To the Student

Chemistry is the science of matter, its properties, and changes. In your classroom work in chemistry, you will learn a great deal of the information that has been gathered by scientists about matter. But chemistry is not just information. It is also a process for finding out more about matter and its changes. Laboratory activities are the primary means that chemists use to learn more about matter. The activities in the *Chemistry Small-Scale Laboratory Manual* require that you form and test hypotheses, measure and record data and observations, analyze those data, and draw conclusions based on those data and your knowledge of chemistry. These processes are the same as those used by professional chemists and all other scientists.

Chemistry Small-Scale Laboratory Manual activities use the latest development in laboratory techniques—small-scale chemistry. In small-scale chemistry, you often use plastic pipettes and microplates instead of large glass beakers, flasks, and test tubes. You also use small amount of chemicals in reactions. Still, when working with small-scale chemistry, you should use the same care in obtaining data and making observations that you would use in large-scale laboratory activities. Likewise, you must observe the same safety precautions as for any chemistry experiment.

Organization of Activities

- **Introduction** Following the title and number of each activity, an introduction provides a background discussion about the problem you will study in the activity.
- **Problem** The problem to be studied in this activity is clearly stated.
- **Objectives** The objectives are statements of what you should accomplish by doing the investigation. Recheck this list when you have finished the activity.
- **Materials** The materials list shows the apparatus you need to have on hand for the activity.
- **Safety Precautions** Safety symbols and statements warn you of potential hazards in the laboratory. Before beginning any activity, refer to page vii to see what these symbols mean.
- **Pre-Lab** The questions in this section check your knowledge of important concepts needed to complete the activity successfully.
- **Procedure** The numbered steps of the procedure tell you how to carry out the activity and sometimes offer hints to help you be successful in the laboratory. Some activities have **CAUTION** statements in the procedure to alert you to hazardous substances or techniques.
- **Hypothesis** This section provides an opportunity for you to write down a hypothesis for this activity.
- **Data and Observations** This section presents a suggested table or form for collecting your laboratory data. Always record data and observations in an organized way as you do the activity.
- **Analyze and Conclude** The Analyze and Conclude section shows you how to perform the calculations necessary for you to analyze your data and reach conclusions. It provides questions to aid you in interpreting data and observations in order to reach an experimental result. You are also asked to form a scientific conclusion based on what you actually observed, not what "should have happened." An opportunity to analyze possible errors in the activity is also given.
- **Real-World Chemistry** The questions in this section ask you to apply what you have learned in the activity to other real-life situations. You may be asked to make additional conclusions or research a question related to the activity.

Small-Scale Laboratory Techniques

Small-scale chemistry uses smaller amounts of chemicals than do other chemistry methods. The hazards of glass have been minimized by the use of plastic labware. If a chemical reaction must be heated, hot water will provide the needed heat. Open flames or burners are seldom used in microchemistry techniques. By using small-scale chemistry, you will be able to do more experiments and have a safer environment in which to work.

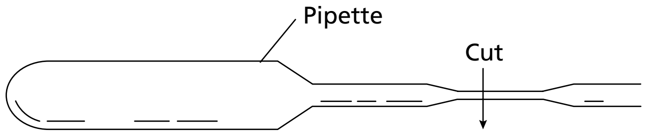
Small-scale chemistry uses two basic tools.

The Microplate

The first is a sturdy plastic tray called a microplate. The tray has shallow wells arranged in rows (running across) and columns (running up and down). These wells are used instead of test tubes, flasks, and beakers. Some microplates have 96 wells; other microplates have 24 larger wells.

The Plastic Pipette

Small-scale chemistry uses a pipette made of a form of plastic that is soft and very flexible. The most useful property of the pipette is the fact that the stem can be stretched without heating into a thin tube. If the stem is stretched and then cut with scissors, the small tip will deliver a tiny drop of reagent. You may also use a pipette called a microtip pipette, which has been pre-stretched at the factory. It is not necessary to stretch a microtip pipette.



Cutting a stretched pipette

The pipette can be used over and over again simply by rinsing the stem and bulb between reagents. The plastic inside the pipette is non-wetting and does not hold water or solutions the way glass does.

The Microplate Template and Microplate Data Form

Your teacher can provide you with Microplate Templates and Microplate Data Forms whenever you carry out an activity that requires them.

To help you with your observations, place the Microplate Template beneath your 24-well or 96-well microplate. The template is marked with the correct number of wells, and each row and column is labeled to help guide you with your placement of chemicals from the micropipettes. The white paper background provided by the template allows you to observe color changes and precipitate formations with ease.

Use Microplate Data Forms to write down the chemicals used and to record your observations of the chemical reactions that occur in each well.

