Laboratory Program

Skills Practice Labs and Inquiry Labs

Working in the World of a Chemist

Meeting Today's Challenges

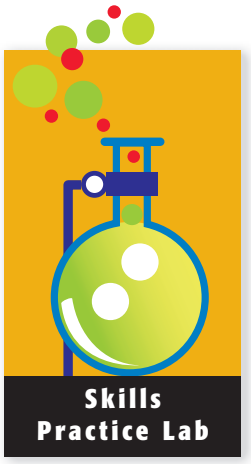
Even though you have already taken science classes with lab work, you will find the two types of laboratory experiments in this book organized differently from those you have done before. The first type of lab is called a Skills Practice Lab. Each Skills Practice Lab helps you gain skills in lab techniques that you will use to solve a real problem presented in the second type of lab, which is called an Investigation. The Skills Practice Lab serves as a Technique Builder, and the Investigation is presented as an exercise in Problem Solving.

Both types of labs refer to you as an employee of a professional company, and your teacher has the role of supervisor. Lab situations are given for real-life circumstances to show how chemistry fits into the world outside of the classroom. This will give you valuable practice with skills that you can use in chemistry and in other careers, such as creating a plan with available resources, developing and following a budget, and writing business letters.

As you work in these labs, you will better understand how the concepts you studied in the chapters are used by chemists to solve problems that affect life for everyone.

Skills Practice Labs

The Skills Practice Labs provide step-by-step procedures for you to follow, encouraging you to make careful observations and interpretations as you progress through the lab session. Each Skills Practice Lab gives you an opportunity to practice and perfect a specific lab technique or concept that will be needed later in an Investigation.



What Should You Do Before a Skills Practice Lab?

Preparation will help you work safely and efficiently. The evening before a lab, be sure to do the following:

- Read the lab procedure to make sure you understand what you will do.
- Read the safety information that begins on page 751, as well as any safety information provided in the lab procedure itself.
- Write down any questions you have in your lab notebook so that you can ask your teacher about them before the lab begins.
- Prepare all necessary data tables so that you will be able to concentrate on your work when you are in the lab.

What Should You Do After a Skills Practice Lab?

Most teachers require a lab report as a way of making sure that you understand what you are doing. Your teacher will give you specific details about how to organize your lab reports, but most lab reports will include the following:

- title of the lab

- summary paragraph(s) describing the purpose and procedure
- data tables and observations that are organized and comprehensive
- worked-out calculations with proper units
- answers that are, boxed, circled, or highlighted for items in the Analysis and Interpretation, Conclusion, and Extensions sections

Inquiry Labs

The Inquiry Labs differ from Skills Practice Labs because they do not provide step-by-step instructions. In each Inquiry Lab, you are required to develop your own procedure to solve a problem presented to your company by a client. You must decide how much money to spend on the project and what equipment to use. Although this may seem difficult. Inquiry Labs contain a number of clues about how to successfully solve the problem.

What Should You Do Before an Inquiry Lab?

Before you will be allowed to work on the lab, you must turn in a preliminary report. Usually, you must describe in detail the procedure you plan to use, provide complete data tables for the data and observations you will collect, and list exactly what equipment you will need and the costs. Only after your teacher, acting as your supervisor, approves your plans are you allowed to proceed. Before you begin writing a preliminary report, follow these steps.

- Read the Inquiry Lab thoroughly, and search for clues.
- Jot down notes in your lab notebook as you find clues.
- Consider what you must measure or observe to solve the problem.
- Think about Skills Practice Labs you have done that used a similar technique or reaction.
- Imagine working through a procedure, keeping track of each step, and determining what equipment you need.
- Carefully consider whether your approach is the best, most efficient one.

What Should You Do After an Inquiry Lab?

After you finish, organize a report of your data as described in the Memorandum. This is usually in the form of a one- or two-page letter to the client. Your teacher may have additional requirements for your report. Carefully consider how to convey the information the client needs to know. In some cases, a graph or diagram can communicate information better than words can.

If you need help with graphing or with using significant figures, ask your teacher.

Materials List for Inquiry Labs

Refer to the Equipment and Chemical lists below when planning your procedure for the Inquiry Labs. Include in your budget only the items you will need to solve the problem presented to your company by the client. Remember, you must always include the cost of lab space and the standard disposal fee in your budget.

Equipment
Aluminum foil
Balance
Beaker, 250 mL
Beaker, 400 mL
Beaker tongs
Büchner funnel
Bunsen burner/related equipment
Buret
Cobalt glass plate
Crucible and cover
Crucible tongs
Desiccator
Drying oven
Erlenmeyer flask, 250 mL
Evaporating dish
Filter flask with sink attachment
Filter paper
Flame-test wire
Glass funnel
Glass plate
Glass stirring rod
Graduated cylinder,100 mL
Hot plate
Index card (3 in. x 5 in.)
Lab space/fume hood/utilities
Litmus paper
Magnetic stirrer
Mortar and pestle
Paper clips
pH meter

Equipment (continued)
Plastic bags
Ring stand/ring/wiregauze or pipestem triangle
Ring stand with buretclamp
Rubber policeman
Spatula
Spectroscope
Standard disposal fee
Stopwatch
6 test tubes/holder/rack
Thermistor probe
Thermometer
Wash bottle
Watch glass
Weighing paper

Reagents and Additional Materials
Ring stand with buret clamp
Rubber policeman
Spatula
Spectroscope
Standard disposal fee
Stopwatch
Ring stand with buretclamp
Rubber policeman
Spatula
6 test tubes/holder/rack
Thermistor probe
Thermometer
Wash bottle
Watch glass
Weighing paper

Safety in the Chemistry Laboratory

Any chemical can be dangerous if it is misused. Always follow the instructions for the experiment. Pay close attention to the safety notes. Do not do anything differently unless you are instructed to do so by your teacher.

Chemicals, even water, can cause harm. The challenge is to know how to use chemicals correctly. If you follow the rules stated below, pay attention to your teacher's directions, and follow the precautions on chemical labels and in the experiments, then you will be using chemicals correctly.

These Safety Precautions Always Apply in the Lab

1. Always wear a lab apron and safety goggles.

Laboratories contain chemicals that can damage your clothing even if you aren't working on an experiment at the time. Keep the apron strings tied.

Some chemicals can cause eye damage and even blindness. If your safety goggles are uncomfortable or if they cloud up, ask your teacher for help. Try lengthening the strap, washing the goggles with soap and warm water, or using an anti-fog spray.

2. Do not wear contact lenses in the lab.

Even if you wear safety goggles, chemicals can get between contact lenses and your eyes and cause irreparable eye damage. If your doctor requires you to wear contact lenses instead of glasses, then you should wear eye-cup safety goggles in the lab. Ask your doctor or your teacher how to use this very important and special eye protection.

3. NEVER WORK ALONE IN THE LABORATORY.

Do lab work only under the supervision of your teacher.

4. Wear the right clothing for lab work.

Necklaces, neckties, dangling jewelry, long hair, and loose clothing can knock things over or catch on fire. Tuck in neckties, or take them off. Do not wear a necklace or other dangling jewelry, including hanging earrings. It also might be a good idea to remove your wristwatch so that it is not damaged by a chemical splash.

Pull back long hair, and tie it in place. Wear cotton clothing if you can. Nylon and polyester fabrics burn and melt more readily than cotton does. It's best to wear fitted garments, but if your clothing is loose or baggy, tuck it in or tie it back so that it does not get in the way or catch on fire. It is also important to wear pants, not shorts or skirts.

Wear shoes that will protect your feet from chemical spills. Do not wear open-toed shoes or sandals or shoes with woven leather straps. Shoes made of solid leather or polymer are preferred over shoes made of cloth.

5. Only books and notebooks needed for the experiment should be in the lab.

Do not bring textbooks, purses, bookbags, backpacks, or other items into the lab; keep these things in your desk or locker.

6. Read the entire experiment before entering the lab.

Memorize the safety precautions. Be familiar with the instructions for the experiment. Only materials and equipment authorized by your teacher should be used. When you do your lab work, follow the instructions and safety precautions described in the experiment.

7. Read chemical labels.

Follow the instructions and safety precautions stated on the labels.

8. Walk with care in the lab.

Sometimes you will have to carry chemicals from the supply station to your lab station. Avoid bumping into other students and spilling the chemicals. Stay at your lab station at other times.

9. Food, beverages, chewing gum, cosmetics, and smoking are NEVER allowed in the lab.

(You should already know this.)

10. NEVER taste chemicals or touch them with your bare hands.

Keep your hands away from your face and mouth while working, even if you are wearing gloves.

11. Use a sparker to light a Bunsen burner.

Do not use matches. Be sure that all gas valves are turned off and that all hot plates are turned off and unplugged when you leave the lab.

12. Be careful with hot plates, Bunsen burners, and other heat sources.

Keep your body and clothing away from flames. Do not touch a hot plate after it has just been turned off because it is probably still hot. The same is true of glassware, crucibles, and other things that have been removed from the flame of a Bunsen burner or from a drying oven.

