INVESTIGATION 7
INTERMOLECULAR FORCES

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Safety

- Chemical-splash resistant goggle, long pants, closed lab coat, and shoes that COMPLETELY enclose the foot must be worn throughout the experiment.
- Wear GLOVES while handling chemicals.
- Always wash your hands before leaving the laboratory.

Waste Disposal

- The paper used to wrap probes may be disposed of in the trash.

Clean-Up

PRELAB 1

- Disassemble all molecular models completely. Check your work area thoroughly for parts that may have fallen off during model building.
- Organize all the pieces in the kit according to the inventory picture that is attached to the inside cover the kit box.
- Have your instructor inspect your model kit and initial your worksheet to indicate that the kit is complete and organized.

LAB INVESTIGATION 1

- Stopper the test tubes containing the liquids. Leave the test tube rack/test tubes assembly, rubber bands and temperature probes at your workstation.
- Close logger Pro and logout of the computer.
- Wipe off your workstation's countertop with a wet sponge and dry with a paper towel.
- Wipe of whiteboards.
- Have your instructor check you out of the workstation. Your instructor will initial the first page of your proposal form to indicate that you are in compliance with the clean-up procedure.

CONCEPT OVERVIEW

Under appropriate conditions, the attractions between all gas molecules will cause them to form liquids or solids. This is due to intermolecular forces, not intramolecular forces. **Intramolecular** forces are those within the molecule that keep the molecule together, for example, the bonds between the atoms.

Intermolecular forces are the attractions between molecules, which determine many of the physical properties of a substance.

INTRAmolecular Force Energy (kJ/mole)
Ionic 400-4000
Covalent 150-1100

INTERmolecular Force Energy (kJ/mole)
London Dispersion 0.05-40
Dipole-dipole 5-25
Hydrogen bonding 10-4

The type of intermolecular forces in a molecule are a result of bond polarity and molecular shape.

- Bond Polarity – determined from electronegativity differences
- Molecular Shape – determined from electron-dot structure

Electronegativity is the relative attraction for the shared electrons in a covalent bond. Electronegativity is a periodic trend increasing across a period (row) and decreasing down a group (column).

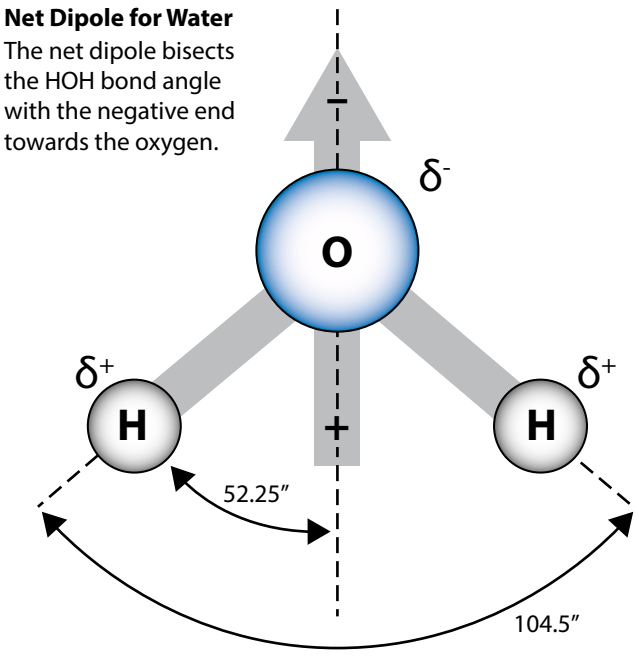

Figure 7.1

The physical properties of water (H_2O) and carbon dioxide (CO_2) illustrate the role of shape and bond polarity. The difference in the strength of intermolecular forces explains the striking difference

in physical properties, i.e, water is a liquid with a boiling point of 100 °C and carbon dioxide is a gas under normal conditions, with a sublimation point of -78.5 °C.