Waste Disposal

Discard all substances according to your teacher's instructions. All plastic small-scale chemistry equipment can be washed with distilled water for reuse.

Safety in the Laboratory

The chemistry laboratory is a place to experiment and learn. You must assume responsibility for your own personal safety and that of people working near you. Accidents are usually caused by carelessness, but you can help prevent them by closely following the instructions printed in this manual and those given to you by your teacher. The following are some safety rules to help guide you in protecting yourself and others from injury in a laboratory.

1. The chemistry laboratory is a place for serious work. Do not perform activities without your teacher's permission. **Never** work alone in the laboratory. Work only when your teacher is present.
2. Study your lab activity **before** you come to the lab. If you are in doubt about any procedures, ask your teacher for help.
3. Safety goggles and a laboratory apron must be worn whenever you work in the lab. Gloves should be worn whenever you use chemicals that cause irritations or can be absorbed through the skin.
4. Contact lenses should not be worn in the lab, even if goggles are worn. Lenses can absorb vapors and are difficult to remove in an emergency.
5. Long hair should be tied back to reduce the possibility of it catching fire.
6. Avoid wearing dangling jewelry or loose, draping clothing. The loose clothing may catch fire and either the clothing or jewelry could catch on chemical apparatus.
7. Wear shoes that cover the feet at all times. Bare feet or sandals are not permitted in the lab.
8. Know the location of the fire extinguisher, safety shower, eyewash, fire blanket, and first-aid kit. Know how to use the safety equipment provided for you.
9. Report any accident, injury, incorrect procedure, or damaged equipment immediately to your teacher.
10. Handle chemicals carefully. *Check the labels of all bottles **before** removing the contents.* Read the labels three times: before you pick up the container, when the container is in your hand, and when you put the bottle back.
11. Do **not** return unused chemicals to reagent bottles.
12. Do **not** take reagent bottles to your work area unless specifically instructed to do so. Use test tubes, paper, or beakers to obtain your chemicals. Take only small amounts. It is easier to get more than to dispose of excess.
13. Do **not** insert droppers into reagent bottles. Pour a small amount of the chemical into a beaker.
14. **Never** taste any chemical substance. **Never** draw any chemicals into a pipette with your mouth. Eating, drinking, chewing gum, and smoking are prohibited in the laboratory.
15. If chemicals come into contact with your eyes or skin, flush the area immediately with large quantities of water. Immediately inform your teacher of the nature of the spill.
16. Keep combustible materials away from open flames. (Alcohol and acetone are combustible.)
17. Handle toxic and combustible gases only under the direction of your teacher. Use the fume hood when such materials are present.
18. When heating a substance in a test tube, be careful not to point the mouth of the tube at another person or yourself. Never look down the mouth of a test tube.
19. Use caution and the proper equipment when handling hot apparatus or glassware. Hot glass looks the same as cool glass.
20. Dispose of broken glass, unused chemicals, and products of reactions only as directed by your teacher.
21. Know the correct procedure for preparing acid solutions. ***Always** add the acid slowly to the water*.
22. Keep the balance area clean. Never weigh chemicals directly on the pan of the balance.
23. Do **not** heat graduated cylinders, burettes, or pipettes with a laboratory burner.
24. After completing an activity, clean and put away your equipment. Clean your work area. Make sure the gas and water are turned off. Wash your hands

Chemistry uses safety symbols to alert you to possible laboratory dangers. These symbols are provided in the textbook and are explained below. Be sure you understand each symbol before you begin an activity that displays a symbol.

