquid: If the liquid contains other substances, it will have a lower capacity for evaporation.
- Pressure: In an area of less pressure, evaporation happens faster because there is less exertion on the surface keeping the molecules from launching themselves.
- Density: The higher the density, the slower a liquid evaporates.

RESOURCES

- National Library of Medicine's Hazardous Substances Data Bank – properties of acetone, benzene, ethanol, and toluene: ***http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?HSDB***

VANISHING VAPORS

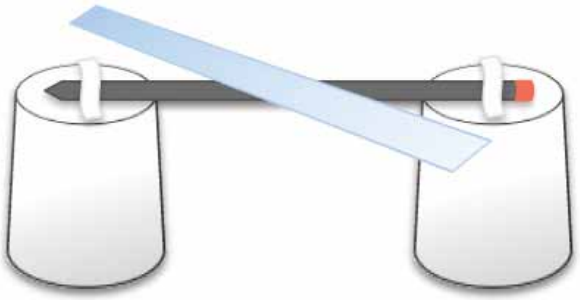
Working with organic solvent liquids like toluene or benzene can be dangerous, because they easily vaporize into toxic fumes. But why do these chemicals evaporate so quickly?

In this activity, you will conduct an experiment that shows the different evaporation rates of alcohol and water, and you will determine the reason for this difference. Finally, you will be able to explain why organic solvents like acetone, benzene, and toluene evaporate so quickly.

MATERIALS

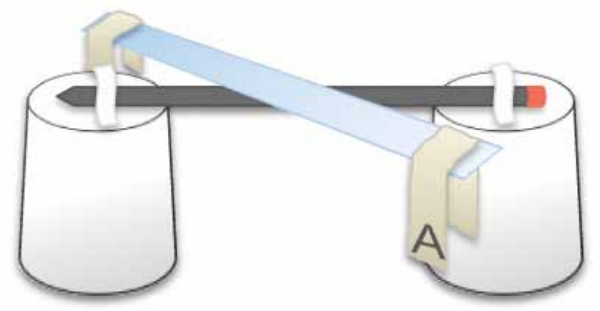
- Water
- Alcohol (Ethanol)
- Paper towel
- Scissors
- Pencil (round diameter)
- Ruler
- 2 paper or plastic cups (16 oz)

- 2 smaller paper or plastic cups
- Tape
- Tablespoon measure



PROCEDURE

1. Read the procedure and formulate a hypothesis of what you think will happen in this experiment. Record your hypothesis in experiment sheet 1.
2. Place the two large cups upside down on a flat surface.
3. Place the pencil across the cups and tape the pencil down, so that the pencil is fixed on top of the cups.



4. Place a ruler on the pencil so that the ruler is as balanced as possible. It might be perpendicular to the pencil, or slightly diagonal as shown in the picture.
5. Cut two strips of paper towel, each 20 centimeters (cm) long and 4 cm wide, and write "W" on one strip and "A" on the other with a pencil.
6. Pour one tablespoon of water into one small cup, and one tablespoon of alcohol into another.
7. One member of your team tips the "W" paper towel strip into the water until it is completely saturated; the other team member dips the "A" strip into the alcohol until it is completely saturated.
8. Work together with your teammate to place the wet strips at the very ends of the ruler. The ruler should remain balanced on the pencil.
9. Record your observation on experiment sheet
10. With your partner, discuss the following:
    - Which of the strips dried first and why?
    - What happened as the strips dried?
    - Did the experiment confirm or reject your hypothesis?
11. Record your explanations on experiment sheet 2.
12. Finally, think about acetone, benzene, and toluene:
    - Fill out the sheet "Where's the hydrogen bond?"
    - Be prepared to share your answers on the following questions:
        - ◊ Why do acetone, benzene, and toluene evaporate quicker than ethanol?
        - ◊ Why didn't you use these chemicals in your experiment?

Name _____ Class _____ Date _____

EXPERIMENT SHEET 1

Write down your hypothesis and observation here. Use bullet points to summarize what you saw.

Hypothesis:

Observation:

Name _____ Class _____ Date _____

EXPERIMENT SHEET 2

Write down your explanations here. Use complete sentences.

Explanation:

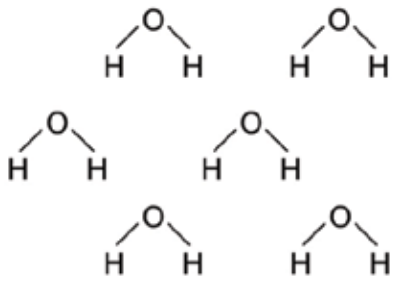
- Why did the _____ strip dry first?

- What happened as the strips dried?

