



Chemistry with TI-Nspire™ and TI-Nspire™ Navigator™ – Day 4

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Materials for Workshop Participant*

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T³ Professional Development Categories and Learning Objectives

There are three categories of T³ Professional Development, each with a unique set of learning objectives. This workshop is focused on technology integration, and its objectives are as follows:

Technology Integration

- Emphasis on learning to use TI technology, with broad “how-to” coverage highlighting a wide range of features
 - Subject/content-focused training on appropriate usage of TI technology in the classroom
 - I am comfortable with essential technology skills for exploring math and science content.
 - I can design opportunities for students to use technology as a tool to deepen their understanding of mathematics and science.
 - I can locate and download TI activities that align to my standards.
 - I can describe the role technology should play in the successful implementation of my standards, and I can implement a vision of a classroom where students routinely use technology to engage in the practice and content standards.
-

Workshops focused on instructional practices and content knowledge have the following objectives:

Instructional Practices

- Emphasis on classroom practices with technology as a tool to enhance student learning
- Models CCSS, TEKS, and STEM tasks using in-depth discussions, reflective practices, and essential technology skills
 - I can demonstrate the importance of teacher actions for students’ engagement in the Practices, and I can take actions that will enable students to become mathematical and scientific practitioners.
 - I can describe the role that technology should play in the successful implementation of my standards, and I can implement a vision of a classroom where students routinely use technology to engage in practice and content standards.
 - I can design tasks for students to employ the Practices, using technology as a tool to deepen their understanding of mathematics and science.
 - I can ask questions designed to make student thinking visible – to push them to think about connections, make comparisons, or probe their understanding.

Content Knowledge

- Emphasis on content with technology as support
- Addresses critical, tough-to-teach topics and new content standards for CCSS or TEKS
 - I have a deeper understanding of the mathematics and science in my content area, and I am aware of the shifts in content that affect what I teach.
 - I can design opportunities for students to use technology as a tool to deepen their understanding of mathematics and science.
 - I can locate and download TI activities that align to my standards.
 - I can describe the role technology should play in the successful implementation of my standards, and I can implement a vision of a classroom where students routinely use technology to engage in the practice and content standards.



Activity	Page #
1. Calorimetry	
Who's Got a Better Coffee Cup?	4–5
Vernier – Energy in Food	4–9
Endothermic and Exothermic Reactions	4–19
2. Intermolecular Forces	4–21
3. Vernier – Evaporation and Intermolecular Attractions	4–29
4. Integration of the TI-Nspire™ Navigator™ System Use the Class Capture feature to capture images of TI-Nspire handheld screens, and insert them into Microsoft® Word documents.	

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Who's Got a Better Coffee Cup?

Student Activity

Name _____

Class _____

Activity Overview

In this activity, you will determine the characteristics that make a better coffee cup. After writing a hypothesis, you will design and conduct a lab to determine the heat loss or gain of a coffee cup.

Materials

- TI-Nspire™ handheld or computer software
 - TI-Nspire™ Lab Cradle
 - Vernier® EasyTemp™ USB temperature sensor
 - Styrofoam coffee cup, paper coffee cup, or cups of your choice
 - Hot plate or hot pot for heating water
 - Ice
-

Activity Challenge

Problem: What makes the best coffee cup?

1. Create a hypothesis about which cup is best and why you believe this is true.
2. Determine the variables you need to control and observe for comparison.
3. Design a test to evaluate these variables.
4. Create a data table to store the variables that have been defined.
5. Analyze any data to support or refute your hypothesis.
6. Write a convincing statement which includes a summary of your hypothesis, how your data and calculation support your hypothesis, and any potential reasons for why a cup is better. Add notes on any future study of coffee cup design that could be considered to create a better cup.

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Math and Science Objectives

- Students will design a lab to determine heat loss or gain of a coffee cup.
- Students will have varying methods of determining their winner. They might use slope to look at temperature loss over time. They might look at the (amount of water) X (the change in temperature) X (specific heat) to determine energy loss.
- Students will write a summary with supporting evidence from the lab to justify their decisions.

Vocabulary

- temperature change
- slope
- specific heat
- heat
- insulation
- heat transfer
- linear
- minimum and maximum

About the Lesson

- In this lesson, students will be challenged to determine which characteristics create the best coffee cup.
- As a result, students will:
 - Devise multiple methods of solving a problem.
 - Justify why they decided on a particular cup using supporting data and analysis.

Materials and Materials Notes

- TI-Nspire™ handheld or TI-Nspire™ computer software
- TI-Nspire™ Lab Cradle
- Three Vernier® EasyTemp™ USB temperature sensors
- Hot plate and beaker or hot pot for warming water
- Ice
- Plastic tub

TI-Nspire™ Technology Skills:

- Collect temperature data using up to three different temperature probes. Time settings can be changed by selecting **Menu > Experiment > Collection Setup**, or by simply clicking on the Rate or Duration sections on the left of the window.

Tech Tips:

- The Vernier DataQuest™ app will open when a sensor is plugged in.
- An alternate method of opening the app is pressing **ctrl** **menu** and selecting **Add Vernier DataQuest**.


Lesson Files:

Student Activity

- Whos_Got_a_Better_Coffee_Cup.pdf

Discussion Points and Possible Answers

The goal is to encourage students to first make a hypothesis. Many will focus in on the heat loss right away. Ask them how they will determine the heat loss in the coffee cup.

Tech Tip: The Vernier DataQuest™ app should launch when the TI-Nspire™ Lab Cradle and EasyTemp™ sensor are connected. To begin data collection, click the green **Start Collection**  arrow in the upper-left corner. Or press **Tab** until the start arrow is highlighted, then press **Enter**. The default time setting is 180 seconds (3 minutes). This can be changed by selecting **Menu > Experiment > Collection Setup**, or by simply clicking on the **Duration** area on the left of the window.

Activity Challenge

Problem: What makes the best coffee cup?

1. Create a hypothesis about which cup is best and why you believe this is true.

Discuss what a strong hypothesis is with the students. They not only predict the outcome, but they need to give reasons why they believe this is true.

2. Determine the variables you need to control and observe for comparison.

Help students define variables that will be involved in the experiment. Different groups will have slightly different variables.

3. Design a test to evaluate these variables.

4. Create a data table to store the variables that have been defined.

Student data tables should show all variables that are being considered to support their hypothesis.

5. Analyze any data to support or refute your hypothesis.

6. Write a convincing statement which includes a summary of your hypothesis, how your data and calculation support your hypothesis, and any potential reasons for why a cup is better. Add notes on any future study of coffee cup design that could be considered to create a better cup.