13. Do not use electrical equipment with frayed or twisted wires.

14. Be sure your hands are dry before you use electrical equipment.

Before plugging an electrical cord into a socket, be sure the equipment is turned off. When you are finished with the equipment, turn it off. Before you leave the lab, unplug the equipment, but be sure to turn it off FIRST.

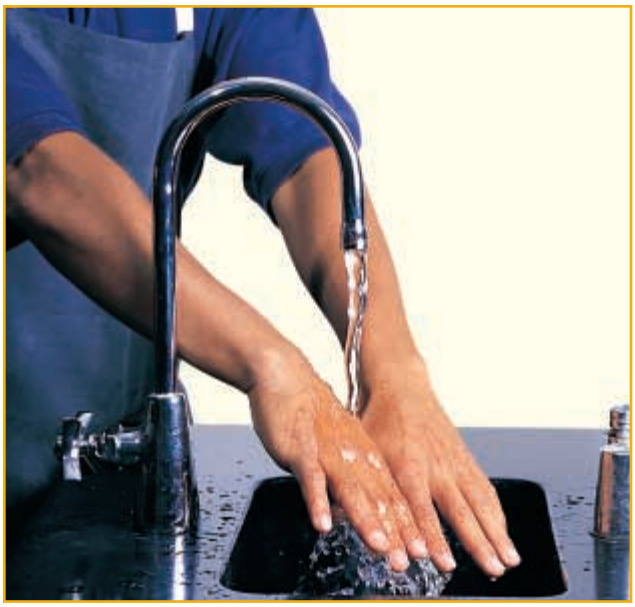
15. Do not let electrical cords dangle from work stations.

Dangling cords can cause tripping or electrical shocks. The area under and around electrical equipment should be dry, and cords should not lie in puddles of spilled liquid.

16. Know fire-drill procedures and the locations of exits.

17. Know the location and operation of safety showers and eyewash stations.

18. If your clothes catch on fire, walk to the safety shower, stand under it, and turn it on.



19. If you get a chemical in your eyes, walk immediately to the eyewash station, turn it on, and lower your head so that your eyes are in the running water.

Hold your eyelids open with your thumbs and fingers, and roll your eyeballs around. Flush your eyes continuously for at least 15 minutes. Call out to your teacher as you do this.

20. If you spill anything on the floor or lab bench, call your teacher rather than trying to clean it up by yourself.

Your teacher will tell you if it is OK for you to do the cleanup; if not, your teacher will know how the spill should be cleaned up safely.

21. If you spill a chemical on your skin, wash the chemical off at the sink and call your teacher.

If you spill a solid chemical on your clothing, brush it off carefully without scattering it onto somebody else, and call your teacher. If you get liquid on your clothing, wash it off right away using the faucet at the sink, and call your teacher. If the spill is on your pants or somewhere else that will not fit under the sink faucet, use the safety shower. Remove the pants or other affected clothing while you are under the shower, and call your teacher. (It may be temporarily embarrassing to remove pants or other clothing in front of your class, but failing to flush that chemical off your skin could cause permanent damage.)

22. The best way to prevent an accident is to stop it before it happens.

If you have a close call, tell your teacher so that you and your teacher can find a way to prevent it from happening again. Otherwise, the next time, it could be a harmful accident instead of just a close call. If you get a headache, feel sick to your stomach, or feel dizzy, tell your teacher immediately.

23. All accidents, no matter how minor, should be reported to your teacher.

24. For all chemicals, take only what you need.

If you take too much and have some left over, DO NOT put it back in the bottle. If a chemical is accidently put into the wrong bottle, the next person to use it will have a contaminated sample. Ask your teacher what to do with leftover chemicals.

25. NEVER take any chemicals out of the lab.

26. Horseplay and fooling around in the lab are very dangerous.

NEVER be a clown in the laboratory.

27. Keep your work area clean and tidy.

After your work is done, clean your work area and all equipment.

28. Always wash your hands with soap and water before you leave the lab.

29. All of these rules apply all of the time you are in the lab.

SAFETY SYMBOLS

CLOTHING PROTECTION

- Wear laboratory aprons in the laboratory. Keep the apron strings tied so that they do not dangle.

EYE SAFETY

- Wear safety goggles in the laboratory at all times. Know how to use the eyewash station.

CLEAN UP

- Keep your hands away from your face and mouth.
- Always wash your hands before leaving the laboratory.

CHEMICAL SAFETY

- Never taste, eat, or swallow any chemicals in the laboratory. Do not eat or drink any food from laboratory containers. Beakers are not cups, and evaporating dishes are not bowls.
- Never return unused chemicals to their original containers.
- It helps to label the beakers and test tubes containing chemicals. (This is not a new rule, just a good idea.)
- Never transfer substances by sucking on a pipet or straw; use a suction bulb.

WASTE DISPOSAL

- Some chemicals are harmful to our environment. You can help protect the environment by following the instructions for proper disposal.

GLASSWARE SAFETY

- Never place glassware, containers of chemicals, or anything else near the edges of a lab bench or table.

HAND SAFETY

- If a chemical gets on your skin or clothing or in your eyes, rinse it immediately, and alert your teacher.

CAUSTIC SAFETY

- If a chemical is spilled on the floor or lab bench, tell your teacher, but do not clean it up yourself unless your teacher says it is OK to do so.

HEATING SAFETY

- When heating a chemical in a test tube, always point the open end of the test tube away from yourself and other people.

Safety Quiz

Refer to the list of rules on p. 751–753, and identify whether a specific rule applies or whether the rule presented is a new rule.

1. Tie back long hair, and confine loose clothing. (Rule ? applies)
2. Never reach across an open flame. (Rule ? applies)
3. Use proper procedures when lighting Bunsen burners. Turn off hot plates, Bunsen burners, and other heat sources when they are not in use. (Rule ? applies)
4. Heat flasks or beakers on a ring stand with wire gauze between the glass and the flame. (Rule ? applies)
5. Use tongs when heating containers. Never hold or touch containers while heating them. Always allow heated materials to cool before handling them. (Rule ? applies)
6. Turn off gas valves when they are not in use. (Rule ? applies)
7. Use flammable liquids only in small amounts. (Rule ? applies)
8. When working with flammable liquids, be sure that no one else is using a lit Bunsen burner or plans to use one. (Rule ? applies)
9. What additional rules apply to every lab? (Rule ? applies)
10. Check the condition of glassware before and after using it. Inform your teacher of any broken, chipped, or cracked glassware because it should not be used. (Rule ? applies)
11. Do not pick up broken glass with your bare hands. Place broken glass in a specially designated disposal container. (Rule ? applies)
12. Never force glass tubing into rubber tubing, rubber stoppers,, or wooden corks. To protect your hands, wear heavy cloth gloves or wrap toweling around the glass and the tubing, stopper, or cork, and gently push in the glass. (Rule ? applies)
13. Do not inhale fumes directly. When instructed to smell a substance, use your hand to wave the fumes toward your nose, and inhale gently. (Rule ? applies)
14. Keep your hands away from your face and mouth. (Rule ? applies)
15. Always wash your hands before leaving the laboratory.(Rule ? applies)

Finally, if you are wondering how to answer the question that asks what additional rules apply to every lab, here is the correct answer.

Any time you see any of the safety symbols, you should remember that all 29 of the numbered laboratory rules apply.

Skills Practice Lab

1 Laboratory Techniques

Objectives

- Demonstrate proficiency in using a Bunsen burner, a balance, and a graduated cylinder.
- Demonstrate proficiency in handling solid and liquid chemicals.
- Develop proper safety techniques for all lab work.
- Use neat and organized data-collecting techniques.
- Use graphing techniques to plot data.

Materials

- balance
- beakers, 250 mL (2)
- Bunsen burner and related equipment
- copper wire
- crucible tongs
- evaporating dish
- graduated cylinder, 100 mL
- heat-resistant mat
- NaCl
- spatula
- test tube
- wax paper or weighing paper

Introduction

You have applied to work at a company that does research, development, and analysis work. Although the company does not require employees to have extensive chemical experience, all applicants are tested for their ability to follow directions, heed safety precautions, perform simple laboratory procedures, clearly and concisely communicate results, and make logical inferences.

The company will consider your performance on the test in deciding whether to hire you and determining what your initial salary will be. Pay close attention to the procedures and safety precautions because you will continue to use them throughout your work if you are hired by this company. In addition, you will need to pay attention to what is happening around you, make careful observations, and keep a clear and legible record of these observations in your lab notebook.

This laboratory orientation session will teach you some of the following techniques:

- how to use a Bunsen burner
- how to handle solids and liquids
- how to use a balance
- how to practice basic safety techniques in lab work

Safety Procedures

- Wear safety goggles when working around chemicals, acids, bases, flames, or heating devices. Contents under pressure may become projectiles and cause serious injury.
- Never look directly at the sun through any optical device or use direct sunlight to illuminate a microscope.
- Avoid wearing contact lenses in the lab.
- If any substance gets in your eyes, notify your instructor immediately and flush your eyes with running water for at least 15 min.

- Secure loose clothing, and remove dangling jewelry. Don't wear open-toed shoes or sandals in the lab.
- Wear an apron or lab coat to protect your clothing when working with chemicals.
- If a spill gets on your clothing, rinse it off immediately with water for at least 5 min while notifying your instructor.