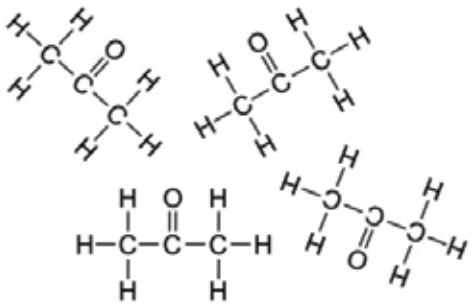
- Did the experiment confirm or reject your hypothesis?

Where's the hydrogen bond?

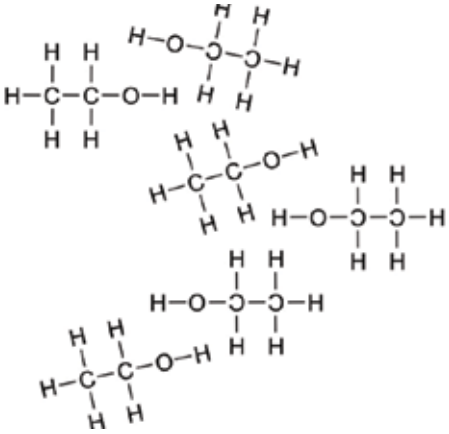
Could these molecules form intermolecular hydrogen bonds? Circle the areas where hydrogen bonds could occur.



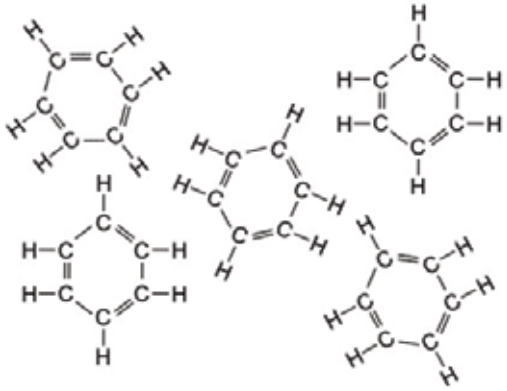
WATER



ACETONE



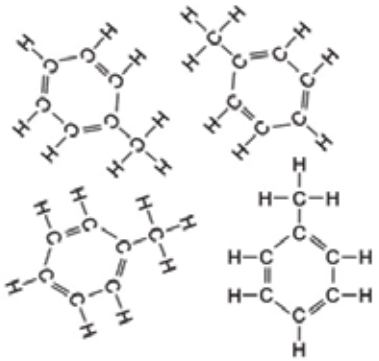
ETHANOL



BENZENE

Answer the following question:

When a substance consists of molecules that form intermolecular hydrogen bonds, the intermolecular forces are _____, and the substance evaporates _____.



TOLUENE

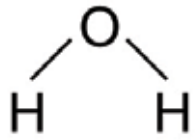
STUDENT ACTIVITIES

EXTENSION ACTIVITY

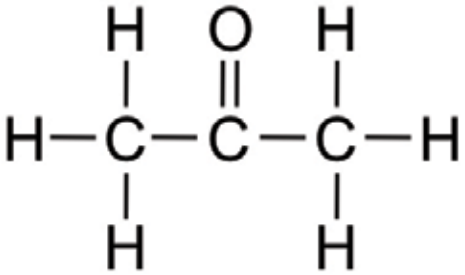
Brainstorm other things that could affect a substance's evaporation rate. You may list your ideas below.

Factors that can affect evaporation rates:

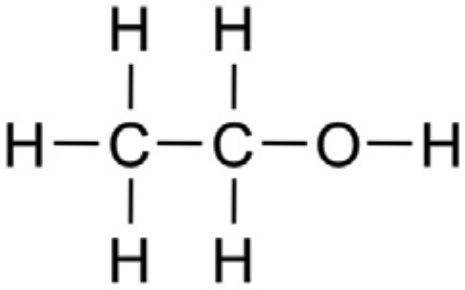
APPENDIX: CHEMICALS STRUCTURES AND FORMULAS



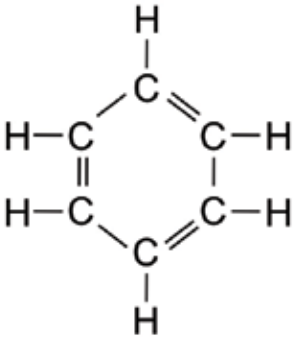
WATER (H_2O)



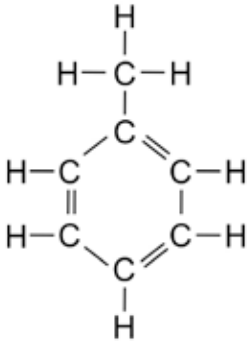
ACETONE (C_3H_6O)



ETHANOL (C_2H_5OH)



BENZENE (C_6H_6)



TOLUENE ($C_6H_6CH_3$)