Students' conclusions should contain information on either 'the rate of decrease (slope) of the line is less' if they used hot water in the cup or 'the rate of increase is less' if they used cold water in the cup, if they compared slopes.

If they compared change in temperature, the cup with the least overall change under equivalent conditions would be the best for maintaining energy. There can be multiple solutions that are correct. Students' justification must be considered and supported by their data.

Energy in Food

Food supplies energy for all animals—without it we could not live. The quantity of energy stored in food is of great interest to humans. The energy your body needs for running, talking, and thinking comes from the foods you eat. Not all foods contain the same amount of energy, nor are all foods equally nutritious for you. An average person should consume a minimum of 2,000 kilocalories per day, which is equivalent to 8,360 kilojoules. Calories and joules are both units of energy. We will use joules in this lab since it is the accepted SI metric standard.

You can determine the energy content of food by burning a portion of it and capturing the heat released to a known amount of water. This technique is called *calorimetry*. The energy content of the food is the amount of heat produced by the combustion of 1 gram of a substance. It is measured in kilojoules per gram (kJ/g).

OBJECTIVES

In this experiment, you will

- Use a temperature probe to measure temperature changes.
- Monitor the energy given off by food as it burns.
- Determine and compare the energy content of different foods.

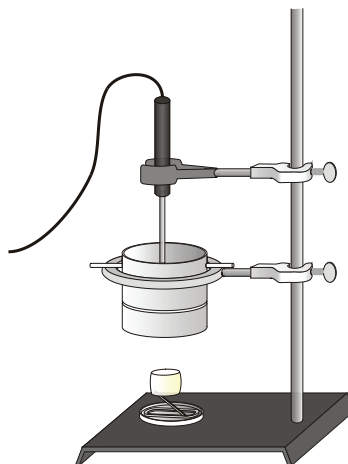






Figure 1

MATERIALS

TI-Nspire handheld **or**
 computer and TI-Nspire software
 EasyTemp **or** Go!Temp **or**
 Temperature Probe and data-collection interface
 100 mL graduated cylinder
 ring stand and 10 cm (4") ring
 balance
 utility clamp
 food holder

aluminum foil
 matches
 soup or juice can
 wooden splint
 two stirring rods
 cold water
 two single-hole stoppers
 two food samples (nut, popcorn,
 or marshmallow)

PROCEDURE

1. Obtain and wear goggles.
2. Connect the Temperature Probe to the data-collection interface. Connect the interface to the TI-Nspire handheld or computer. (If you are using an EasyTemp or Go!Temp, you do not need a data-collection interface.)
3. Set up DataQuest for data collection.
 - a. Choose New Experiment from the  Experiment menu
 - b. Choose Collection Setup from the  Experiment menu.
 - c. Enter **0.2** as the rate (samples/second).
 - d. Enter **480** as experiment duration in seconds. The number of points collected will be 97.
 - e. Select OK.
4. Obtain a sample of food and a food holder similar to the one shown in Figure 1. Mount the food onto the food holder so that it can burn without damaging the holder. Determine and record the initial mass of the food sample and food holder in Table 1. **CAUTION:** *Do not eat or drink in the laboratory.*
5. Set up the apparatus shown in Figure 1.
 - a. Determine the mass of an empty can. Record the value in Table 1.
 - b. Place about 50 mL of cold water into the can.
 - c. Determine and record the mass of the can plus the water.
 - d. Insert a stirring rod through the holes in the top of the can and hold it in place with two one-hole stoppers. Position the can 2.5 cm (~1 inch) above the food sample.
 - e. Use a utility clamp to suspend the temperature probe in the water as shown in Figure 1. The probe should not touch the bottom or side of the can.
6. You are now ready to begin collecting data.
 - a. Start data collection by hitting the play  button.
 - b. Use a match to light the food sample. Position the burning food sample directly below the center of the water-filled can. Quickly light the food sample again if it stops burning during data collection. **CAUTION:** *Always keep hair and clothing away from open flames.*
 - c. A real-time graph of temperature vs. time will be displayed on the screen during data collection.
 - d. Temperature readings (in °C) are displayed in the Graph Details box located to the left of the graph.
7. Stir the water slowly and continuously using the stirring rod until data collection stops.
8. After data collection has stopped, click any data point by using the cursor  button to examine the data points on the graph. Locate the maximum and minimum temperatures and record these values in Table 1.
9. Remove the food holder and determine the final mass of the food and holder. Record the mass in Table 1.
10. Clean off the food holder and empty the can of water.

11. Click the Store Data button to save the first run data.
12. Repeat Steps 4–10 for the second food sample.
13. A good way to compare the two samples is to view both sets of data on one graph. To display a graph click on graph view and click **run 2** then click select **All**. Sketch or print the graph as directed by your instructor.
14. When finished, discard all burnt matches and food samples as directed by your teacher.

DATA

Table 1		
Measurements	Sample 1	Sample 2
Food used		
Mass of empty can (g)		
Mass of can plus water (g)		
Initial temperature of water (°C)		
Final temperature of water (°C)		
Initial mass of food and holder (g)		
Final mass of food and holder (g)		

PROCESSING THE DATA

Record the following calculations in Table 2. Show your work in Table 3.

1. Determine the mass of the water and record in Table 2.
2. Calculate the change in mass of each food sample. Show your calculations.
3. Calculate the changes in the temperature of the water, Δt . Record this in Table 2. Show your calculations.
4. Calculate the energy gained by the heated water. Show your calculations. To do this, use the following equation:

$$\text{Energy gained by water} = (\text{mass of water}) \times (\Delta t \text{ of water}) \times (4.18 \text{ J/g}^\circ\text{C})$$

5. Convert the energy you calculated in Step 4 to kilojoules (1 kJ = 1000 J).
6. Use your answer in Step 5 to calculate the energy content of each food sample (in kJ/g):

$$\text{Energy content of food} = \text{Energy gained by water} / \Delta \text{mass of food}$$

7. Record your results and the results of other groups in Table 4.

Table 2		
Calculations	Sample 1	Sample 2
Mass of water (g)		
Δt of water ($^{\circ}\text{C}$)		
Δ mass of food (g)		
Energy gained by water (J)		
Energy content of food (J/g)		

Table 3		
Calculation	Sample 1	Sample 2
Δ mass		
Δt		
Energy gained		
Energy content		

Table 4: Class Results				
Food type:				
Energy content (kJ/g)				
Group 1				
Group 2				
Group 3				
Group 4				
Group 5				
Group 6				
Class Average:				

QUESTIONS

1. Which of the foods has the greatest energy content?
2. Which of the tested foods is the best energy source? Why?
3. What was the original source of energy in the foods tested?
4. Why might some foods with a lower energy content be better energy sources than other foods with a higher energy content?
5. Would you expect the energy content values that you measured to be close to the value listed in dietary books? Why?