SAFETY SYMBOLS	HAZARD	EXAMPLES	PRECAUTION	REMEDY
DISPOSAL	Special disposal procedures need to be followed.	certain chemicals, living organisms	Do not dispose of these materials in the sink or trash can.	Dispose of wastes as directed by your teacher.
BIOLOGICAL	Organisms or other biological materials that might be harmful to humans	bacteria, fungi, blood, unpreserved tissues, plant materials	Avoid skin contact with these materials. Wear mask or gloves.	Notify your teacher if you suspect contact with material. Wash hands thoroughly.
EXTREME TEMPERATURE	Objects that can burn skin by being too cold or too hot	boiling liquids, hot plates, dry ice, liquid nitrogen	Use proper protection when handling.	Go to your teacher for first aid.
SHARP OBJECT	Use of tools or glassware that can easily puncture or slice skin	razor blades, pins, scalpels, pointed tools, dissecting probes, broken glass	Practice common-sense behavior and follow guidelines for use of the tool.	Go to your teacher for first aid.
FUME	Possible danger to respiratory tract from fumes	ammonia, acetone, nail polish remover, heated sulfur, moth balls	Make sure there is good ventilation. Never smell fumes directly. Wear a mask.	Leave foul area and notify your teacher immediately.
ELECTRICAL	Possible danger from electrical shock or burn	improper grounding, liquid spills, short circuits, exposed wires	Double-check setup with teacher. Check condition of wires and apparatus.	Do not attempt to fix electrical problems. Notify your teacher immediately.
IRRITANT	Substances that can irritate the skin or mucous membranes of the respiratory tract	pollen, moth balls, steel wool, fiberglass, potassium permanganate	Wear dust mask and gloves. Practice extra care when handling these materials.	Go to your teacher for first aid.
CHEMICAL	Chemicals that can react with and destroy tissue and other materials	bleaches such as hydrogen peroxide; acids such as sulfuric acid, hydrochloric acid; bases such as ammonia, sodium hydroxide	Wear goggles, gloves, and an apron.	Immediately flush the affected area with water and notify your teacher.
TOXIC	Substance may be poisonous if touched, inhaled, or swallowed	mercury, many metal compounds, iodine, poinsettia plant parts	Follow your teacher's instructions.	Always wash hands thoroughly after use. Go to your teacher for first aid.
OPEN FLAME	Open flame may ignite flammable chemicals, loose clothing, or hair	alcohol, kerosene, potassium permanganate, hair, clothing	Tie back hair. Avoid wearing loose clothing. Avoid open flames when using flammable chemicals. Be aware of locations of fire safety equipment.	Notify your teacher immediately. Use fire safety equipment if applicable.

Eye Safety
Proper eye protection should be worn at all times by anyone performing or observing science activities.

Clothing Protection
This symbol appears when substances could stain or burn clothing.

Radioactivity
This symbol appears when radioactive materials are used.

Handwashing
After the lab, wash hands with soap and water before removing goggles.

Specific Heat of Metals

Heat flows from a warmer object to a cooler object. As heat flows, the temperature of the warmer object decreases and the temperature of the cooler object increases. The magnitude of the temperature change depends in part upon what each object is made of. Objects that experience a large temperature change when they absorb or release a given amount of heat have a low specific heat. Objects that experience a small temperature change for a given amount of heat transfer have a high specific heat.

Problem

How can you use water to measure the specific heat of metals?

Objectives

- **Construct** a calorimeter.
- **Measure** changes in the temperature of water in the calorimeter when warmer metals are added.
- **Calculate** the specific heat of each metal.

Materials

aluminum, iron, and lead samples
plastic-foam cups (2)
400-mL beakers (2)
100-mL graduated cylinder
large test tubes (3)
boiling chips
scissors
balance
hot plate
thermometer
test-tube rack

Safety Precautions

- **Always wear safety goggles, gloves, and a lab apron.**
- **Broken glassware may have sharp edges. Be careful when using scissors.**
- **Use caution and proper protection when handling hot objects.**
- **Avoid spilling water on the hot plate power cord.**
- **Wipe up any water spills immediately to avoid slipping.**

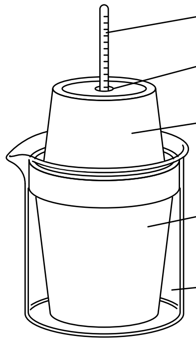
Pre-Lab

1. Define *specific heat*.
2. A sample of substance X has a mass of 123 g. When the sample releases 795 J of heat, its temperature falls from 45.1°C to 17.6°C. What is the specific heat of substance X?
3. What is a calorimeter?
4. Why is it important that a calorimeter be made of an insulating material?
5. Read the entire laboratory activity. Form a hypothesis about which of the three metals will cause the largest change in water temperature for its mass. Explain your reasoning. Record your hypothesis on page 46.

Procedure

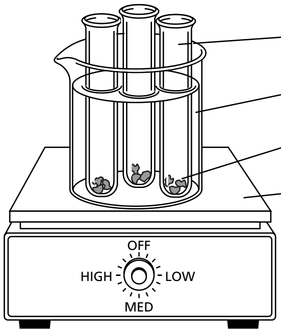
1. Use scissors to remove the lip from one of the plastic-foam cups. As shown in **Figure A,** this cup will be the top of the calorimeter. Invert it and set it on top of the other cup, which will be the bottom of the calorimeter.
2. Use a pencil to punch a hole in the center of the top of the calorimeter. The hole should be large enough to hold the thermometer.
3. Place the calorimeter in one of the beakers to keep it from tipping over.
4. Measure the mass of each metal sample to the nearest 0.1 g. Record the masses in **Data Table 1.** Place each metal in a separate test tube, and label each tube.