- Always use caution when working with chemicals.
- Never mix chemicals unless specifically directed to do so.
- Never taste, touch, or smell chemicals unless specifically directed to do so.
- Add acid or base to water; never do the opposite.
- Never return unused chemicals to the original container.
- Never transfer substances by sucking on a pipette or straw; use a suction bulb.
- Follow instructions for proper disposal.

- Avoid wearing hair spray or hair gel on lab days.
- Whenever possible, use an electric hot plate as a heat source instead of an open flame.
- When heating materials in a test tube, always angle the test tube away from yourself and others.
- Glass containers used for heating should be made of heat-resistant glass.
- Know your school's fire-evacuation routes.

- Clean and decontaminate all work surfaces and personal protective equipment as directed by your instructor.
- Dispose of all sharps (broken glass and other contaminated sharp objects) and other contaminated materials (biological and chemical) in special containers as directed by your instructor.

Data Table 1

Material	Mass (g) step 11	Mass (g) step 12
empty beaker		
beaker and 50 mL of water		
50 mL of water		
beaker and 100 mL of water		
100 mL of water		
beaker and 150 mL of water		
150 mL of water		

Procedure

1. Copy Data Tables 1 and 2 in your lab notebook. Be sure that you have plenty of room for observations about each test.

Data Table 2

Material	Mass (g)
weighing paper	
weighing paper and NaCl	

2. Record in your lab notebook the location and use of the following emergency items: lab shower, eyewash station, and emergency telephone numbers.

3. Check to be certain that the gas valve at your lab station and at the neighboring lab stations are turned off. Notify your teacher immediately if a valve is on, because the fumes must be cleared before any work continues.

4. Compare the Bunsen burner in **Figure A** with your burner. Construction may vary, but the air and methane gas, CH_4, always mix in the barrel, the vertical tube in the center of the burner.

Figure A

5. Partially close the air ports at the base of the barrel, turn the gas on full, hold the sparker about 5 cm above the top of the barrel, and proceed to light. Adjust the gas valve until the flame extends about 8 cm above the barrel. Adjust the air supply until you have a quiet, steady flame with a sharply defined, light-blue inner cone. If an internal flame develops, turn off the gas valve, and let the burner cool down. Otherwise, the metal of the burner can get hot enough to set fire to anything nearby that is flammable. Before you relight the burner, partially close the air ports.

6. Using crucible tongs, hold a 10 cm piece of copper wire for 2–3 s in the part of the flame labeled "a" in **Figure B.** Repeat this step for the parts of the flame labeled "b" and "c." Record your observations in your lab notebook.

7. Experiment with the flame by completely closing the air ports at the base of the burner. Observe and record the color of the flame and the sounds made by the burner. Using crucible tongs, hold an evaporating dish in the tip of the flame for about 3 min. Place the dish on a heat-resistant mat, and shut off the burner. After the dish cools, examine its un derside, and record your observations.

8. Before using the balance, make sure that it is level and showing a mass of zero. If necessary, adjust the calibration knob. To avoid discrepancies, use the same balance for all measurements during a lab activity. Never put chemicals directly on the balance pan.

9. Place a piece of weighing paper on the balance pan. Determine the mass of the paper, and record this mass to the nearest 0.01 g in your data table. Put a small quantity of NaCl on a separate piece of weighing paper. Then, transfer 13 g of the NaCl to the weighing paper on the balance pan. Record the exact mass to the nearest 0.01 g in your data table.

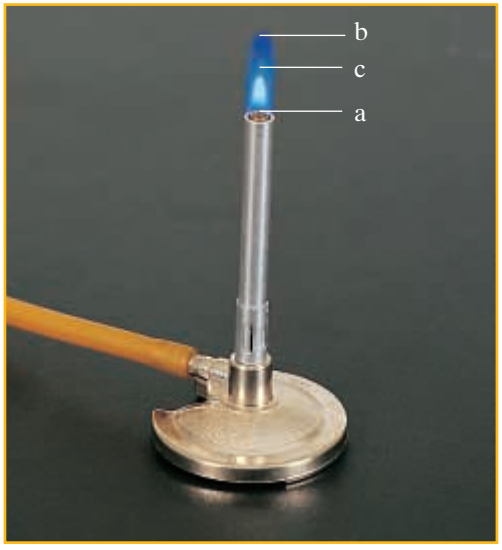


Figure B

10. Remove the weighing paper and NaCl from the balance pan. Lay the test tube flat on the table, and transfer the NaCl into the tube by rolling the weighing paper and sliding it into the test tube. As you lift the test tube to a vertical position, tap the paper gently, and the solid will slip into the test tube, as shown in **Figure C.**

11. Measure the mass of a dry 250 mL beaker, and record the mass in your data table. Add water up to the 50 mL mark, determine the new mass,

Figure C

and record the new mass in your data table. Repeat the procedure by filling the beaker to the 100 mL mark and then to the 150 mL mark, and record the mass each time. Subtract the mass of the empty beaker from the other measurements to determine the masses of the water.

12. Repeat step 11 with a second dry 250 mL beaker, but use a graduated cylinder to measure the volumes of water to the nearest 0.1 mL before pouring the water into the beaker. Read the volumes by using the bottom of the meniscus, the curve formed by the water's surface.

13. Clean all apparatus and your lab station. Put the wire, NaCl, and weighing paper in the containers designated by your teacher. Pour the water from the beakers into the sink. Scrub the cooled evaporating dish with soap, water, and a scrub brush. Be certain that the gas valves at your lab station and the nearest lab station are turned off. Be sure lab equipment is completely cool before storing it. Always wash your hands thoroughly after all lab work is finished and before you leave the lab.

Analysis

1. Analyzing data Based on your observations, which type of flame is hotter: the flame formed when the air ports are open or the flame formed when they are closed? What is the hottest part of the flame? (Hint: The melting point of copper is 1083°C.)

2. Examining data Which of the following measurements could have been made by your balance: 3.42 g of glass, 5.666 72 g of aspirin, or 0.000 017 g of paper?

3. Constructing graphs Make a graph of mass versus volume for data from steps 11 and 12. The mass of water (g) should be graphed along the y-axis as the dependent variable, and the volume of water (mL) should be graphed along the x-axis as the independent variable.

Conclusions

4. Interpreting information When methane is burned, it usually produces carbon dioxide and water. If there is a shortage of oxygen, the flame is not as hot and black carbon solid is formed. Which steps in the lab demonstrate these flames?

5. Applying conclusions Which is the most accurate method for measuring volumes of liquids, a beaker or a graduated cylinder? Explain why.

6. Evaluating data In Mandeville High School, Jarrold got only partway through step 7 of this experiment when he had to put everything away. Soon after Jarrold left, his lab drawer caught on fire. How did this happen?

7. Drawing conclusions The density of water is equal to its mass divided by its volume. Calculate the density of water by using your data from step 11. Then, calculate the density of water by using your data from step 12.

Extensions

8. Designing experiments You have been asked to design an experiment to find the density of sand. The density of sand is equal to its mass divided by its volume. Describe how you could measure the density of sand by using the equipment from this lab.

9. Research and communications Scientists use a number of different instruments to measure the mass of an object. Find information on different types of balances, and make a poster comparing at least three different kinds of balances. The poster should show the smallest amount of mass that could be measured on the balance and identify something appropriate to measure on the balance.

1 Conservation of Mass

Percentage of Water in Popcorn

Inquiry LAB
Design Your Own Experiment

THE PROBLEM

January 9, 2004

Director of Research
CheMystery Labs, Inc.
52 Fulton Street
Springfield, VA 22150

Dear Director of Research:

Juliette Brand Foods is preparing to enter the rapidly expanding popcorn market with a new popcorn product. As you may know, the key to making popcorn pop is the amount of water contained within the kernel.

As of today, the product development division has created three different production techniques for the popcorn, each of which creates popcorn that contains differing amounts of water. We need an independent lab such as yours to measure the percentage of water contained in each sample and to determine which technique produces the best-popping popcorn.

I have enclosed samples from each of the three techniques, labeled "technique beta," "technique gamma," and "technique delta." Please send us the bill when the work is complete.

Sincerely,

Mary Biedenbecker

Mary Biedenbecker, Director
Product Development Division

References

Popcorn pops because of the natural moisture inside each kernel. When the internal water is heated above 100°C, the kernel expands rapidly and the liquid water changes to a gas, which takes up much more space than the liquid.

The percentage of water in popcorn can be determined by the following equation.

$$\frac{\text{initial mass} - \text{final mass}}{\text{initial mass}} \times 100 = \text{percent } H_2O$$

The popping process works best when the kernels are first coated with a small amount of vegetable oil. Make sure you account for the presence of this oil when measuring masses.

THE PLAN

CheMystery Labs, Inc.52 Fulton Street, Springfield, VA 22150

CheMystery Labs, Inc.
52 Fulton Street
Springfield, VA 22150

Memorandum

Date: January 11, 2004
To: Leon Fuller
From: Martha Li-Hsien

Your team needs to design a procedure for determining the percentage of water in three samples of popcorn. Some of the popcorn was damaged in the mail, so each team will have only 80 kernels of popcorn per technique. Make sure to use your samples carefully!

