10A Pure Substance or Mixture?

How can observing the melting point identify a pure substance or a mixture?

Matter can be divided into two main categories: mixtures and pure substances. *Pure substances* are homogeneous throughout. They have the same chemical properties no matter where the sample is obtained or how large the sample is. *Mixtures* are combinations of two or more substances, with each substance retaining its chemical identity.

In this lab, you will obtain four test tubes containing unknown solids. The melting point, or the temperature at which the matter changes from a solid to a liquid, will be measured to determine if the matter is a mixture or a pure substance. Any given pure substance will always have the same melting point. Pure substances usually melt over a small temperature range while mixtures often melt over a very wide temperature range.

Materials

- 4 test tubes with unknowns
- hot plate
- Stirring rod
- 1 250-mL beaker
- water
- Safety goggles
- Lab apron
- Data Collector
- temperature probe

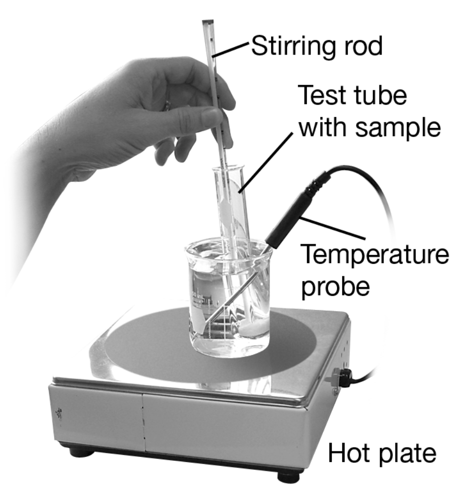
1 Thinking about what you will do

Why do you think a pure substance will melt over a smaller range of temperatures than a mixture?

WARNING — This lab contains chemicals that may be harmful if misused. Read cautions on individual containers carefully. Not to be used by children except under adult supervision.

2 Doing the experiment

1. Attach the temperature probe to the Data Collector and set it to meter mode for the entire experiment. Record your sample label (A-D) in Table 1.
2. Add approximately 200 mL of cold water to a 250 mL beaker. Place the beaker on the hot plate, and turn the hot plate on to medium.
3. Place the first sample into the water bath and have one group member hold the temperature probe about halfway in the water.
4. Another group member should stir the contents of the test tube with a stirring rod as it heats.



5. Watch the contents of the test tube carefully. At the moment the contents begin to melt, measure and record the temperature in Table 1.
6. Continue stirring the contents of the test tube and watching the contents until the entire sample is liquefied. Once the last solid particle melts, measure and record the temperature in Table 1.
7. Return your sample to your instructor.
8. Pour out the hot water in the beaker.
9. Repeat steps 2-8 for each of the remaining samples. Be sure to start with a fresh sample of cold water for the water bath.

Table 1: Melting data

Sample label	Temperature melting starts, °C	Temperature melting ends, °C
A		
B		
C		
D		

3 Analyzing the data

a. How would you know which test tubes contain pure substances and which contain mixtures?

b. If a sample contained 1 gram of pure substance A and another test tube contained 4 g of pure substance A, how would the melting points differ? How would the experiment differ?

c. Name two possible sources of error for this experiment. How would they affect your data?

4 Applying your knowlege

A white, waxy substance is heated in a test tube. Part of the substance melts almost immediately, and is poured off into a seperate test tube after a minute of further heating, leaving a little more than half or the original sample behind.

a. Explain why you think the original sample was a pure substance or a mixture.

b. Is the melted portion that was poured off a pure substance or a mixture? What evidence do you base your answer on?

c. Can you be sure that the remaining portion left behind in the test tube is a pure substance or a mixture? How could you know for sure?

10B Determining Freezing/Melting Point

How do you determine the freezing/melting point of cetyl alcohol?

A cooling/heating curve is a plot of temperature vs. time. It illustrates the effect on a substance as the temperature decreases/increases through a phase change. In this experiment, you will study the effects of cooling and heating cetyl alcohol through a phase chage. The data will be recorded using a data collector and then plotted on graphs. Based on your observations, measurements, and graphs you will be able to determine the freezing/melting point of cetyl alcohol.