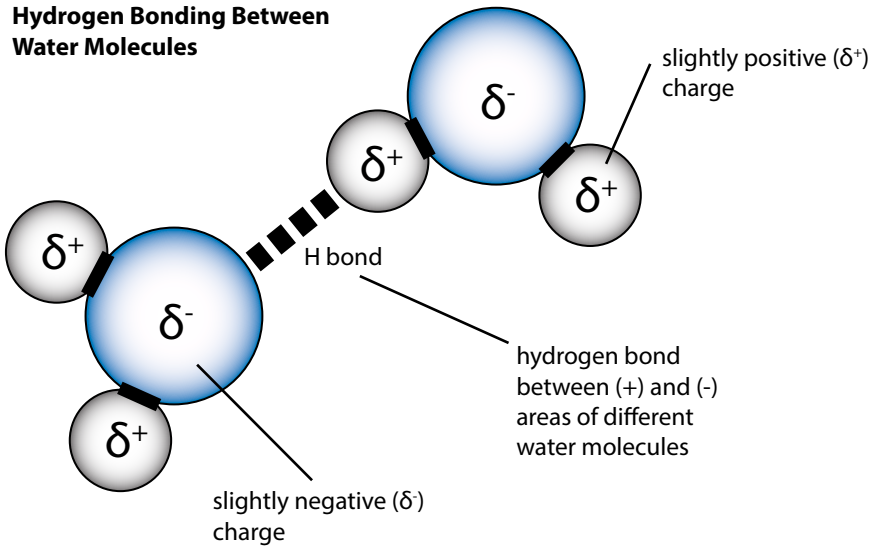

Figure 7.2

Water has a tetrahedral electron dot structure, but 2-lone pairs make the molecular structure bent. The difference in electronegativity of Oxygen and Hydrogen results in polar bonds. The bent shape means the dipoles do not cancel, making the molecule polar. Water has strong intermolecular forces called hydrogen-bonding.

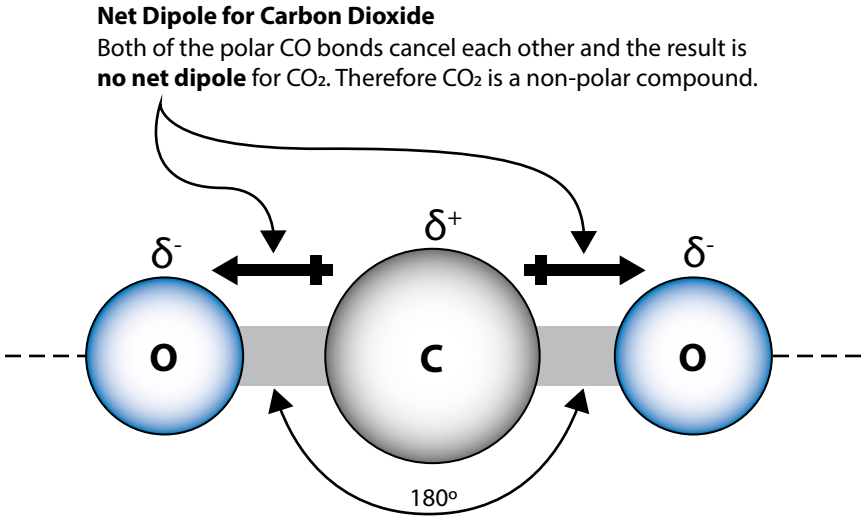

Figure 7.3

Carbon dioxide has a linear electron dot and molecular structure. The difference in electronegativity of Oxygen and Carbon results in polar bonds. The linear shape means the dipoles do cancel, making the molecule nonpolar. Carbon dioxide only has dispersion forces.

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INVESTIGATION 7: PRE-LAB

WHY DO LIQUIDS EVAPORATE AT DIFFERENT RATES?

In your own words describe the three types of intermolecular forces (IMFs).

Dispersion Forces:

Dipole – Dipole:

Hydrogen Bonding:

1. Use the molecular model kit and make a model of ethanol, water, pentane and acetone.
2. Draw a complete structure showing all the bonds and indicating the shape around each atom.
3. Indicate dipoles with ∂+/∂–.
4. Identify the strongest intermolecular force present in each compound.
5. Rank the molecules 1 to 4 for rate of evaporation, with 1 being the fastest and 4 being the slowest.