Before you begin the lab work, I must approve your procedure. Give the following items to me ASAP:

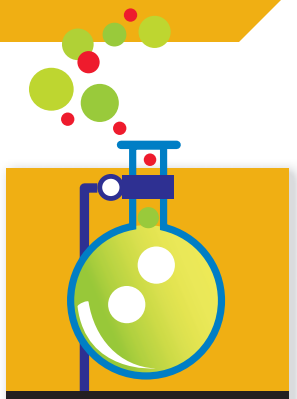
- a detailed one-page plan for your procedure, including any necessary data tables
- a detailed list of the equipment and materials you will need

When you finish your experiment, prepare a report in the form of a two-page letter to Mary Biedenbecker that includes the following:

- a paragraph summarizing how you analyzed the samples
- your findings about the percentage of water in each sample, including calculations and a discussion of the multiple trials
- a detailed and organized data table
- a graph comparing your findings with those of the other teams
- suggestions for improving the analysis procedure

Required Precautions

- Wear safety goggles when working around chemicals, acids, bases, flames, or heating devices. Contents under pressure may become projectiles and cause serious injury.
- Avoid wearing contact lenses in the lab.
- If any substance gets in your eyes, notify your instructor immediately and flush your eyes with running water for at least 15 min.
- Secure loose clothing, and remove dangling jewelry. Don't wear open-toed shoes or sandals in the lab.
- Wear an apron or lab coat to protect your clothing when working with chemicals.
- If a spill gets on your clothing, rinse it off immediately with water for at least 5 min while notifying your instructor.
- Always use caution when working with chemicals.
- Never taste, touch, or smell chemicals unless specifically directed to do so.
- Follow instructions for proper disposal.
- Whenever possible, use an electric hot plate as a heat source instead of an open flame.
- When heating materials in a test tube, always angle the test tube away from yourself and others.
- Know your school's fire-evacuation routes.
- Clean and decontaminate all work surfaces and personal protective equipment as directed by your instructor.
- Dispose of all sharps (broken glass and other contaminated sharp objects) and other contaminated materials (biological and chemical) in special containers as directed by your instructor.



2 Separation of Mixtures

Objectives

- **Recognize** how the solubility of a salt varies with temperature.
- **Demonstrate** proficiency in fractional crystallization and in filtration.
- **Solve** the percentage of two salts recovered by fractional crystallization.

Materials

- balance
- beaker tongs or hot mitt
- beakers, 150 mL (4)
- Bunsen burner or hot plate
- filter paper
- graduated cylinder, 100 mL
- ice and rock salt
- NaCl–KNO_3 solution (50 mL)
- nonmercury thermometer
- ring stand set up
- rubber policeman
- spatula
- stirring rod, glass
- tray, tub, or pneumatic trough
- vacuum filtration setup or gravity-filtration setup

Optional Equipment

- CBL unit
- graphing calculator with cable
- Vernier temperature probe

Introduction

Your company has been contacted by a fireworks factory. A mislabeled container of sodium chloride, NaCl, was accidentally mixed with potassium nitrate, KNO_3. KNO_3 is used as an oxidizer in fireworks to ensure that the fireworks burn thoroughly. The fireworks company wants your company to investigate ways they could separate the two compounds. They have provided an aqueous solution of the mixture for you to work with.

The substances in a mixture can be separated by physical means. For example, if one substance dissolves in a liquid solvent but another does not, the mixture can be filtered. The substance that dissolved will be carried through the filter by the solvent, but the other substance will not.

Because both NaCl and KNO_3 dissolve in water, filtering alone cannot separate them. However, there are differences in the way they dissolve. The graph in **Figure A** shows the same amount of NaCl dissolving in water regardless of the temperature of the water. On the other hand, KNO_3 is very soluble in warm water but much less soluble at 0°C.

Safety Procedures

- Wear safety goggles when working around chemicals, acids, bases, flames, or heating devices. Contents under pressure may become projectiles and cause serious injury.
- Never look directly at the sun through any optical device or use direct sunlight to illuminate a microscope.
- Avoid wearing contact lenses in the lab. If any substance gets in your eyes, notify your instructor immediately and flush your eyes with running water for at least 15 min.

- Secure loose clothing, and remove dangling jewelry. Don't wear open-toed shoes or sandals in the lab.
- Wear an apron or lab coat to protect your clothing when working with chemicals.
- If a spill gets on your clothing, rinse it off immediately with water for at least 5 min while notifying your instructor.

- Always use caution when working with chemicals.
- Never mix chemicals unless specifically directed to do so.
- Never taste, touch, or smell chemicals unless specifically directed to do so.
- Add acid or base to water; never do the opposite.
- Never return unused chemicals to the original container.
- Never transfer substances by sucking on a pipette or straw; use a suction bulb.
- Follow instructions for proper disposal.

- Avoid wearing hair spray or hair gel on lab days.
- Whenever possible, use an electric hot plate as a heat source instead of an open flame.
- When heating materials in a test tube, always angle the test tube away from yourself and others.
- Glass containers used for heating should be made of heat-resistant glass.
- Know your school's fire-evacuation routes.

- Clean and decontaminate all work surfaces and personal protective equipment as directed by your instructor.
- Dispose of all sharps (broken glass and other contaminated sharp objects) and other contaminated materials (biological and chemical) in special containers as directed by your instructor.

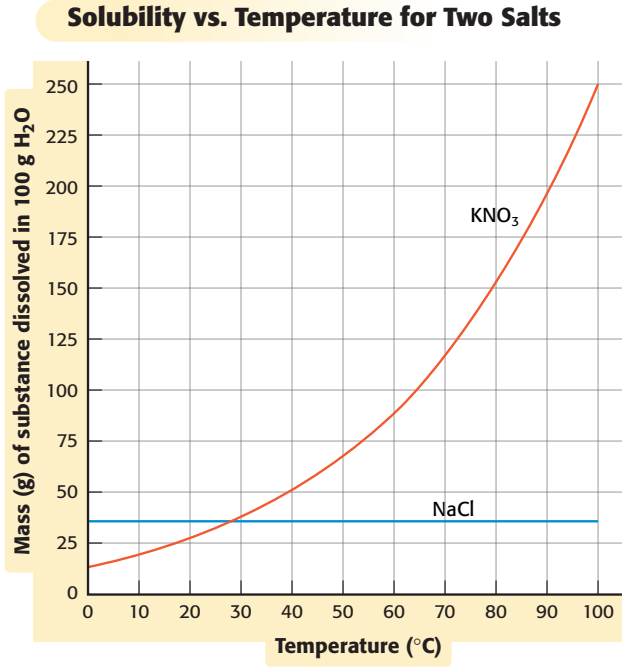


Figure A
This graph shows the relationship between temperature and the solubility of NaCl and KNO_3.

You will make use of the differences in solubility to separate the two salts. This technique is known as fractional crystallization. If the water solution of NaCl and KNO_3 is cooled from room temperature to a temperature near 0°C, some KNO_3 will crystallize. This KNO_3 residue can then be separated from the NaCl solution by filtration. The NaCl can be isolated from the filtrate by evaporation of the water. To determine whether this method is efficient, you will measure the mass of each of the recovered substances. Then, your client can decide whether this method is cost-effective.

Filtration-Technique Option

Figure B
Vacuum filtration

Figure C
Gravity filtration

Vacuum-Filtration Setup

1. To set up a vacuum filtration, screw an aspirator nozzle onto the faucet. Attach the other end of the plastic tubing to the side arm of the filter flask.
2. Place a one-hole rubber stopper on the stem of the funnel, and fit the stopper snugly in the neck of the filter flask, as shown in **Figure B.**
3. Place a piece of filter paper on the bottom of the funnel so that it is flat and covers all of the holes in the funnel.
4. When you are ready, turn on the water at the faucet that has the aspirator nozzle attached. This action creates a vacuum, which helps the filtering process go much faster. If the suction is working properly, the filter paper should be pulled against the bottom of the funnel, which results in covering all of the holes. If the filter paper appears to have bubbles of air under it or is not centered well, turn the water off, reposition the filter paper, and begin again.

Gravity-Filtration Setup

1. Set up a ring stand with a ring. Gently rest a glass funnel inside the ring, and place a beaker under the glass funnel, as shown in **Figure C.**
2. Fold a piece of filter paper in half along its diameter, and then fold it again to form a quadrant, as shown in **Figure D.** Separate the folds of the filter paper so that three thicknesses are on one side and one thickness is on the other.
3. Fit the filter paper in the funnel, and wet it with a little water so that it will adhere to the sides of the funnel. Gently but firmly press the paper against the sides of the funnel so that no air is between the funnel and the filter paper. Be certain that the filter paper does not extend above the sides of the funnel.