Materials

- Data Collector
- Temperature probe
- Test tube, 22 × 150-mm
- Cetyl alcohol
- Hot water
- Safety goggles
- lab apron
- Heat resistant gloves or hot mitts
- 250 mL beaker
- 400–600 mL beaker

1 Thinking about what you will do

WARNING — This lab contains chemicals that may be harmful if misused. Read cautions on individual containers carefully. Not to be used by children except under adult supervision.

a. The cetyl alcohol you will be using is a pure substance. What do you expect to observe in terms of the temperature range for the freezing/melting point?

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b. Suppose your cetyl alcohol sample became contanimated with another substance. How would this affect the freezing/melting point?

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2 Melting cetyl alcohol

1. Fill a 250 mL beaker with cold water.
2. Fill a 400 to 600 mL beaker with approximately 250 mL of hot water (75–80 °C).
3. Measure out approximately 4-5 grams of cetyl alcohol in a test tube.
4. Measure the temperature of the hot water to make sure it is within the range in step 1.

5. Quickly immerse the temperature probe into the cold water. Then remove and dry it making sure it is cooled to room temperature.
6. Place the temperature probe into the test tube and put the test tube containing the solid into the water bath and press START on the Data Collector. View the experiment in graph mode.
7. Stir the solid vigorously with the temperature probe.
8. Continue to stir as long as some solid remains.
9. Once all of the material is liquid, stop and store the experiment. Record the experiment name assigned by the Data Collector.
10. Leave the sample in the warm water for use in Part 4.

3 Stop and think

a. Predict the effect of sample size on the melting/freezing point.

b. Describe and carefully sketch the shape of the graph from Part 2.

4 Freezing cetyl alcohol

1. Observe the cetyl alcohol in the test tube to make sure it is still all liquid. If some solid has formed, pour out the water in the warm beaker and add more warm water.
2. Remove the test tube from the warm beaker and start a new experiment on the data collector.
3. Stir the liquid vigorously with the temperature probe as the solid begins to form.
4. Continue to stir until all of the liquid turns into a solid. (NOTE: If you need to repeat any part of the experiment, you may re-use your sample.)
5. When you are finished recording data return your sample of cetyl alcohol to your teacher.
6. Record the name of the experiment from the data collector in your notebook.

5 Thinking about what you observed

a. Describe and carefully sketch the graph from Part 4.

b. Referring to both of your graphs, determine the melting and freezing point of cetyl alcohol. Are they the same? Should they be?

c. Based on the shapes of your curves, which data do you think is more reliable - the heating or cooling data? Why do you think this is so?

d. What is happening to the molecules of cetyl alcohol during the diagonal portions of the heating curve? What about the plateau?

e. Your graph from Part 2 shows that during a change from solid to liquid, the temperature stays the same. Explain why the temperature does not increase, even though energy is being added.

11A Temperature and Heat

How are temperature and heat related?

Hot and cold are familiar sensations. What happens when something hot comes in contact with something cold? Think about putting some ice cubes in a drink. Things don't remain the same, changes occur and these changes have to do with the movement of energy from one material to the other. This investigation will explore the difference between temperature and thermal energy, and how the movement of thermal energy relates to the concept of heat.

Materials

- Temperature probe
- Data Collector
- Digital balance
- Aluminum cube from density kit
- 3 x 12-oz. foam cups
- Ice
- Hot water
- Tongs
- 100 mL graduated cylinder
- Safety goggles
- Lab apron

1 Making a prediction

Suppose you mix equal masses of water. One sample is at 0 °C and the other is at 50 °C. What do you think the final temperature of the mixture will be? Why?

2 Mixing hot and cold water

1. You will need three 12 ounce foam cups for this experiment. Label two of the cups as follows: HOT and COLD.
2. Prepare an ice bath by placing approximately 250mL of water in the unlabeled cup and add 4 or 5 ice cubes.
3. Connect the temperature probe to the Data Collector and select Meter mode for this experiment.
4. Place the temperature probe in the ice water bath.
5. Use a graduated cylinder to measure 100 mL of very hot tap water. Pour the hot water into the HOT cup.
6. Use a graduated cylinder to measure 100 mL of the ice water. Pour the cold water into the COLD cup.
7. Place the temperature probe into the COLD cup, wait until the reading stabilizes and record the temperature in Table 1.
8. Place the temperature probe into the HOT cup. Wait until the reading stabilizes and record the temperature in Table 1.
9. Immediately pour the hot water into the cold water. This is the mixture.
10. Stir well using the temperature probe and measure the final temperature (when it has stabilized). Record your data in Table 1.
11. Do not throw away your ice water. You will be using it again in the second part of the investigation.