EXTENSION

1. Determine the energy content of other combustible foods.

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TEACHER INFORMATION

Energy in Food

1. The student pages with complete instructions for data collection using LabQuest App, Logger *Pro* (computers), DataQuest (TI-Nspire Technology), EasyData or DataMate (calculators), and DataPro (Palm handhelds), can be found on the CD that accompanies this book. See *Appendix A* for more information.
2. Any four nuts could be used for this experiment. Walnuts, pecans, peanuts, and almonds are easy to obtain and give excellent results.
3. The water should be approximately 1-1/2 to 2 inches in diameter and about 3 inches long. A small juice can will do. Drill two holes in the can just under the metal rim, large enough so that a solid glass rod can easily fit in. The can will be suspended by the glass rod with a one-hole rubber stopper at each end. The rubber stoppers will rest on a metal 4 inch ring.
4. The food stand is made using a cork stopper, size 7 or larger, and a paper clip. Straighten one end of the paper clip and push it into the bottom of the cork stopper. Bend the other end of the paper clip into a ring so it will cup the food sample.
5. The two rubber stoppers on the very end of the stirring rod holding the can will prevent the can from slipping off the ring stand.
6. Heat is lost to the environment during this experiment as the fuel is burning. Therefore, the energy content that students measure will not be similar to the published values. This lab is still valid, however, since the heat lost to the environment is nearly proportional in every experiment. If the physical conditions in every experiment are the same, the energy contents will be proportional. Several key factors include:
 - The distance from the bottom of the can to the flame (or table top) should be equal.
 - The cans should be of equal dimensions.
 - The flame should not be in a breeze.
7. Provide each lab group with a container to discard their burnt foods. The charred pieces will make a mess otherwise. Soot will accumulate on the outside of the calorimeter can. Provide a paper towel for students to set the can onto between experiments. Soap may be needed after this experiment!
8. The Vernier temperature calibrations that are stored in the data-collection software will work fine for this experiment.
9. Use of nuts, especially peanuts, is being restricted and phased out of schools due to increasing numbers of allergic reactions and the heightened sensitivity that some students exhibit.
10. If you are collecting data on a calculator, we suggest that you clear all other programs and miscellaneous data off of the calculators to make room in the memory for collected data before loading EasyData.

Experiment 1**SAMPLE RESULTS**

Table 1			
Measurements	Sample 1	Sample 2	Sample 3
Food used	walnut	almond	pine nut
Mass of empty can (g)	28.51	28.51	28.51
Mass of can plus water (g)	77.35	78.27	76.99
Initial temperature of water (°C)	21.6	22.5	22.3
Final temperature of water (°C)	47.7	49.8	31.4
Initial mass of food (g)	12.85	12.92	12.30
Final mass of food (g)	12.25	12.18	12.10

Table 2			
Calculations	Sample 1	Sample 2	Sample 3
Mass of water (g)	49.18	49.76	48.48
Δt of water (°C)	26.1	27.3	9.1
Δ mass of food (g)	0.60	0.74	0.20
Energy gained by water (J)	5330	5680	1840
Energy content of food (J/g)	8880	7670	9220

Since this experiment is designed for 9th and 10th grade students, the mathematics has been simplified. Here is a more complete description of some of the mathematical reasoning.

The law of conservation of energy states that the energy lost by the food should equal the energy gained by the water.

$$\Delta E_{\text{food}} = \Delta E_{\text{water}}$$

The energy lost to the environment is nearly proportional in every experiment so it can be ignored. The energy gained by the water can be calculated using the equation below where m_{water} is the mass of the water in grams, C_p is the heat capacity of water which is equal to 4.186 J/g°C, and Δt is the change in temperature in °C.

$$\Delta E_{\text{water}} = m_{\text{water}} \cdot C_p \cdot \Delta t$$

Since the energy gained by the water is equal to the energy lost by the food, then the energy lost by the food can be found by using this equation.

$$\Delta E_{\text{food}} = \Delta E_{\text{water}} = m_{\text{water}} \cdot C_p \cdot \Delta t$$

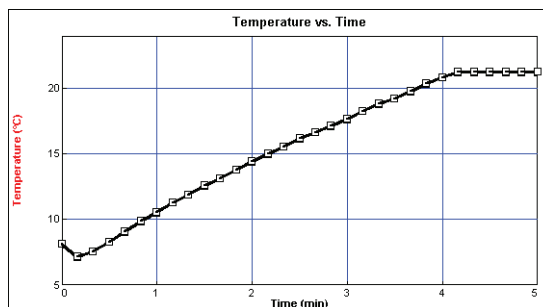
To calculate how much energy would be lost by one gram of the same food, divide the energy lost by the food by the mass of food that did burn.

$$\text{Energy content} = \frac{\Delta E_{\text{food}}}{1 \text{ gram}} = \frac{m_{\text{water}} \cdot C_p \cdot \Delta t}{\Delta m_{\text{food}}}$$

After converting joules to kilojoules, this gives us an answer similar to that in the student handout. We define the term *energy content* to be that amount of energy that can be obtained by the combustion of one gram of food.

The energy contents of a few sample foods are listed below. Note that these should be proportional to the measured energy contents, not equal to them, since heat was lost to the environment, and combustion was not complete.

Food	Energy content (kJ/g)	Food	Energy content (kJ/g)
almond	26.8	lard	37.6
brazil nuts	29.0	lima bean	14.3
cashews	25.5	peanuts	25.9
coconut (dry)	23.8	walnut	29.3
kidney beans	25.9		



Walnut burning and warming water

ANSWERS TO QUESTIONS

- Answers may vary, depending upon the type of food used. In the above experiment, pine nuts had the highest heat content, followed by walnuts, then almonds.
- Answers may vary. The food with the highest energy content is the best energy source.
- The sun is the source of energy for land plants. Plants can transform this radiant energy into chemical energy. This energy is used to manufacture many different substances, possibly in the form of fats, carbohydrates, or other high energy chemicals. When these chemicals are broken down, they release energy.
- Some high energy foods might be indigestible. Food with a high energy content might be high in cholesterol or saturated fats. These may be harmful to some people in large amounts.
- No, the measured values should be lower than those listed in a reference book.
 - There would be a certain amount of heat lost to the air and is not used to heat the water.
 - Soot that collects indicates incomplete combustion of the food. The published values assume complete combustion.