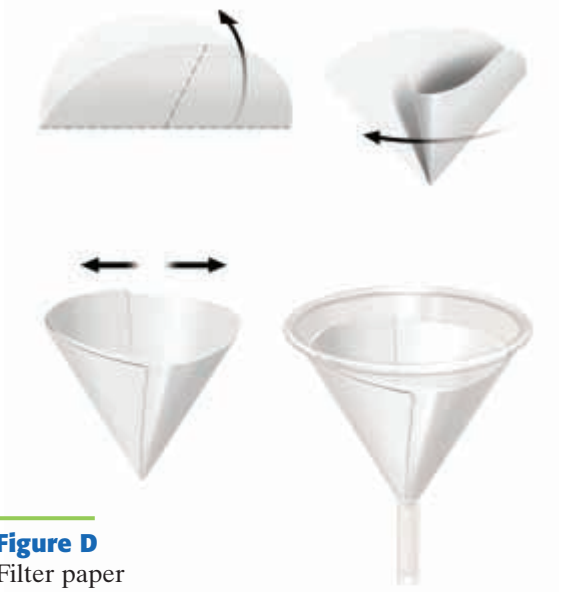


Figure D
Filter paper

Procedure

Advance Preparation

1. Copy the data table below in your lab notebook. Be sure that you have plenty of room for observations about each test.

Data Table 1

Mass of beaker 1
Volume of $NaCl–KNO_3$ solution added to beaker 1
Temperature of mixture before cooling
Mass of filter paper
Mass of beaker 4
Mass of beaker 4 with NaCl
Mass of beaker 1 with filter paper and KNO_3
Temperature of mixture after cooling

2. Obtain four clean, dry 150 mL beakers, and label them 1, 2, 3, and 4.

Thermometer procedure continues on page 767.

CBL and Sensors

3. Connect the CBL to the graphing calculator with the unit-to-unit link cable using the I/O ports located on each unit. Connect the temperature probe to the CH1 port. Turn on the CBL and the graphing calculator. Start the program CHEMBIO on the graphing calculator.
   a. Select option *SET UP PROBES* from the MAIN MENU. Enter 1 for the number of probes. Select the temperature probe from the list. Enter 1 for the channel number.
   b. Select the *COLLECT DATA* option from the MAIN MENU. Select the *TRIGGER* option from the DATA COLLECTION menu.

4. Set up your filtering apparatus. If you are using a Büchner funnel for vacuum filtration or a glass funnel for gravity filtration, follow the setup procedure under "Filtration-Technique Option."

5. Measure the mass of beaker 1 to the nearest 0.01 g, and record the mass in your data table.

6. Measure about 50 mL of the $NaCl–KNO_3$ solution into a graduated cylinder. Record the exact volume in your data table. Pour this mixture into beaker 1.

7. Using the temperature probe, measure the temperature of the mixture. Press TRIGGER on the CBL to collect the temperature reading of the mixture. Record this temperature in your data table. Select *CONTINUE* from the TRIGGER menu on the graphing calculator.

8. Measure the mass of a piece of filter paper to the nearest 0.01 g, and record the mass in your data table.

9. Make an ice bath by filling a tray, tub, or trough half-full with ice. Add a handful of rock salt. The salt lowers the freezing point of water so that the ice bath can cool to a lower temperature. Fill the ice bath with water until it is three-quarters full.

10. Using a fresh supply of ice and distilled water, fill beaker 2 half-full with ice, and add water. Do not add rock salt to this ice-water mixture. You will use this water to wash your purified salt.

First Filtration

11. Put beaker 1 with your $NaCl–KNO_3$ solution into the ice bath. Place the temperature probe in the solution to monitor the temperature. Stir the solution with a stirring rod while it cools. (Do not stir the solution with the temperature probe.) The lower the temperature of the mixture is, the more KNO_3 that will crystallize out of solution. When the temperature nears 4°C, press TRIGGER on the CBL to collect the temperature reading of the mixture. Record this temperature in your data table. Select *STOP* from the TRIGGER menu on the graphing calculator. Proceed with step 11a if you are using the Büchner funnel or step 11b if you are using a glass funnel.

a. Vacuum filtration
Prepare the filtering apparatus by pouring approximately 50 mL of ice-cold distilled water from beaker 2 through the filter paper. After the water has gone through the funnel, empty the filter flask into the sink. Reconnect the filter flask, and pour the salt-and-water mixture in beaker 1 into the funnel. Use the rubber policeman to transfer all of the cooled mixture into the funnel, especially any crystals that are visible. It may be helpful to add small amounts of ice-cold water from beaker 2 to beaker 1 to wash any crystals onto the filter paper. After all of the solution has passed through the funnel, wash the KNO_3 residue by pouring a very small amount of ice-cold water from beaker 2 over it. When this water has passed through the filter paper, turn off the faucet and carefully remove the tubing from the aspirator. Empty the filtrate, which has passed through the filter paper and is now in the filter flask, into beaker 3. When finished, continue with step 12.

b. Gravity filtration
Place beaker 3 under the glass funnel. Prepare the filtering apparatus by pouring approximately 50 mL of ice-cold water from beaker 2 through the filter paper. The water will pass through the filter paper and drip into beaker 3. When the dripping stops, empty beaker 3 into the sink. Place beaker 3 back under the glass funnel so that it will collect the filtrate from the funnel. Pour the salt-water mixture into the funnel. Use the rubber policeman to transfer all of the cooled mixture into the funnel, especially any visible crystals. It may be helpful to add small amounts of ice-cold water from beaker 2 to beaker 1 to wash any crystals onto the filter paper. After all of the solution has passed through the funnel, wash the KNO_3 by pouring a very small amount of ice-cold water from beaker 2 over it.

12. After you have finished filtering, use either a hot plate or a Bunsen burner, ring stand, ring, and wire gauze to heat beaker 3. When the liquid in beaker 3 begins to boil, continue heating gently until enough water has vaporized to decrease the volume to approximately 25–30 mL. Be sure to use beaker tongs. Remember that hot glassware does not always look hot.

Second Filtration

13. Allow the solution in beaker 3 to cool. Then set it in the ice bath and stir until the temperature is approximately 4°C.

14. Measure the mass of beaker 4, and record the mass in your data table.

15. Repeat step 11a or step 11b, pouring the solution from beaker 3 onto the filter paper and using beaker 4 to collect the filtrate that passes through the filter.

16. Wash and dry beaker 1. Carefully remove the filter paper with the KNO_3 from the funnel, and put it in the beaker. Avoid spilling the crystals. Place the beaker in a drying oven overnight.

Figure E
Use beaker tongs to move a beaker that has been heated, even if you believe that the beaker is cool.

Recovery of NaCl

17. Heat beaker 4 with a hot plate or Bunsen burner until the water begins to boil. Continue to heat the beaker gently until all of the water has vaporized and the salt appears dry. Turn off the hot plate or burner, and allow the beaker to cool. Use beaker tongs to move the beaker, as shown in **Figure E.** Measure the mass of beaker

4 with the NaCl to the nearest 0.01 g, and record the mass in your data table.

18. The next day, use beaker tongs to remove beaker 1 with the filter paper and KNO_3 from the drying oven. Allow the beaker to cool. Measure the mass using the same balance you used to measure the mass of the empty beaker. Record the new mass in your data table. Be sure to use beaker tongs. Remember that hot glassware does not always look hot.

19. Clean all apparatus and your lab station. Once the mass of the NaCl has been determined, add water to dissolve the NaCl, and rinse the solution down the drain. Do not wash KNO_3 down the drain. Dispose of the KNO_3 in the waste container designated by your teacher. Wash your hands thoroughly after all lab work is finished and before you leave the lab.

Thermometer

3. Set up your filtering apparatus. If you are using a Büchner funnel for vacuum filtration or a glass funnel for gravity filtration, follow the setup procedure under "Filtration-Technique Option."

4. Measure the mass of beaker 1 to the nearest 0.01 g, and record the mass in your data table.

5. Measure about 50 mL of the NaCl–KNO_3 solution into a graduated cylinder. Record the exact volume in your data table. Pour this mixture into beaker 1.

6. Using a thermometer, measure the temperature of the mixture. Record this temperature in your data table.

7. Measure the mass of a piece of filter paper to the nearest 0.01 g, and record the mass in your data table.

8. Make an ice bath by filling a tray, tub, or trough half-full with ice. Add a handful of rock salt. The salt lowers the freezing point of water so that the ice bath can cool to a lower temperature. Fill the ice bath with water until it is three-quarters full.

9. Using a fresh supply of ice and distilled water, fill beaker 2 half-full with ice, and add water. Do not add rock salt to this ice-water mixture. You will use this water to wash your purified salt.