Table 1: Temperature data for mixing equal masses of water

Cold water temp. (ºC)	Hot water temp. (ºC)	Mixture temp. (ºC)

3 Thinking about what you observed

a. Did the result of your experiment agree with your prediction (within 3 degrees)? Discuss why the temperature value may not have matched exactly your predicted value.

b. How do you think your results would have been different if you had used more hot water than cold water, instead of equal masses?

4 Making another prediction

Suppose you mix equal masses of cold water and hot metal. Will the final temperature follow the same pattern as the experiment you did in Part 2? Explain your answer.

5 Combining hot metal and cold water

1. Find the mass of the aluminum cube and record in Table 2.
2. Connect the temperature probe to the Data Collector and select Meter mode for this experiment.
3. Place the temperature probe in the ice water bath that was left from part 2 of the experiment.
4. Place the aluminum cube in a foam cup and cover it with very hot tap water. Let the aluminum cube stay in the hot water for several minutes so it gets warm.
5. Measure out a mass of water from the ice water bath that is equal to the mass of the aluminum cube and pour it into a foam cup. Record the mass of the cold water in Table 2. Make sure there is no ice in the foam cup of cold water.
6. Move the temperature probe from the ice water bath to the cup of cold water and record the temperature of the cold water in Table 2.

7. Record the temperature of the hot water and aluminum cube just before putting the cube in the cup of cold water. Record the value in Table 2.
8. Use the tongs to put the aluminum cube in the foam cup containing the cold water.
9. Stir the mixture with the temperature probe.
10. Record the temperature of the cold water and metal cube when the temperature has stabilized. Do not wait longer than one minute to measure the temperature. Record this value in Table 2.

Table 2: Temperature data for combining water and metal

Metal mass (g)	Metal temp. before mix (°C)	Cold water mass (g)	Cold water temp. before mix (°C)	Mixture temp. (°C)

6 Thinking about what you observed

a. Why didn't the temperature of the water and aluminum mixture come out halfway between the temperature of the cold water and hot aluminum cube, even though you mixed equal masses?

b. Explain what is happening between the aluminum cube and water in terms of temperature and energy.

c. How much energy does it take to raise the temperature of one gram of aluminum by 1 °C compared to raising the temperature of one gram of water by 1 °C? (Look up this value.) Relate your answer back to your experimental results.

d. Heat and temperature are related, but they are not the same thing. According to your results, what does the concept of heat energy take into account that temperature does not?

11B The Specific Heat of a Metal

How can you use specific heat to identity an unknown metal sample?

If you have ever walked barefoot on a concrete walkway or street during the summertime, you have felt its warmth on your feet. In fact, the thermal energy transferred to your feet may send you retreating to the grass or even a swimming pool. Why is the temperature of the concrete so different compared to the temperature of the soil or the swimming pool? Even though the sunlight shines on all three surfaces, it is easier to raise the temperature of concrete compared to the water in a swimming pool. A hot summer day may only raise the temperature in a pool by one or two degrees.

In this experiment, you will use a calorimeter, the specific heat of water, and the law of conservation of energy to determine the specific heat of a sample of copper and two unknown metal samples.

Materials

- Data Collector
- Temperature probe
- 3 Foam Cups (with or without lids)
- Balance
- Safety goggles
- Lab Apron
- Metal Samples (from Density cubes kit): Copper, 2 unknown samples
- Hot water
- Tongs