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Endothermic and Exothermic Reactions

TI PROFESSIONAL DEVELOPMENT

Science Objectives

- Use a temperature sensor to measure the temperature changes during two reactions.
- Calculate Δt for the reactions and determine whether the reactions are endothermic or exothermic.
- Differentiate between physical changes and chemical reactions.

Materials Needed

- TI-Nspire™ or TI-Nspire™ CAS unit for each student
- DampRid (Calcium Chloride)
- Vernier EasyLink® USB sensor interface
- Vernier EasyTemp® USB temperature sensor
- Calorimeter (small insulated cup)
- Alka Setzler® tablets
- Ring stand and test tube or finger clamp
- 100 mL graduated cylinder
- Gram balance
- Ruler with 1 mm marks

Vocabulary

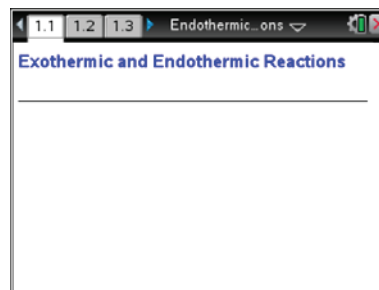
- endothermic
- endergonic
- exothermic
- exergonic
- Δt
- specific heat

About the Lesson

- Two chemical reactions will be done in this activity. One will be endothermic and the other will be exothermic.
- Students will use a temperature probe to measure the heat lost or gained during the reaction.
- Students will calculate the rate of heat lost or gained.

TI-Nspire™ Navigator™

- Send and collect TI-Nspire™ documents
- Use Class Capture to monitor student progress.
- Save graded work to the Portfolio.



TI-Nspire™ Technology Skills:

- Download a TI-Nspire document
- Open a document
- Move between pages
- Collecting and analyzing data

Lesson Files:

TI-Nspire document

- Endothermic_and_Exothermic_Reactions.tns

**Discussion Points and Possible Answers**

1. What is characteristic of an exothermic reaction?

Answer: Heat is given off.

2. What is characteristic of an endothermic reaction?

Answer: Heat is absorbed.

3. What is the significance of Δt when determining whether a reaction is endothermic or exothermic?

Answer: A $+\Delta t$ means the reaction is exothermic, and a $-\Delta t$ means the reaction is endothermic.

4. In this activity, which reaction was exothermic? What was your evidence?

Answer: The DampRid/water reaction. The Δt was positive.

5. Which reaction was endothermic? What was your evidence?

Answer: The Alka seltzer/water reaction. The Δt was negative.

6. What are three possible evidences that a chemical reaction has taken place?

Answer: Gas production, color change temperature change.

7. Which of the two reactions took place at a greater rate? Explain.

Answer: Answers will vary.

8. What are three examples of physical changes in matter?

Answer: Answers will vary.

TI-Nspire Navigator Opportunity: Class Capture can be used to monitor students.
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Wrap Up

Review the characteristics of chemical reactions; in particular the energy change involved in each.

Assessment

Formative assessment will consist of questions embedded in the TI-Nspire document. The questions will be graded when the document is retrieved. The Review Workspace can be utilized to give students immediate feedback on their assessment.



Intermolecular Forces

Student Activity

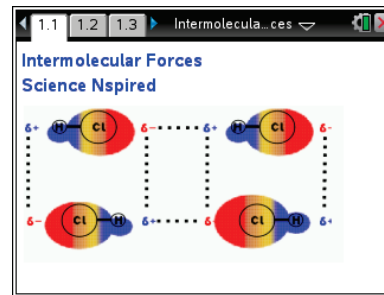


Name _____

Class _____

Open the TI-Nspire document *Intermolecular_Forces.tns*.

What is it about molecules that makes them stick together? It is the sticking together of molecules that causes them to form liquids and solids. In this activity you will observe the differences between polar and non-polar molecules and discover the different ways these two types of molecules stick together.

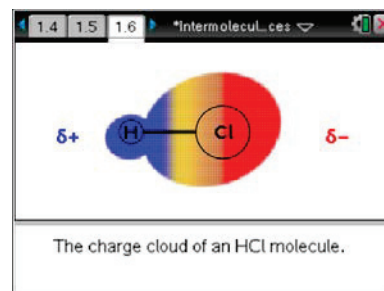


Move to pages 1.2–1.4. Answer the following questions here or in the .tns file.

- Q1. The forces within a molecule, for example covalent and ionic bonds, are known as _____ forces.
- A. intermolecular B. intramolecular
- Q2. Intermolecular forces are forces _____.
- A. between two or more molecules B. within a single molecule
- Q3. Intermolecular forces arise from the charge clouds surrounding molecules.
- A. True B. False

Move to pages 1.5 and 1.6.

1. Read and follow the instructions on page 1.5 and observe the simulation on page 1.6.



Move to page 1.7. Answer the following question here or in the .tns file.

- Q4. In the charge cloud for HCl the positive charge _____.
- A. remains on the left end (H) of the molecule C. oscillates regularly between the right and left ends
- B. remains on the right end (Cl) of the molecule D. moves randomly between the right and left ends

Move to page 1.8.

2. Read the information on page 1.8.

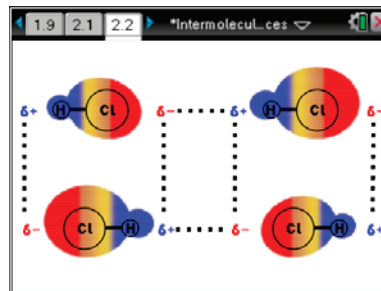
Move to page 1.9. Answer the following question here on in the .tns file.

- Q5. HCl _____. (More than one response may be correct.)
- A. is a non-polar molecule C. has a permanent dipole moment
- B. is a polar molecule D. has a temporary dipole moment



Move to pages 2.1 and 2.2.

3. Read and follow the instructions on page 2.1 and observe the simulation on page 2.2.

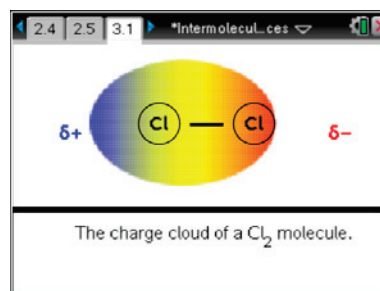


Move to pages 2.3–2.5. Answer the following questions here or in the .tns file.