Ethanol	Water
Acetone	**Pentane**

6. Build three ethanol molecules and orient them to each other based on IMF. Draw the three compounds and use dashed lines to indicate the strongest IMF.

7. Build three acetone molecules and orient them to each other based on IMF. Draw the three compounds and use dashed lines to indicate the strongest IMF.

INVESTIGATION 7

WHY DO LIQUIDS EVAPORATE AT DIFFERENT RATES?

Have you ever had a sunburn or high fever? If so, you may have used rubbing alcohol to help cool your skin. The alcohol works because it evaporates quickly and lowers skin temperature. The evaporation of a volatile liquid is an endothermic process that results in a temperature decrease. The magnitude of temperature decrease is related to the strength of intermolecular forces of attraction. Rate of evaporation can be described as the absolute change (i.e. positive value) in temperature divided by the change in time it takes to reach the lowest temperature $\Delta T/\Delta t$ (°C/s). In this experiment, you will investigate factors that determine the strength of intermolecular forces by determining the rate of evaporation for a series of volatile liquids.

Your Task

In this investigation you will develop an explanation for the differences in evaporation rates of seven liquids.

Guiding Question

Why do liquids evaporate at different rates?

Materials

- distilled water, H_2O
- acetone, C_3H_6O
- methanol, CH_4O
- pentane, C_5H_{12}
- propanol, C_3H_8O
- ethanol, C_2H_6O
- butanol, $C_4H_{10}O$
- rubber bands
- chromatography paper
- Vernier LabPro system with temperature probe

Getting Started

1. Open Logger Pro. In the main menu, Click Expt >Data collection. Set time to 300 second.
2. Wrap the probe with chromatography paper and secure with a rubber band. Wrapped probes provide more uniform liquid amounts, and generally greater ΔT values than bare probes.
3. Stand the probe in the liquid until the temperature reading is stable, click start and collect data for 15 seconds to establish the initial temperature, T_i. Then remove the probe from the liquid.
4. Find the minimum and the maximum temperature readings. **NOTE:** The minimum temperature reading may occur before 300 seconds for some liquids.

Table 7.1

Name	Molecular Formula	Structural Formula
Methanol	CH_4O	CH_3OH
Ethanol	C_2H_6O	CH_3CH_2OH
Propanol	C_3H_8O	$CH_3CH_2CH_2OH$
Butanol	$C_4H_{10}O$	$CH_3CH_2CH_2CH_2OH$
Water	H_2O	HOH
Pentane	C_5H_{12}	$CH_3CH_2CH_2CH_2CH_3$
Acetone	C_3H_6O	$CH_3\overset{\overset{O}{\|}}{C}CH_3$

LAB REPORT

Why Do Liquids Evaporate at Different Rates?

Once you have completed your work, you will prepare an *investigation report* that consists of three sections. Your report should answer these questions in 2 pages of text. This report must be typed (12 pt font and 1-inch margins) and any diagrams, figures, or tables should be embedded into the document (these are not counted in the 2-pages of text).

Generally, you need one page for the first two sections and the second page for third section.

SECTION 1

What concept were you investigating and how does it relate to the guiding question?

- Describe and compare the relevant types of intermolecular forces (see PreLab)
- What is evaporation rate?
- Relate IMF's to Evaporation rate

SECTION 2

How did you go about your work and why? This is NOT the details of your procedure, but a discussion and justification of the process.

- Why wrap the probe in paper?
- Show a sample calculation.
- What determined time of evaporation?

SECTION 3

What is your argument? This third section is where you not only present your data, but also use the values you obtain as evidence in your reasoning. Statements like, "see data table for values" are NOT acceptable.

- **Discuss ALL 7 liquids.**
- Are the rates of evaporation consistent with the predicted IMFs

- Relate your data to intermolecular forces. You should prepare a graph of evaporation rates visualize your conclusion.

DATE: _____ SECTION/GROUP: _____

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NAME: _____ NAME _____

Lab Investigation 7 Proposal

The Guiding Question…

↓

What data will you collect?

↓

How will you collect your data?

What safety precautions will you follow?

↓

How will you analyze your data?

I approve of this investigation. _____ _____

Instructor's Signature Date

Data Tables and Observations

Data Analysis and Results Tables

Claim