1 Doing the experiment

1. Place your sample of copper on the balance and record its mass in Table 1.
2. Make a calorimeter by nesting two foam cups.
3. Pour about 150 mL of room temperature water into the calorimeter. Use the balance to measure and record the mass of the water you add to the calorimeter (Density of water = 1g/mL). (Note: Make sure there is sufficient water in the calorimeter to submerge your metal samples COMPLETELY).
4. Fill a styrofoam cup 2/3 with hot water.
5. Place your sample of copper into the cup with hot water. Allow the copper sample to sit in the water for about a minute so it will get warmed by the hot water.
6. Use the temperature probe to measure the temperature of the hot water, and record this temperature once it stabilizes as the initial temperature of the metal in Table 1.
7. Place the temperature probe in the calorimeter. When the temperature stabilizes record it as the initial temperature of water. Leave the temperature probe in the calorimeter.
8. Use the tongs to remove the copper from the hot water and place the copper into the calorimeter. Try to transfer as little hot water as possible into the calorimeter when moving the copper. Go as quickly as possible but do not spill any hot water.
9. Once the temperature stabilizes, record the final temperature in Table 1.
10. Repeat steps 1–9 with each unknown metal provided by your teacher. You may be asked to conduct two trials with your unknown samples, if time allows.

Table 1: Mass and temperature data

	Copper	Unknown Metal # 1	Unknown Metal # 2
Mass of Metal (g)			
Mass of Water in Calorimeter (g)			
Initial Temperature of Water (ºC)			
Initial Temperature of Metal (ºC)			
Final Temperature of Mixture (ºC)			

2 Processing the Data

a. Calculate the temperature change of the water.

b. Calculate the temperature change of the metal.

c. Calculate the heat gained by the water using the equation below:

HEAT EQUATION

$$E = mC_p\,(T_2 - T_1)$$

Where: E = thermal energy (Joules) lost or gained by the water in the calorimeter
m = original mass of the measured water in the calorimeter
C_p = specific heat of water (4.184 J/g °C)
T_2 - T_1 = change in temperature of the water (also referred to as ΔT)

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d. The amount of energy released by the metal is equal to the energy absorbed by the water. Knowing the value of E for the metal, calculate the specific heat (C_p) of the metal. (Remember, since the energy is being released by the metal, change the sign of E from answer #3 to use for #4).

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e. Identify your unknown metal(s) by comparing your calculated value of its specific heat to known specific heat values of common metals provided by your teacher.

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f. Calculate the percent error for your unknown sample(s).

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3 Thinking about what you observed

a. What did you determine was the identity of your unknown metal(s)?

b. Looking at your data/class data, were the experimental values too high or too low? Based on the experimental procedure, give an explanation for your observations.

c. How does the Law of Conservation of Energy allows us to make the calculations needed to determine the specific heat of the mystery metal?

d. The second unknown metal sample you tested is an alloy containing up to 80% of one of the other two metals you tested. The specific heat of this alloy should be almost the same as ***one*** of the other two metals. According to your results, which metal makes up 80% of the second unknown metal?

e. Water has a high specific heat. How does the fact that humans are largely made up of water help us regulate our body temperature?

12A Mystery Material

How do solids and liquids differ?

Review, in your mind, what you know about solids and liquids. You know, for example, that liquids do not keep their shape. They flow. Solids do not flow, they keep their shape. Consider the possibility of a material that is able to act like both a solid and a liquid. Could that be? In this investigation, you will not only consider the possibility, but actually play with such a material.

Materials

- Wax paper or small plastic bowls
- Mystery material

1 Doing the experiment

1. Your teacher will give you a sample of mystery material on a piece of wax paper or in a small plastic bowl.
2. Feel it. Smell it. Look at it. Use your senses to make as many observations as you can. Write down your observations in Table 1.

Table 1: Observations about the Mystery Material

1.	7.
2.	8.
3.	9.
4.	10.
5.	11.
6.	12.

2 Thinking about what you observed

a. What happens when you squeeze the mystery material and when you release it?

b. How does this material mimic some of the properties of solids and liquids?

c. The mystery material is made of only two ingredients - cornstarch and water. Using your answer from #1, what do you think is happening to the cornstarch and water when you squeeze it and let go? Or when you hit it quickly or stick your finger slowly into it?

d. A colloidal suspension is a suspension of tiny particles of one substance in a medium of another substance. (The suspension remains intact indefinitely because it is unaffected by gravity). Based on your observations and the first part of this definition, is the cornstarch and water mixture a colloidal suspension?

3 Stop and Think

a. How is the cornstarch and water mixture similar to quicksand?

b. Why does a substance that acts as both a solid and a liquid seem unusual?

c. Can you think of any common material/products that might act as both a solid and a liquid?