- Q6. The attractive forces are between the ____ end of a HCl molecule and the ____ end of another HCl molecule.
- | | |
|-----------------------|-----------------------|
| A. positive, positive | C. negative, negative |
| B. positive, negative | D. hydrogen, hydrogen |
- Q7. The lines of force between HCl molecules ____ as the charge cloud changes.
- | | |
|--------------------|-----------|
| A. remain constant | C. change |
|--------------------|-----------|
- Q8. The intermolecular forces between HCl molecules are ____.
- | | |
|---|-------------------------|
| A. induced dipole-induced dipole (London dispersion) forces | C. dipole-dipole forces |
| B. dipole-induced dipole forces | D. ionic bonds |

Move to page 3.1.

4. Observe the simulation on page 3.1.



Move to pages 3.2 and 3.3. Answer the following questions here or in the .tns file.

- Q9. The positive charge for Cl_2 ____.
- | | |
|---|---|
| A. remains on the left end of the molecule | C. oscillates regularly between the right and left ends |
| B. remains on the right end of the molecule | D. moves randomly between the right and left ends |
- Q10. Cl_2 _____. (More than one response may be correct.)
- | | |
|----------------------------|----------------------------------|
| A. is a non-polar molecule | C. has a permanent dipole moment |
| B. is a polar molecule | D. has a temporary dipole moment |

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Intermolecular Forces

SCIENCE NSPIRED



TEACHER NOTES

Science Objectives

- Students will be able to distinguish between intermolecular and intramolecular forces.
- Students will understand the differences between dipole-dipole interactions and induced dipole-induced dipole (London dispersion) interactions.

Vocabulary

- dipole-dipole interactions
- dipole moment
- induced dipole-induced dipole interactions
- intermolecular forces
- intramolecular forces
- London dispersion forces
- van der Waals forces

About the Lesson




- In this lesson students will first observe the changing charge cloud that surrounds a single polar molecule (HCl) and a single non-polar molecule (Cl_2).
- Next students are shown the lines of force that develop between adjacent HCl molecules and adjacent Cl_2 molecules. These simulations will give students new insights into why molecules attract each other. They will also explore the different types of intermolecular interactions.

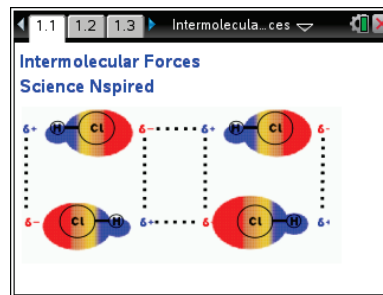


TI-Nspire™ Navigator™

- Send out the *Intermolecular_Forces.tns* file.
- Monitor student progress using Class Capture.
- Use Live Presenter to spotlight student answers.

Activity Materials

- Compatible TI Technologies:  TI-Nspire™ CX Handhelds,  TI-Nspire™ Apps for iPad®,  TI-Nspire™ Software



Tech Tips:

- This activity includes screen captures taken from the TI-Nspire CX handheld. It is also appropriate for use with the TI-Nspire family of products including TI-Nspire software and TI-Nspire App. Slight variations to these directions may be required if using other technologies besides the handheld.
- Watch for additional Tech Tips throughout the activity for the specific technology you are using.
- Access free tutorials at <http://education.ti.com/calculators/pd/US/Online-Learning/Tutorials>

Lesson Files:

Student Activity

- Intermolecular_Forces_Student.doc
- Intermolecular_Forces_Student.pdf

TI-Nspire document

- Intermolecular_Forces.tns

Discussion Points and Possible Answers

Move to pages 1.2–1.4.

Have students answer the questions in the .tns file, on the activity sheet, or both.

Q1. The forces within a molecule, for example covalent and ionic bonds, are known as _____ forces.

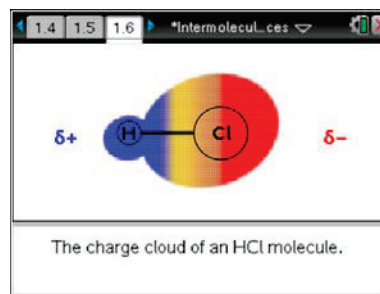
Answer: B. intramolecular

Q2. Intermolecular forces are forces _____.

Answer: A. between two or more molecules

Q3. Intermolecular forces arise from the charge clouds surrounding molecules.

Answer: A. True



Move to pages 1.5 and 1.6.

1. Students should read and follow the instructions on page 1.5 and observe the simulation on page 1.6.

Move to page 1.7.

Have students answer the question in the .tns file, on the activity sheet, or both.

Q4. In the charge cloud for HCl the positive charge _____.

Answer: A. remains on the left end (H) of the molecule

Move to page 1.8.

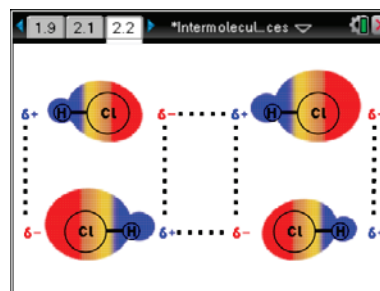
2. Have students read the information on page 1.8.

Move to page 1.9.

Have students answer the question in the .tns file, on the activity sheet, or both.

Q5. HCl _____. (More than one response may be correct.)

Answer: B. is a polar molecule; C. has a permanent dipole moment



Move to pages 2.1 and 2.2.

3. Students should read and follow the instructions on page 2.1 and then observe the simulation on page 2.2.

**Move to pages 2.3–2.5.**

Have students answer the questions in the .tns file, on the activity sheet, or both.

- Q6. The attractive forces are between the ____ end of a HCl molecule and the ____ end of another HCl molecule.

Answer: B. positive, negative

- Q7. The lines of force between HCl molecules ____ as the charge cloud changes.

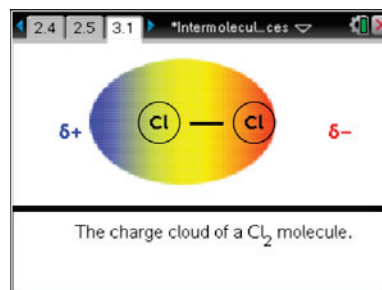
Answer: A. remain constant

- Q8. The intermolecular forces between HCl molecules are ____.

Answer: C. dipole-dipole forces

Move to page 3.1.

4. Students should observe the simulation on page 3.1.

**Move to pages 3.2 and 3.3.**

Have students answer the questions in the .tns file, on the activity sheet, or both.

- Q9. The positive charge for Cl₂ ____.