First Filtration

10. Put beaker 1 with your NaCl–KNO_3 solution into the ice bath. Place a thermometer in the solution to monitor the temperature. Stir the solution with a stirring rod while it cools. The lower the temperature of the mixture is, the more KNO_3 that will crystallize out of solution. When the temperature nears 4°C, record the temperature in your data table. Proceed with step 10a if you are using the Büchner funnel or step 10b if you are using a glass funnel. Never stir a solution with a thermometer; the bulb is very fragile.

a. Vacuum filtration

Prepare the filtering apparatus by pouring approximately 50 mL of ice-cold distilled water from beaker 2 through the filter paper. After the water has gone through the funnel, empty the filter flask into the sink. Reconnect the filter flask, and pour the salt-and-water mixture in beaker 1 into the funnel. Use the rubber policeman to transfer all of the cooled mixture into the funnel, especially any crystals that are visible. It may be helpful to add small amounts of ice-cold water from beaker 2 to beaker 1 to wash any crystals onto the filter paper. After all of the solution has passed through the funnel, wash the KNO_3 residue by pouring a very small amount of ice-cold water from beaker 2 over it. When this water has passed through the filter paper, turn off the faucet and carefully remove the tubing from the aspirator. Empty the filtrate, which has passed through the filter paper and is now in the filter flask, into beaker 3. When finished, continue with step 11.

b. Gravity filtration

Place beaker 3 under the glass funnel. Prepare the filtering apparatus by pouring approximately 50 mL of ice-cold water from beaker 2 through the filter paper. The water

will pass through the filter paper and drip into beaker 3. When the dripping stops, empty beaker 3 into the sink. Place beaker 3 back under the glass funnel so that it will collect the filtrate from the funnel. Pour the salt-water mixture into the funnel. Use the rubber policeman to transfer all of the cooled mixture into the funnel, especially any visible crystals. It may be helpful to add small amounts of ice-cold water from beaker 2 to beaker 1 to wash any crystals onto the filter paper. After all of the solution has passed through the funnel, wash the KNO_3 by pouring a very small amount of ice-cold water from beaker 2 over it.

11. After you have finished filtering, use either a hot plate or a Bunsen burner, ring stand, ring, and wire gauze to heat beaker 3. When the liquid in beaker 3 begins to boil, continue heating gently until enough water has vaporized to decrease the volume to approximately 25–30 mL. Be sure to use beaker tongs. Remember that hot glassware does not always look hot.

Second Filtration

12. Allow the solution in beaker 3 to cool. Then set it in the ice bath and stir until the temperature is approximately 4°C.

13. Measure the mass of beaker 4, and record the mass in your data table.

14. Repeat step 10a or step 10b, pouring the solution from beaker 3 onto the filter paper and using beaker 4 to collect the filtrate that passes through the filter.

15. Wash and dry beaker 1. Carefully remove the filter paper with the KNO_3 from the funnel, and put it in the beaker. Avoid spilling the crystals. Place the beaker in a drying oven overnight.

Recovery of NaCl

16. Heat beaker 4 with a hot plate or Bunsen burner until the water begins to boil. Continue to heat the beaker gently until all of the water has vaporized and the salt appears dry. Turn off the hot plate or burner, and allow the beaker to cool. Use beaker tongs to move the beaker, as shown in Figure E. Measure the mass of beaker 4 with the NaCl to the nearest 0.01 g, and record the mass in your data table.

17. The next day, use beaker tongs to remove beaker 1 with the filter paper and KNO_3 from the drying oven. Allow the beaker to cool. Measure the mass using the same balance you used to measure the mass of the empty beaker. Record the new mass in your data table. Be sure to use beaker tongs. Remember that hot glassware does not always look hot.

18. Clean all apparatus and your lab station. Once the mass of the NaCl has been determined, add water to dissolve the NaCl, and rinse the solution down the drain. Do not wash KNO_3 down the drain. Dispose of the KNO_3 in the waste container designated by your teacher. Wash your hands thoroughly after all lab work is finished and before you leave the lab.

Analysis

1. **Analyzing results** Find the mass of NaCl in your 50 mL sample by subtracting the mass of the empty beaker 4 from the mass of beaker 4 with NaCl.

2. **Analyzing data** Find the mass of KNO_3 in your 50 mL sample by subtracting the mass of beaker 1 and the mass of the filter paper from the mass of beaker 1 with the filter paper and KNO_3.

3. **Analyzing data** Determine the total mass of the two salts.

Conclusions

4. Applying conclusions How many grams of KNO_3 and NaCl would be found in a 1.0 L sample of the solution? (Hint: For each substance, make a conversion factor by using the mass of the compound and the volume of the solution.)

5. Analyzing graphs Use the graph at the beginning of this exploration to determine how much of each compound would dissolve in 100 g of water at room temperature and at the temperature of your ice-water bath.

6. Drawing conclusions Calculate the percentage by mass of NaCl in the salt mixture. Calculate the percentage by mass of KNO_3 in the salt mixture. Assume that the density of your 50 mL solution is 1.0 g/mL.

7. Applying conclusions The fireworks company has another 55 L of the salt mixture dissolved in water just like the sample you worked with. How many kilograms of each compound can the company expect to recover from this sample? (Hint: Use your answer from item 4 to help you answer this question.)

8. Evaluating methods Use the graph shown at the beginning of this lab to estimate how much KNO_3 could still be contaminating the NaCl you recovered.

9. Relating ideas Use the graph shown at the beginning of this lab to explain why it is impossible to completely separate the two compounds by fractional crystallization.

10. Evaluating methods Why was it important to use ice-cold water to wash the KNO_3 after filtration?

11. Evaluating methods If it was important to use very cold water to wash the KNO_3, why was the salt-and-ice-water mixture from the bath not used? After all, it had a lower temperature than the ice and distilled water from beaker 2 did. (Hint: Consider what is contained in rock salt.)

12. Evaluating methods Why was it important to keep the amount of cold water used to wash the KNO_3 as small as possible?

13. Interpreting graphics Using the graph shown at the beginning of this lab, determine the minimum mass of water necessary to dissolve the amounts of each compound from Analysis items 1 and 2. Calculate the mass dissolved at room temperature and at 4°C. What volumes of water would be necessary? (Hint: The density of water is about 1.0 g/mL.)

Extensions

1. Designing experiments Describe how you could use the properties of the compounds to test the purity of your recovered samples. If your teacher approves your plan, use it to check your separation of the mixtures. (Hint: Check a chemical handbook for more information about the properties of NaCl and KNO_3.)

2. Designing experiments How could you improve the yield or the purity of the compounds you recovered? If you can think of ways to modify the procedure, ask your teacher to approve your plan and run the procedure again.

Inquiry LAB
Design Your Own Experiment

2 Separation of Mixtures

Mining Contract

THE PROBLEM

January 20, 2004

George Taylor
Director of Analytical Services
CheMystery Labs, Inc.
52 Fulton Street
Springfield, VA 22150

Dear George:

I thought of your new company when a problem came up here at Goldstake. I think I have some work for your company. While performing exploratory drilling for natural gas near Afton in western Wyoming, our engineers encountered a new subterranean, geothermal aquifer. We estimate the size of the aquifer to be 1×10^{12} L.

The Bureau of Land Management advised us to alert the Environmental Protection Agency. Preliminary qualitative tests of the water identified two dissolved salts: potassium nitrate and copper nitrate.

The EPA is concerned that a full-scale mining operation may harm the environment if the salts are present in large quantities. They are requiring us to halt all operations while we obtain more information for an environmental impact statement. We need your firm to separate the sample, purify the sample, and make a determination of the amounts of the two salts in the Afton Aquifer.

Sincerely,

Lynn L. Brown

Lynn L. Brown
Director of Operations
Goldstake Mining Corporation

References

The procedure for this Investigation is similar to one your team recently completed involving the separation of sodium chloride, NaCl, and potassium nitrate, KNO_3.

THE PLAN

CheMystery Labs, Inc.52 Fulton Street, Springfield, VA 22150

CheMystery Labs, Inc.
52 Fulton Street
Springfield, VA 22150

Memorandum

Date: January 23, 2004
To: Andre Kalaviencz
From: George Taylor

Because this is our first mining-industry contract, we need to plan carefully to get good results at minimum cost. Each research team will receive only a 50.0 mL sample of the aquifer water.

I need the following information from each team before the work begins.

- a detailed, one-page plan for the procedure that you will use to accomplish the analysis, including all necessary data tables
- a list of the materials and supplies you will need

When you have completed your labwork, present the following information to Goldstake in a two page report:

- the mass of potassium nitrate, KNO_3, and copper nitrate, $Cu(NO_3)_2$, in the 50.0 mL sample
- the extrapolated mass of KNO_3 and $Cu(NO_3)_2$ in the Afton Aquifer
- a short paragraph that summarizes and describes the procedures you used
- detailed and organized data and analysis section that shows your calculations and explanations of any possible sources of error

Required Precautions

- Wear safety goggles when working around chemicals, acids, bases, flames, or heating devices. Contents under pressure may become projectiles and cause serious injury.
- Avoid wearing contact lenses in the lab.
- If any substance gets in your eyes, notify your instructor immediately and flush your eyes with running water for at least 15 min.
- Secure loose clothing, and remove dangling jewelry. Don't wear open-toed shoes or sandals in the lab.
- Wear an apron or lab coat to protect your clothing when working with chemicals.
- If a spill gets on your clothing, rinse it off immediately with water for at least 5 min while notifying your instructor.
- Always use caution when working with chemicals.
- Never taste, touch, or smell chemicals unless specifically directed to do so.
- Follow instructions for proper disposal.
- Whenever possible, use an electric hot plate as a heat source instead of an open flame.
- When heating materials in a test tube, always angle the test tube away from yourself and others.
- Know your school's fire-evacuation routes.
- Clean and decontaminate all work surfaces and personal protective equipment as directed by your instructor.
- Dispose of all sharps (broken glass and other contaminated sharp objects) and other contaminated materials (biological and chemical) in special containers as directed by your instructor.