12B Buoyancy

Can you make a clay boat?

A solid material will float if it is less dense than the liquid in which it is immersed, and sink if it is denser than the liquid. You may have noticed, however, that ships are often made of steel, which is obviously denser than water. So how does a steel boat float? In this investigation, you will experiment with modeling clay to discover how and why boats can be made of materials that are denser than water.

Materials

- Stick of clay (1/2 stick can be used as well)
- Centimeter ruler
- Displacement tank
- 250 mL beaker for overflow
- Water
- Paper towels, sponges
- 100 mL graduated cylinder
- Balance
- Disposable cup to catch displaced water when refilling tank
- Dishpan or shallow bucket for testing clay boats
- Wax paper, for ease of cleanup

1 Measuring your stick of clay

Take your stick of clay and find its density. Use a balance to measure its mass. Use the length × width × height method to calculate its volume. Record your measurements in Table 1.

Volume = length × width × height

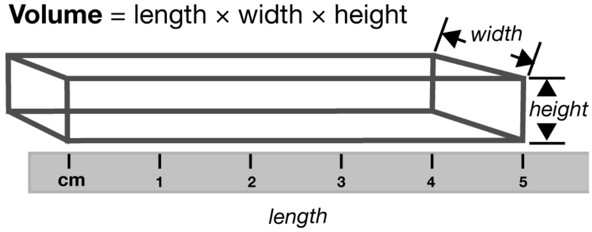

Table 1: Mass, volume, and density of clay stick data

length (cm)		width (cm)		height (cm)		Volume (cm^3)
	×		×		=	

Mass (g)		Volume (cm^3)		Density (g/cm^3)
	÷		=	

a. The density of water is 1g/cm^3. How does the density of your clay compare to water?

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b. Make a prediction: Will your stick of clay sink or float? Why?

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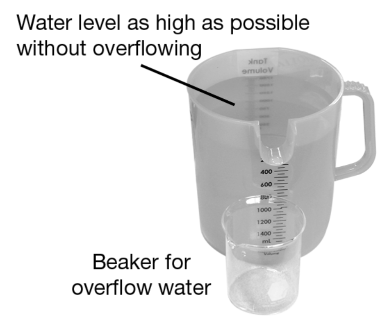
2 Doing the Experiment

A. Testing your prediction

1. Prepare the displacement tank for use. Fill it all the way up until it just starts to overflow. Once it stops remove the cup that was catching the overflow water.
2. Place a dry beaker under the spout to catch the overflow from your clay.
3. Gently put your stick of clay in the water. Did your stick of clay sink or float?



B. Finding the mass and volume of the displaced water

1. Pour the displaced water from the beaker into a 100-mL graduated cylinder. Record the volume in Table 2.
2. Now, calculate the mass of the displaced water using water's density and the volume of displaced water you measured. Record this value in Table 2.

C. Calculating the weight of your clay and the displaced water

Mass and weight measure two different properties of matter. Mass refers to how much matter the object contains. Weight measures the gravitational pull between the object and (in our case) Earth. The gravitational force between a 1-kilogram object and Earth is 9.8 newtons. So a 1-gram object's weight on Earth is 0.0098 newtons.

1. Use the mass of your clay to calculate its weight. Use the formula below and record the mass and weight in Table 2.

mass in grams x (0.0098 N/g) = weight in Newtons

2. Calculate the weight of the displaced water. Use the formula above and record your data in Table 2.

Table 2: Mass and volume of clay and displaced water

	Mass of clay (g)	Weight of clay (N)	Volume of displaced water (mL)	Mass of displaced water (g)	Weight of displaced water (N)
Stick of clay					
Clay boat					

3 Challenge: Can you mold your clay into a shape that floats?

For this part of the investigation, you must use ALL of your clay. Mold it into a shape that you believe will float. Before you do, make a prediction;
How much water will the boat displace compared to the stick of clay?