Figure A



5. Add about 300 mL of water and a few boiling chips to the second beaker. Place all three test tubes in the beaker, as shown in **Figure B.**
6. Be sure the water level in the beaker is above the tops of the metal samples. Add more water to the beaker if necessary, but do not allow any water to get into the test tubes.
7. Set the beaker of water and test tubes on the hot plate. Turn the hot plate on and heat the water to a boil.
8. While the water is heating, pour about 75 mL of cold water into the graduated cylinder. Measure the volume to the nearest 0.1 mL. Record the volume in the data table column for aluminum.
9. Pour the cold water into the calorimeter. With the top of the calorimeter off, measure the temperature of the water every minute until it stays the same for 3 min. Record this temperature as the initial water temperature in the data table column for aluminum.

Figure B



10. After the water has been boiling for 10 min, measure the temperature of the boiling water. You can assume that the metal samples are at the same temperature as the water. Record the temperature as the initial metal temperature in the data table columns for each metal. Keep the water boiling.
11. Use the test-tube holder to remove the test tube that contains the aluminum sample. **CAUTION: Carefully slide the aluminum into the water in the calorimeter without splashing.** Quickly put the top on the calorimeter.
12. Insert the thermometer through the hole in the calorimeter top until the tip of the thermometer touches the bottom of the calorimeter.
13. Gently swirl the beaker containing the calorimeter for 30 s while you monitor the temperature. Do not allow the metal sample to hit the thermometer. Record the highest temperature attained by the water as the final temperature in the data table column for aluminum.
14. Remove the aluminum sample from the calorimeter. Pour the water down the drain.
15. Repeat steps 8, 9, and 11–14 for the iron and lead samples.

Hypothesis

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Cleanup and Disposal

1. Turn off the hot plate. After the boiling water has cooled, pour it down the drain.
2. Dry the metal samples with a paper towel.
3. Make sure your balance is left in the same condition as you found it.
4. Return the metal samples and lab equipment to their proper places.
5. Wash your hands thoroughly with soap or detergent before you leave the lab.

Data and Observations

Data Table 1			
	Aluminum	Iron	Lead
Mass of metal (g)			
Volume of water (mL)			
Initial water temperature (°C)			
Initial metal temperature (°C)			
Final temperature (°C)			
Change in water temperature (°C)			
Change in metal temperature (°C)			
Heat gained by water (J)			
Specific heat, J/(g·°C)			

1. Calculate the change in water temperature caused by each metal by subtracting the initial water temperature from the final temperature. Record the results in **Data Table 1.**
2. Calculate the change in each metal's temperature by subtracting the final temperature from the initial metal temperature. Record the results in **Data Table 1.**
3. Use the equation in Section 16.1 of your textbook to calculate the amount of heat gained by the water from each metal. (To determine the mass of water, assume the density of water is 1.00 g/mL.) Record the results in **Data Table 1.**
4. Use the same equation to calculate the specific heat of each metal. (Rearrange the equation to solve for specific heat, and assume that the amount of heat lost by the metal equals the amount of heat gained by the water.) Record the results in **Data Table 1.**

Analyze and Conclude

1. **Applying Concepts** To calculate each metal's specific heat, you assumed that the amount of heat lost by the metal equals the amount of heat gained by the water. What factors determine whether this assumption is valid or not? (Hint: Identify the system and the surroundings in this experiment.)

2. **Drawing a Conclusion** For each metal, divide the change in water temperature by the mass of the metal. Use the results of this calculation to evaluate your hypothesis.

3. **Observing and Inferring** Which of these metals must release the most heat to experience a given decrease in temperature per gram of metal? Explain.

4. **Error Analysis** Compare the specific heats you calculated for aluminum, iron, and lead with the values given in **Table 16-2** of your textbook. Calculate the percent error if any. Explain possible sources of error in the lab.

Real-World Chemistry

1. Would a fishing sinker dropped into an ice-covered lake reach the temperature of the lake water more quickly if the sinker was made of iron or lead? Use your data on the specific heats of these metals to explain your answer. (Assume the sinkers have a starting temperature of 37°C and have the same shape and mass.)
2. It is possible to remove a sheet of aluminum foil from a hot oven with your bare hands without burning yourself. However, you will surely burn yourself if you touch a thick aluminum pan in the same oven with your bare hands. Why?
3. One way to identify the composition of metal fragments found at the site of an explosion is to measure the specific heat of the fragments. Suppose a fragment is found to have a specific heat of 0.129 J/(g·°C). Would this information alone be enough to identify the metal in the fragment? Explain why or why not. If not, suggest a method for identifying the metal that would not require any additional equipment.