Answer: D. moves randomly between the right and left ends

- Q10. Cl₂ _____. (More than one response may be correct.)

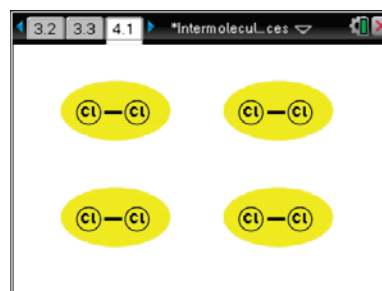
Answer: A. is a non-polar molecule; D. has a temporary dipole moment

Move to page 4.1.

5. Have students observe the simulation on page 4.1.

Move to pages 4.2–4.5.

Have students answer the questions on either the device, on the activity sheet, or both.





Q11. The lines of force between Cl_2 molecules _____ as the charge cloud changes.

Answer: B. change

Q12. The intermolecular forces between Cl_2 molecules are _____.

Answer: A. induced dipole-induced dipole (London dispersion) forces

Q13. For molecules of about the same size, I would expect dipole-dipole intermolecular forces to be _____ than induced dipole-induced dipole forces.

Answer: A. stronger

Q14. Explain your answer to the last question.

Answer: Two reasons the dipole-dipole forces are stronger are (1) the lines of force are constant and (2) the positive and negative ends of the polar molecule have larger charges.



TI-Nspire Navigator Opportunities

If students answer the questions within the .tns file, the files can be collected at the end of class and graded electronically and added to the Portfolio. Use TI-Nspire Navigator to display the animations on pages 1.6, 2.2, 3.1, and 4.1 and ask the students discuss what they are observing.

Wrap Up

When students are finished with the activity, pull back the .tns file using TI-Nspire Navigator. Save grades to Portfolio. Discuss activity questions using Slide Show.

Assessment

- Formative assessment will consist of questions embedded in the .tns file. The questions will be graded when the tns file is retrieved by TI-Nspire Navigator. The TI-Nspire Navigator Slide Show can be utilized to give students immediate feedback on their assessment.
- Summative assessment will consist of questions/problems on the chapter test, inquiry project, performance assessment, or an application/elaborate activity.

Evaporation and Intermolecular Attractions

In this experiment, Temperature Probes are placed in various liquids. Evaporation occurs when the probe is removed from the liquid's container. This evaporation is an endothermic process that results in a temperature decrease. The magnitude of a temperature decrease is, like viscosity and boiling temperature, related to the strength of intermolecular forces of attraction. In this experiment, you will study temperature changes caused by the evaporation of several liquids and relate the temperature changes to the strength of intermolecular forces of attraction. You will use the results to predict, and then measure, the temperature change for several other liquids.

You will encounter two types of organic compounds in this experiment—alkanes and alcohols. The two alkanes are pentane, C_5H_{12} , and hexane, C_6H_{14} . In addition to carbon and hydrogen atoms, alcohols also contain the $-OH$ functional group. Methanol, CH_3OH , and ethanol, C_2H_5OH , are two of the alcohols that we will use in this experiment. You will examine the molecular structure of alkanes and alcohols for the presence and relative strength of two intermolecular forces—hydrogen bonding and dispersion forces.

OBJECTIVES

In this experiment, you will

- Study temperature changes caused by the evaporation of several liquids.
- Relate the temperature changes to the strength of intermolecular forces of attraction.

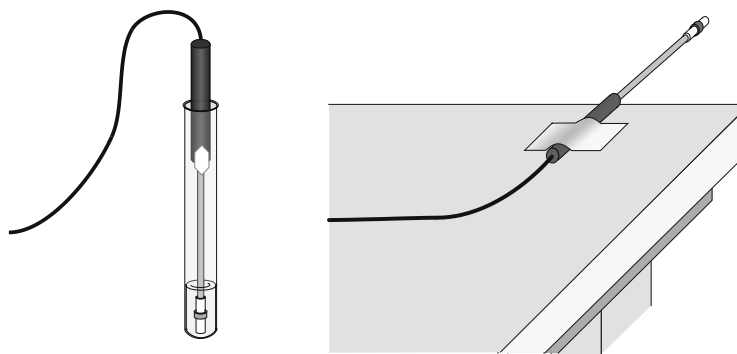


Figure 1

MATERIALS

TI-Nspire handheld **or**
 computer and TI-Nspire software
 data-collection interface
 2 Temperature Probes
 6 pieces of filter paper (2.5 cm x 2.5 cm)
 2 small rubber bands
 masking tape

methanol (methyl alcohol)
 ethanol (ethyl alcohol)
 1-propanol
 1-butanol
 n-pentane
 n-hexane

PRE-LAB QUESTIONS




Prior to doing the experiment, complete the Pre-Lab table. The name and formula are given for each compound. Draw a structural formula for a molecule of each compound. Then determine

DataQuest 20

the molecular weight of each of the molecules. Dispersion forces exist between any two molecules, and generally increase as the molecular weight of the molecule increases. Next, examine each molecule for the presence of hydrogen bonding. Before hydrogen bonding can occur, a hydrogen atom must be bonded directly to an N, O, or F atom within the molecule. Tell whether or not each molecule has hydrogen-bonding capability.

Substance	Formula	Structural formulas	Molecular weight	Hydrogen bond (yes or no)
ethanol	C ₂ H ₅ OH			
1-propanol	C ₃ H ₇ OH			
1-butanol	C ₄ H ₉ OH			
n-pentane	C ₅ H ₁₂			
methanol	CH ₃ OH			
n-hexane	C ₆ H ₁₄			

PROCEDURE

1. Obtain and wear goggles! **CAUTION:** The compounds used in this experiment are flammable and poisonous. Avoid inhaling their vapors. Avoid contacting them with your skin or clothing. Be sure there are no open flames in the lab during this experiment. Notify your teacher immediately if an accident occurs.
2. Connect the Temperature Probes to the data-collection interface. Connect the interface to the TI-Nspire handheld or computer.
3. Choose New Experiment from the  Experiment menu. Choose Collection Setup from the  Experiment menu. Enter **240** as the experiment duration in seconds (4 minutes). The number of points collected should be 481. Select OK.
4. Wrap Probe 1 and Probe 2 with square pieces of filter paper secured by small rubber bands as shown in Figure 1. Roll the filter paper around the probe tip in the shape of a cylinder.
Hint: First slip the rubber band on the probe, wrap the paper around the probe, and then finally slip the rubber band over the paper. The paper should be even with the probe end.
5. Stand Probe 1 in the ethanol container and Probe 2 in the 1-propanol container. Make sure the containers do not tip over.
6. Prepare 2 pieces of masking tape, each about 10 cm long, to be used to tape the probes in position during Step 7.
7. After the probes have been in the liquids for at least 30 seconds, start data collection (). A live graph of temperature vs. time for both Probe 1 and Probe 2 is being plotted on the screen. Live readings are also displayed. Monitor the temperature for 15 seconds to establish

Evaporation and Intermolecular Attractions

the initial temperature of each liquid. Then simultaneously remove the probes from the liquids and tape them so the probe tips extend 5 cm over the edge of the table top as shown in Figure 1. **Note:** avoid moving near the sensors as air movement can affect your results.