1. When you are ready to test a shape, lower it into a container of water approximately three-quarters full. If the clay sinks, retrieve it immediately and dry it with a paper towel. Avoid mixing water into your clay, or it will get very slimy. Keep trying until you get a boat that floats.
2. When you have successfully molded a boat that floats, take it out of the water and dry it with a paper towel. Then, prepare your displacement tank just as you did in step 2A.
3. Carefully place your boat into the displacement tank. Avoiding making waves. When the water stops flowing, move the beaker away from the displacement tank spout. Safely remove a little water from the displacement tank so it doesn't overflow, retrieve your boat and set it aside to dry.
4. Pour the displaced water from the beaker into a graduated cylinder. Record its volume in Table 2.
5. Use the density of water to calculate the mass of the displaced water. Calculate its weight using the formula from C1. Record both the water's mass and weight in Table 2.
6. When your boat is dry, first measure its mass, then calculate its weight using the formula from C1. Record both the mass and weight in Table 2.

4 Analyzing your data

a. Did the weight of the clay change during the investigation? Give a reason for your answer.

b. Which displaced more water – the stick of clay or the clay boat and how much?

c. Which weighed more – the stick of clay or the water it displaced and how much more?

d. Which weighed more – the clay boat or the water it displaced and how much more?

5 Why the boat floats

Use your mass and volume data from Table 2 to calculate the apparent density of your clay boat. This value is called the *apparent* density because the total volume of the floating boat is not displaced. The part of your floating boat that is above the surface isn't displacing any water. To find out how much of the boat is below the surface and **is** displacing water, look at the total amount of water you measured that spilled out into the beaker when the boat was floating.

Table 3: Data for boat

Mass of boat (g)	Volume of water displaced by the boat (mL)	Apparent density of the boat (g/mL)

6 Thinking about what you observed

a. Which displaced more water, the stick of clay or the floating clay boat?

b. Assuming the mass of the clay did not change, how do you explain the difference in the volumes displaced by the stick of clay and the clay boat?

c. Look at the boat's apparent density. Why is it different than the density of the stick of clay? What other substance has a density very similar to the boat's apparent density?

d. Out of all the properties you measured and calculated in this investigation, which property tells you the most about weather an object or material will float in water, and how would you use that property to determine weather it will float?

e. Explain why a solid stick of clay sinks but a clay boat can be made to float.

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f. What would happen if you added "cargo," like pennies, to your boat? Is there a limit to how much mass you can add before the boat sinks? Does the volume of displaced water increase or decrease when the boat gets heavier? Why? Try the experiment.

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13A Boyle's Law

How are pressure and volume of a gas related?

Robert Boyle (1627-1691) conducted a series of experiments to investigate the physical properties of air. It was through these experiments he discovered the relationship between pressure and volume for an enclosed gas. Using a simple experiment, we will measure the pressure of a gas inside a syringe with a gas pressure sensor. You will use your data to derive the mathematical relationship between the pressure and volume of an enclosed gas at constant temperature.

Materials

- Gas pressure sensor
- Gas law kit
- Data Collector

1 Thinking about pressure and volume

a. When you blow up a balloon, what happens to the volume of air inside the balloon?