Skills Practice Lab

3 Flame Tests

Objectives

- Identify a set of flame-test color standards for selected metal ions.
- Relate the colors of a flame test to the behavior of excited electrons in a metal ion.
- Draw conclusions and identify an unknown metal ion by using a flame test.
- Demonstrate proficiency in performing a flame test and in using a spectroscope.

Materials

- beaker, 250 mL
- Bunsen burner
- CaCl2 solution
- cobalt glass plates
- crucible tongs
- distilled water
- flame-test wire
- glass test plate
- HCl solution (1.0 M)
- K_2SO_4 solution
- Li_2SO_4 solution
- Na_2SO_4 solution
- NaCl crystals
- NaCl solution
- spectroscope
- $SrCl_2$ solution
- unknown solution

Introduction

Your company has been contacted by Julius and Annette Benetti. They are worried about some abandoned, rusted barrels of chemicals that their daughter found while playing in the vacant lot behind their home. The barrels have begun to leak a colored liquid that flows through their property before emptying into a local sewer. The Benettis want your company to identify the compound in the liquid. Earlier work indicates that it is a dissolved metal compound. Many metals, such as lead, have been determined to be hazardous to our health. Many compounds of these metals are often soluble in water and are therefore easily absorbed into the body.

Electrons in atoms jump from their ground state to excited states by absorbing energy. Eventually these electrons fall back to their ground state, re-emitting the absorbed energy in the form of light. Because each atom has a unique structure and arrangement of electrons, each atom emits a unique spectrum of light. This characteristic light is the basis for the chemical test known as a flame test. In this test the atoms are excited by being placed within a flame. As they re-emit the absorbed energy in the form of light, the color of the flame changes. For most metals, these changes are easily visible. However, even the presence of a tiny speck of another substance can interfere with the identification of the true color of a particular type of atom.

To determine what metal is contained in the barrels behind the Benettis' house, you must first perform flame tests with a variety of standard solutions of different metal compounds. Then you will perform a flame test with the unknown sample from the site to see if it matches any of the solutions you've used as standards. Be sure to keep your equipment very clean, and perform multiple trials to check your work.

Safety Procedures

- Wear safety goggles when working around chemicals, acids, bases, flames, or heating devices. Contents under pressure may become projectiles and cause serious injury.
- Never look directly at the sun through any optical device or use direct sunlight to illuminate a microscope.
- Avoid wearing contact lenses in the lab.
- If any substance gets in your eyes, notify your instructor immediately and flush your eyes with running water for at least 15 min.

- Secure loose clothing, and remove dangling jewelry. Don't wear open-toed shoes or sandals in the lab.
- Wear an apron or lab coat to protect your clothing when working with chemicals.
- If a spill gets on your clothing, rinse it off immediately with water for at least 5 min while notifying your instructor.

- If a chemical gets on your skin or clothing or in your eyes, rinse it immediately, and alert your instructor.
- If a chemical is spilled on the floor or lab bench, alert your instructor, but do not clean it up yourself unless your teacher says it is OK to do so.

- Always use caution when working with chemicals.
- Never mix chemicals unless specifically directed to do so.
- Never taste, touch, or smell chemicals unless specifically directed to do so.
- Add acid or base to water; never do the opposite.
- Never return unused chemicals to the original container.
- Never transfer substances by sucking on a pipette or straw; use a suction bulb.
- Follow instructions for proper disposal.

- Avoid wearing hair spray or hair gel on lab days.
- Whenever possible, use an electric hot plate as a heat source instead of an open flame.
- When heating materials in a test tube, always angle the test tube away from yourself and others.
- Glass containers used for heating should be made of heat-resistant glass.
- Know your school's fire-evacuation routes.

- Clean and decontaminate all work surfaces and personal protective equipment as directed by your instructor.
- Dispose of all sharps (broken glass and other contaminated sharp objects) and other contaminated materials (biological and chemical) in special containers as directed by your instructor.

Data Table 1

Metal Compound	Color of flame	Wavelengths (nm)
$CaCl_2$ solution		
K_2SO_4 solution		
Li_2SO_4 solution		
Na_2SO_4 solution		
$SrCl_2$ solution		
Na_2SO_4 (cobalt glass)		
K_2SO_4(cobalt glass)		
$Na_2SO_4$and K_2SO_4		
Na_2SO_4 and K_2SO_4 (cobalt glass)		
NaCl solution		
NaCl crystals		
Unknown solution		

Procedure

1. Copy the Data Table 1 in your lab notebook. Be sure that you have plenty of room for observations about each test.

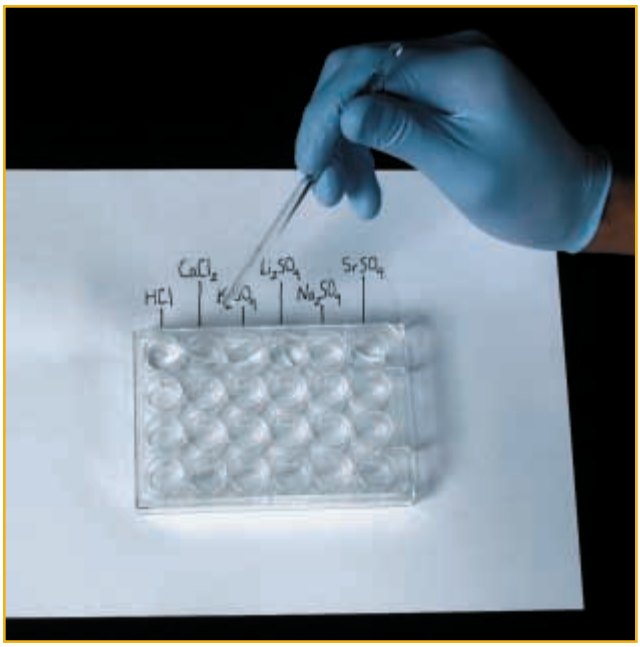


Figure A
Be sure that you record the position of the various metal ion solutions in each well of the well strip.

2. Label a beaker "Waste." Thoroughly clean and dry a well strip. Fill the first well one-fourth full with 1.0 M HCl. Clean the test wire by first dipping it in the HCl and then holding it in the flame of the Bunsen burner. Repeat this procedure until the flame is not colored by the wire. When the wire is ready, rinse the well with distilled water, and collect the rinse water in the waste beaker.

3. Put 10 drops of each metal ion solution listed in the materials list except NaCl in a row in each well of the well strip. Put a row of 1.0 M HCl drops on a glass plate across from the metal ion solutions. Record the position of all of the chemicals placed in the wells. The wire will need to be cleaned thoroughly with HCl between each test solution to avoid contamination from the previous test.

4. Dip the wire into the $CaCl_2$ solution, as shown in **Figure A,** and then hold it in the Bunsen burner flame. Observe the color of the flame, and record it in the data table. Repeat the procedure again, but this time look through the spectroscope to view the results. Record the wavelengths you see from the flame. Perform each test three times. Clean the wire with the HCl as you did in step 2.

5. Repeat step 4 with the K_2SO_4 and with each of the remaining solutions in the well strip. For each solution that you test, record the color of each flame and the wavelength observed with the spectroscope. After the solutions are tested, clean the wire thoroughly, rinse the well strip with distilled water, and collect the rinse water in the waste beaker.

6. Test another drop of Na_2SO_4, but this time view the flame through two pieces of cobalt glass. Clean the wire, and repeat the test by using the K_2SO_4. View the flame through the cobalt glass. Record in your data table the colors and wavelengths of the flames. Clean the wire and the well strip, and rinse the well strip with distilled water. Pour the rinse water into the waste beaker.

7. Put a drop of K_2SO_4 in a clean well. Add a drop of Na_2SO_4. Flame-test the mixture. Observe the flame without the cobalt glass. Repeat the test, this time observing the flame through the cobalt glass. Record the colors and wavelengths of the flames in the data table. Clean the wire, and rinse the well strip with distilled water. Pour the rinse water into the waste beaker.

8. Test a drop of the NaCl solution in the flame, and then view it through the spectroscope. (Do not use the cobalt glass.) Record your observations. Clean the wire, and rinse the well strip with distilled water. Pour the rinse water into the waste beaker. Place a few crystals of NaCl in a clean well, dip the wire in the crystals, and do the flame test once more. Record the color of the flame test. Clean the wire, and rinse the well strip with distilled water. Pour the rinse water into the waste beaker.