8. Data collection will stop after 240 seconds. Click any data point and use ► and ◀ to examine the data pairs on the displayed graph. Based on your data, determine the maximum temperature, t_1 , and minimum temperature, t_2 for both probes. Record t_1 and t_2 for each probe in the data table.
9. For each liquid, subtract the minimum temperature from the maximum temperature to determine Δt , the temperature change during evaporation.
10. Based on the Δt values you obtained for these two substances, plus information in the Pre-Lab exercise, *predict* the size of the Δt value for 1-butanol. Compare its hydrogen-bonding capability and molecular weight to those of ethanol and 1-propanol. Record your predicted Δt , then explain how you arrived at this answer in the space provided. Do the same for n-pentane. It is not important that you predict the exact Δt value; simply estimate a logical value that is higher, lower, or between the previous Δt values.
11. Test your prediction in Step 10. Click the Store Data button (✓). Repeat Steps 5–9 using 1-butanol with Probe 1 and n-pentane with Probe 2.
12. Based on the Δt values you have obtained for all four substances, plus information in the Pre-Lab exercise, *predict* the Δt values for methanol and n-hexane. Compare the hydrogen-bonding capability and molecular weight of methanol and n-hexane to those of the previous four liquids. Record your predicted Δt , then explain how you arrived at this answer in the space provided.
13. Test your prediction in Step 12. Click the Store Data button (✓). Repeat Steps 5–9, using methanol with Probe 1 and n-hexane with Probe 2.

DataQuest 20**DATA**

Substance	t_1 (°C)	t_2 (°C)	Δt ($t_1 - t_2$) (°C)		
ethanol					
1-propanol				Predicted Δt (°C)	Explanation
1-butanol					
n-pentane					
methanol					
n-hexane					

PROCESSING THE DATA

Plot a graph of Δt values of the four alcohols versus their respective molecular weights. Plot molecular weight on the horizontal axis and Δt on the vertical axis.

- Insert a new problem in the document, then Insert a new DataQuest App into problem 2. Click on the Table View tab () to view the Table.
- Double click on the X column to access the column options. Enter **Molecular Weight** for the Name, **Weight** for the short name, and **amu** for the units. Change the Display Precision to 0 decimal places. Select OK.
- Double click on the Y column to access the column options. Enter **ΔT** for the column name. Enter **°C** as the units. Select OK.
- Using the data recorded in the tables, enter the values in the DataQuest Table.
- Click on the Graph View tab () to view the graph.

QUESTIONS

- Two of the liquids, n-pentane and 1-butanol, had nearly the same molecular weights, but significantly different Δt values. Explain the difference in Δt values of these substances, based on their intermolecular forces.
- Which of the alcohols studied has the strongest intermolecular forces of attraction? The weakest intermolecular forces? Explain using the results of this experiment.
- Which of the alkanes studied has the stronger intermolecular forces of attraction? The weaker intermolecular forces? Explain using the results of this experiment.

TEACHER INFORMATION

Evaporation and Intermolecular Attractions

1. Editable Microsoft Word versions of the student pages and pre-configured TI-Nspire files can be found on the CD that accompanies this book. See *Appendix A* for more information.
2. This experiment, as written, is not intended for use with Easy or Go! products since data from two sensors must be collected at the same time. A single, multi-channel interface is preferred.
3. If you are using Easy or Go! products, or if you have a limited number of temperature probes, you can do this experiment with only a single sensor, testing a single alcohol with each run. Similarly, you can use more than two temperature probes if you have a multi-channel interface.
4. We recommend wrapping the probes with paper as described in the procedure. Wrapped probes provide more uniform liquid amounts, and generally greater Δt values, than bare probes. Chromatography paper, filter paper, and various other paper types work well.
5. Snug-fitting rubber bands can be made by cutting short sections from a small rubber hose. Surgical tubing works well. Orthodontist's rubber bands are also a good size.
6. Other liquids can be substituted. Although it has a somewhat larger Δt , 2-propanol can be substituted for 1-propanol. Some petroleum ethers have a high percentage of hexane and can be used in its place. Other alkanes of relatively high purity, such as n-heptane or n-octane can be used. Water, with a Δt value of about 5°C , emphasizes the effect of hydrogen bonding on a low-molecular weight liquid. However, students might have difficulty comparing its hydrogen bonding capability with that of the alcohols used.
7. Sets of the liquids can be supplied in 13×100 mm test tubes stationed in stable test-tube racks. This method uses very small amounts of the liquids. Alternatively, the liquids can be supplied in sets of small bottles kept for future use. Adjust the level of the liquids in the containers so it will be above the top edge of the filter paper.
8. Because several of these liquids are highly volatile, keep the room well-ventilated. Cap the test tubes or bottles at times when the experiment is not being performed. The experiment should not be performed near any open flames.
9. Other properties, besides Δt values, vary with molecular size and consequent size of intermolecular forces of attraction. Viscosity increases noticeably from methanol through 1-butanol. The boiling temperatures of methanol, ethanol, 1-propanol, and 1-butanol are 65°C , 78°C , 97°C , and 117°C , respectively.
10. **HAZARD ALERTS:**
n-Hexane: Flammable liquid: dangerous fire risk; may be irritating to respiratory tract. Hazard Code: B—Hazardous.
Methanol: Flammable; dangerous fire risk; toxic by ingestion (ingestion may cause blindness). Hazard Code: B—Hazardous.

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Ethanol: Dangerous fire risk; flammable; addition of denaturant makes the product poisonous—it cannot be made non-poisonous; store in a dedicated flammables cabinet or safety cans. If a flammables cabinet or safety cans are not available, store in a Flinn *Saf-Stor*[®] Can. Hazard Code: C—Somewhat hazardous.

n-Pentane: Flammable liquid; narcotic in high concentrations. Hazard Code: B—Hazardous.

1-Propanol: Flammable liquid; dangerous fire risk; harmful to eyes and respiratory tract. Hazard Code: B—Hazardous.