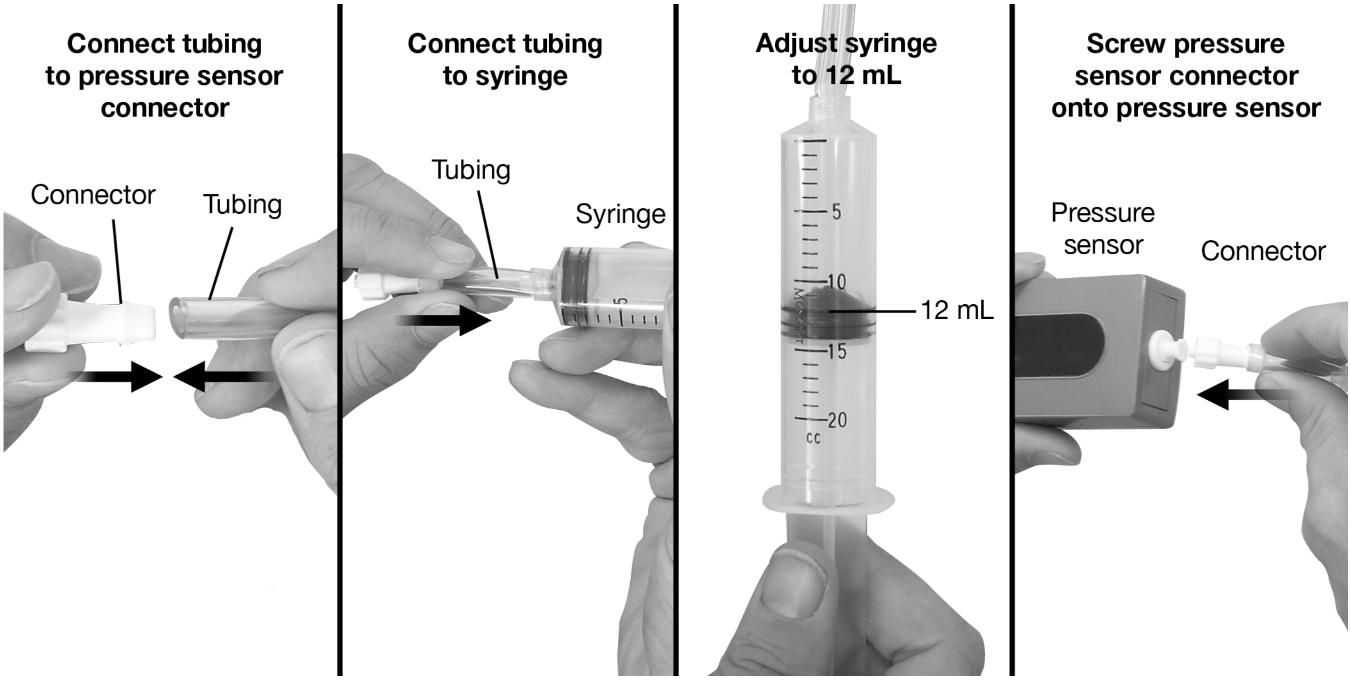
b. What about the pressure? Does the pressure increase, decrease, or stay the same?

c. Now think about both pressure and volume together. Make a hypothesis about the relationship between pressure and volume of an enclosed gas. (Hint: When volume changes, what do you think happens to pressure?)

2 Setting up the experiment

1. Connect the 4 cm piece of tubing to the pressure sensor connector as shown.
2. Connect the other end of the tubing to the syringe.
3. Adjust the syringe until the volume of air is 12.0 mL.

4. Screw the pressure sensor connector onto the pressure sensor.



3 Doing the experiment

1. Start the data collector. Record the pressure at 12.0 mL (in kPa) in Table 1.
2. Pull the syringe out until it measures 16.0 mL. Hold it until the pressure stabilizes. Again, record the pressure in Table 1.
3. Repeat Step 3 for volumes of 18.0 mL and 10.0 mL.
4. Repeat Step 3 with a volume of 6.0 mL, however, take the measurement quickly to prevent air from escaping.
5. Stop the data collection. Do not disconnect the syringe from the sensor yet!

Table 1: Pressure and volume data

Volume (mL)	Pressure (kPa)	P • V (kPa • mL)	P/V (kPa/mL)
6.0 mL			
10.0 mL			
12.0 mL			
16.0 mL			
18.0 mL			

4 Graphing your data

a. Use your data to make a graph of pressure vs. volume.

Title: ____

y label: ____________________

x label: ____________________

b. Does the graphical model support your hypothesis? Explain your answer.

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c. What happens to the pressure of an enclosed gas when the volume increases?

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5 Finding a relationship between pressure and volume

a. Multiply the pressure and volume values for each trial and record the values in the third column of Table 1. Remember to use appropriate numbers of significant figures.

b. Divide the pressure by the volume for each trial and record the values in the last column of Table 1. Again, use the correct number of significant figures.

c. Boyle's law states that there is a mathematical relationship between pressure and volume that always equals a constant value. Based on your calculations, is that relationship $P \times V$ or P/V?

d. According to your data, what is the constant value?

6 Using Boyle's law to make a prediction

a. Using your constant value, calculate what the pressure would be when the volume of the syringe is set to 14.0 mL.

b. Using your graph, what is the pressure that corresponds to 14.0 mL? How does this compare to your calculated value?

c. Test your predicted pressure value for 14.0 mL. How do the values compare?

13B Pressure and Temperature Relationship

How are temperature and pressure of a gas related?