1-Butanol: Moderate fire risk; toxic on prolonged inhalation; eye irritant; absorbed by skin. Hazard Code: B—Hazardous.

The hazard information reference is: Flinn Scientific, Inc., *Chemical & Biological Catalog Reference Manual*, 1-800-452-1261, www.flinnsci.com. See *Appendix F* for more information.

11. Piping which can be purchased at a yard goods or sewing store can serve as an appropriate sleeve for the temperature probe. You have to cut it pieces and remove the "rope".

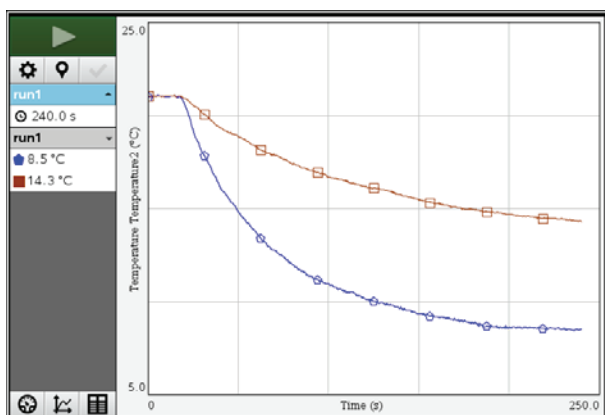
ANSWERS TO PRE-LAB QUESTIONS

Substance	Formula	Structural Formulas	Molecular Weight	Hydrogen Bond (Yes or No)
ethanol	C ₂ H ₅ OH	<pre> H H H-C-C-O-H H H </pre>	46	yes
1-propanol	C ₃ H ₇ OH	<pre> H H H H-C-C-C-O-H H H H </pre>	60	yes
1-butanol	C ₄ H ₉ OH	<pre> H H H H H-C-C-C-C-O-H H H H H </pre>	74	yes
n-pentane	C ₅ H ₁₂	<pre> H H H H H H-C-C-C-C-C-H H H H H H </pre>	72	no
methanol	CH ₃ OH	<pre> H H-C-O-H H </pre>	32	yes
n-hexane	C ₆ H ₁₄	<pre> H H H H H H H-C-C-C-C-C-C-H H H H H H H </pre>	86	no

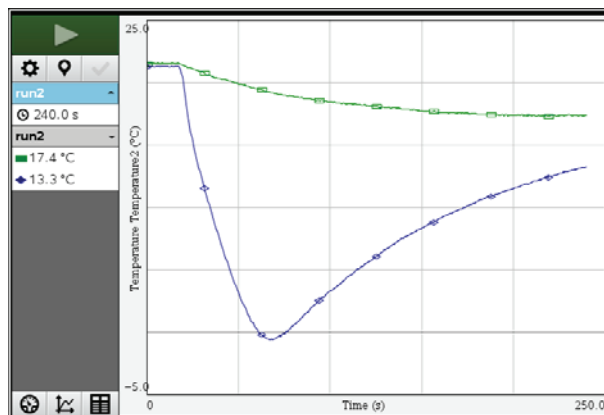
SAMPLE RESULTS

Substance	t_1 (°C)	t_2 (°C)	Δt ($t_1 - t_2$) (°C)
ethanol	21.0	8.5	12.5
1-propanol	21.1	14.3	6.8
1-butanol	21.5	17.4	4.1
n-pentane	21.3	-0.6	21.9
Methanol	21.0	1.3	19.7
n-hexane	22.8	6.7	16.1

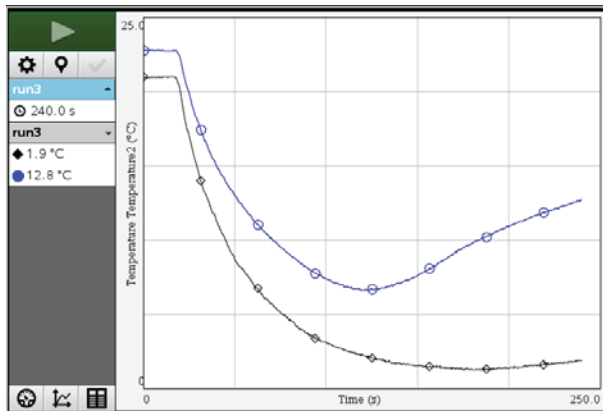
Predicted Δt (°C)	Explanation
varies (< 4.9°C)	It has a higher molecular wt. than 1-propanol (both have H-bonds).
varies (> 8.3°C)	It has a higher molecular wt. than either, but no H-bonding.
varies (> 8.3°C)	It has a lower molecular wt. than ethanol (both have H-bonds).
varies (< 16.1°C)	It has a higher molecular wt. than n-pentane; also no H-bonding.



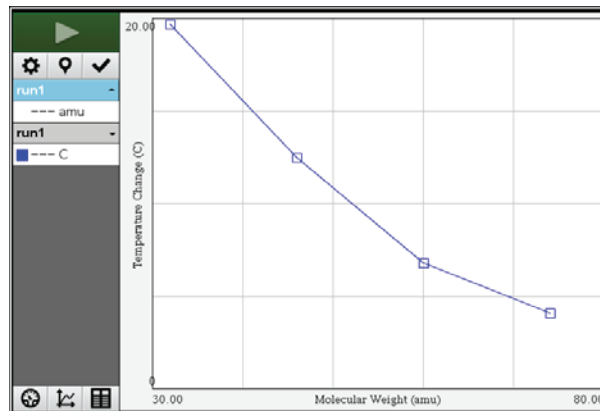
Evaporation of ethanol (●)
and 1-propanol (□).



Evaporation of 1-butanol (□)
and n-pentane (◆)

Experiment 20

*Evaporation of methanol (■)
and n-hexane (○).*



*Temperature change vs.
alcohol molecular weight.*

ANSWERS TO QUESTIONS

1. Even though n-pentane and 1-butanol have molecular weights of 72 and 74, respectively, 1-butanol has a much smaller Δt due to the presence of hydrogen bonding between its molecules. This results in a stronger attraction, and a slower rate of evaporation.
2. The 1-butanol has the strongest attractions between its molecules. Methanol has the weakest attractions. The 1-butanol has the largest molecules and resulting strongest dispersion forces. This gives it the lowest evaporation rate and the smallest Δt .
3. The n-hexane has the stronger attractions between its molecules. The n-pentane has the weaker attractions. The n-hexane has the larger molecules and the resulting stronger dispersion forces. This gives it a lower evaporation rate and the smallest Δt .