Gas molecules are in constant motion. When the temperature of a gas increases, the molecules move faster. When this happens, the velocity and number of molecular collisions increases. The opposite is true for a gas when the temperature decreases. In this experiment, you will study the relationship between the pressure a gas exerts and the temperature of the gas.

Materials

- Gas pressure sensor
- single-hole rubber stopper/tube assembly
- Temperature probe
- Data collector
- 125-mL Erlenmeyer flask
- Large cup or 500-mL beaker
- Cold water
- Hot water
- Safety goggles

1 Thinking about temperature and pressure

a. Car manuals tell you to inflate the tires to a certain pressure when the tires are cold (before driving around on them). Why do you think this is important?

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b. Make a hypothesis about the relationship between pressure and temperature of an enclosed gas. (Hint: When temperature increases, what do you think happens to the pressure?)

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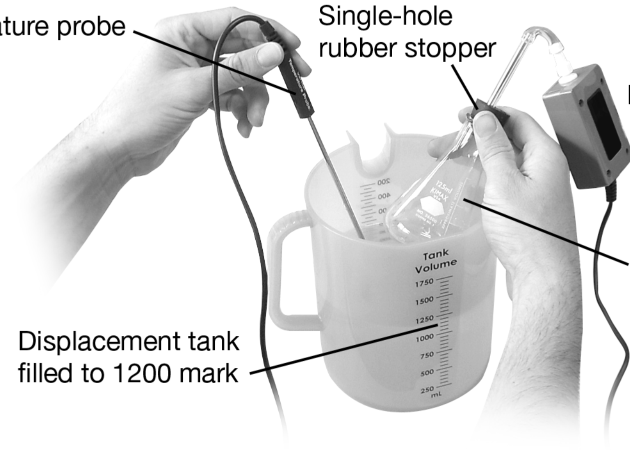
2 Setting up the experiment

1. Fill the displacement tank with ice cold water to the 1200 mL mark.
2. Place a temperature probe in the water and connect the probe to the Data Collector. The water temperature should be about 10–12 °C, but any cold starting temperature is fine.
3. Place the rubber stopper/tube assembly into the 125-mL Erlenmeyer flask. Attach the pressure sensor to the tube.

4. Connect the pressure sensor to the Data Collector.



3 Doing the experiment

1. Place the flask into the cold water bath and allow to sit for 2 min. Record the temperature and pressure in Table 1.
2. Take the flask out of the water. Use a container to remove 400 mL of water from the displacement tank.
3. Get 400 mL of hot water from your teacher and pour it into the displacement tank.
4. Place the flask into this warmer water and wait 2 min. Record the temperature and pressure in Table 1.
5. Repeat steps 2–4 two more times so you have a total of 4 data points.
6. Convert Celsius temperatures to Kelvin and record in Table 1.

Table 1: Pressure and temperature data

Pressure (kPa)	Temperature (°C)	Temperature (K)	P/T (kPa/K)	P • T (kPa • K)

4 Graphing your data

a. Use your data to make a graph of pressure vs. temperature.

Title: ______________________________

y label: ______________________________

x label: ______________________________

b. Does the graphical model support your hypothesis? Explain your answer.

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c. What happens to the pressure of an enclosed gas when the temperature increases?

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5 Finding a relationship between pressure and temperature

a. Divide the pressure and temperature values for each trial and record the answers in the fourth column of Table 1. Remember to use appropriate numbers of significant figures.

b. Multiply the pressure by the temperature for each trial and record the values in the last column of Table 1. Again, use the correct number of significant figures.

c. There is a mathematical relationship between pressure and temperature that always equals a constant value. Based on your calculations, is that relationship P/T or P × T?

d. According to your data, what is the constant value?

6 Using the pressure-temperature relationship to make a prediction

a. Using your constant value, calculate what the pressure of the air in the flask would be when the temperature is 333K.

b. Using your graph, what is the pressure that corresponds to 333K? How does this compare to your calculated value?

c. How would you use the experiment setup to test your predicted pressure value for 333K?

7 Thinking about what you observed

a. You used a water bath to change the temperature of the air in the flask. Draw a diagram of the experiment setup and use arrows to show the heat transfer that took place when more and more hot water was added to the displacement tank.

b. What two factors in the experiment were constant?

c. Go back to your answer to question 1a. Would you answer the question the same way now? Explain.