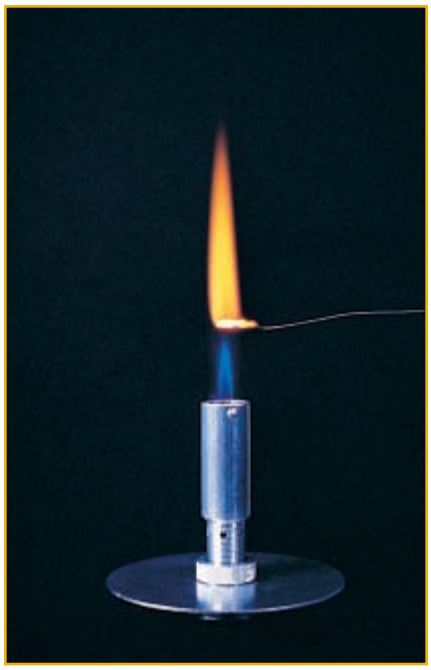


Figure B
Flame test

9. Dip the wire into the unknown solution; then hold it in the Bunsen burner flame, as shown in **Figure B.** Perform flame tests for the wire, both with and without the cobalt glass. Record your observations. Clean the wire, and rinse the well strip with distilled water. Pour the rinse water into the waste beaker.

10. Clean all apparatus and your lab station. Dispose of the contents of the waste beaker into the container designated by your teacher. Wash your hands thoroughly after cleaning up the lab area and equipment.

Analysis

1. **Organizing data** Examine your data table, and create a summary of the flame test for each metal ion.

2. **Analyzing data** Account for any differences in the individual trials for the flame tests for the metal ions.

3. **Explaining events** Explain how viewing the flame through cobalt glass can make analyzing the ions being tested easier.

4. **Explaining events** Explain how the lines seen in the spectroscope relate to the position of electrons in the metal atom.

5. **Identifying patterns** For three of the metal ions tested, explain how the flame color you saw relates to the lines of color you saw when you looked through the spectroscope.

Conclusions

6. **Evaluating results** What metal ions are in the unknown solution from the barrels on the vacant lot?

7. **Evaluating methods** How would you characterize the flame test with respect to its sensitivity? What difficulties could occur when identifying ions by the flame test?

8. **Evaluating methods** Explain how you can use a spectroscope to identify the components of solutions containing several different metal ions.

9. **Applying ideas** Some stores sell jars of "fireplace crystals." When sprinkled on a log, these crystals make the flames blue, red, green, and violet. Explain how these crystals can change the flame's color. What ingredients would you expect the crystals to contain?

Extensions

10. **Designing experiments** A student performed flame tests on several unknown substances and observed that they all were shades of red. What could the student do to correctly identify these substances? Explain your answer.

11. **Designing experiments** During a flood, the labels from three bottles of chemicals were lost. The three unlabeled bottles of white solids were known to contain the following substances: strontium nitrate, ammonium carbonate, and potassium sulfate. Explain how you could easily test the substances and relabel the three bottles. (Hint: Ammonium ions do not provide a distinctive flame color.)

Inquiry LAB
Design Your Own Experiment

3 Spectroscopy and Flame Tests

Identifying Materials

January 27, 2004

Director of Investigations
CheMystery Labs, Inc.
52 Fulton Street
Springfield, VA 22150

Dear Director:

As you may have seen in news reports, one of our freelance pilots, David Matthews, was killed in a crash of an experimental airplane.

The reports did not mention that Matthews's airplane was a recently perfected design that he had developed for us. The notes he left behind indicate that the coating on the nose cone was the key to the plane's speed and maneuverability. Unfortunately, he did not reveal what substances he used, and we were able to recover only flakes of material from the nose cone after the accident.

We have sent you samples of these flakes dissolved in a solution. Please identify the material Matthews used so that we can duplicate his prototype. We will pay $200,000 for this work, provided that you can identify the material within three days.

Sincerely,

Jared MacLaren

Jared MacLaren
Experimental Testing Agency

References

Review information about spectroscopic analysis. The procedure is similar to one your team recently completed to identify an unknown metal in a solution. As before, use small amounts of metal, and clean equipment carefully to avoid contamination. Perform multiple trials for each sample.
The following information is the bright-line emission data (in nm) for the four possible metals.

- Lithium: 670, 612, 498, 462
- Potassium: 700, 695, 408, 405
- Strontium: 710, 685, 665, 500, 490, 485, 460, 420, 405
- Calcium: 650, 645, 610, 485, 460, 445, 420

CheMystery Labs, Inc.52 Fulton Street, Springfield, VA 22150

CheMystery Labs, Inc.
52 Fulton Street
Springfield, VA 22150

Memorandum

Date: January 28, 2004
To: Edwin Thien
From: Marissa Bellinghausen

We have narrowed down the material used to four possibilities. It is a compound of either lithium, potassium, strontium, or calcium. Using flame tests and the wavelengths of spectroscopic analysis, you should be able to identify which of these is in the sample.

Because our contract depends on timeliness, give me a preliminary report that includes the following as soon as possible:

- a detailed, one-page summary of your plan for the procedure
- an itemized list of equipment

After you complete your analysis, prepare a report in the form of a two-page letter to MacLaren. The report must include the following:

- the identity of the metal in the sample
- a summary of your procedure
- a detailed and organized analysis and data sections showing tests and results

Required Precautions

- Wear safety goggles when working around chemicals, acids, bases, flames, or heating devices. Contents under pressure may become projectiles and cause serious injury.
- Avoid wearing contact lenses in the lab.
- If any substance gets in your eyes, notify your instructor immediately and flush your eyes with running water for at least 15 min.
- Secure loose clothing, and remove dangling jewelry. Don't wear open-toed shoes or sandals in the lab.

- Wear an apron or lab coat to protect your clothing when working with chemicals.
- If a spill gets on your clothing, rinse it off immediately with water for at least 5 min while notifying your instructor.

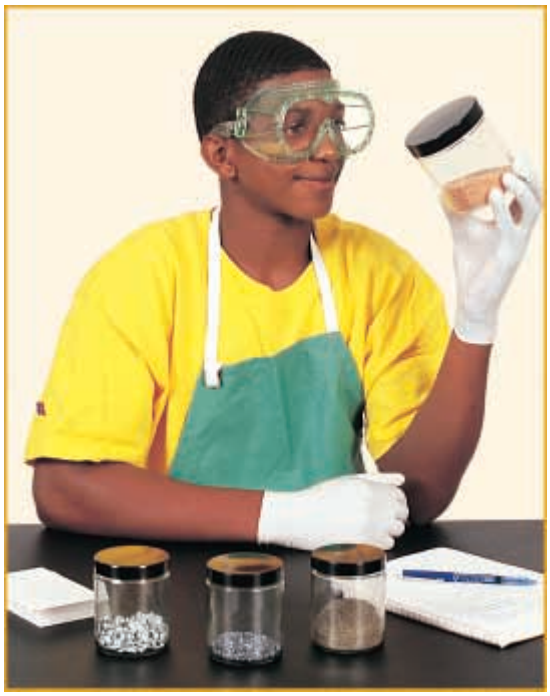
- Always use caution when working with chemicals.
- Never taste, touch, or smell chemicals unless specifically directed to do so.
- Follow instructions for proper disposal.

- Whenever possible, use an electric hot plate as a heat source instead of an open flame.
- When heating materials in a test tube, always angle the test tube away from yourself and others.
- Know your school's fire-evacuation routes.
- Clean and decontaminate all work surfaces and personal protective equipment as directed by your instructor.

- Dispose of all sharps (broken glass and other contaminated sharp objects) and other contaminated materials (biological and chemical) in special containers as directed by your instructor.

Skills Practice Lab

4 The Mendeleev Lab of 1869



Objectives

- Observe the physical properties of common elements.
- Observe the properties and trends in the elements on the periodic table.
- Draw conclusions and identify unknown elements based on observed trends in properties.

BASIC SCIENTIFIC METHODS

Materials

- blank periodic table
- elemental samples of Ar, C, Cu, Sn, and Pb
- note cards, 3 × 5
- periodic table

Introduction

Russian chemist Dmitri Mendeleev is generally credited as being the first chemist to observe that patterns emerge when the elements are arranged according to their properties. Mendeleev's arrangement of the elements was unique because he left blank spaces for elements that he claimed were undiscovered as of 1869. Mendeleev was so confident that he even predicted the properties of these undiscovered elements. His predictions were eventually proven to be quite accurate, and these new elements fill the spaces that originally were blank in his table.

Use your knowledge of the periodic table to determine the identity of each of the nine unknown elements in this activity. The unknown elements are from the groups in the periodic table that are listed below. Each group listed below contains at least one unknown element.

1 2 11 13 14 17 18

None of the known elements serves as one of the nine unknown elements.

No radioactive elements are used during this experiment. The relevant radioactive elements include Fr, Ra, At, and Rn. You may not use your textbook or other reference materials. You have been provided with enough information to determine each of the unknown elements.

Safety Procedures

- Wear safety goggles when working around chemicals, acids, bases, flames, or heating devices. Contents under pressure may become projectiles and cause serious injury.
- Never look directly at the sun through any optical device or use direct sunlight to illuminate a microscope.
- Avoid wearing contact lenses in the lab.

- If any substance gets in your eyes, notify your instructor immediately and flush your eyes with running water for at least 15 min.
- Secure loose clothing, and remove dangling jewelry. Don't wear open-toed shoes or sandals in the lab.
- Wear an apron or lab coat to protect your clothing when working with chemicals.
- If a spill gets on your clothing, rinse it off immediately with water for at least 5 minutes while notifying your instructor.

Data Table 1

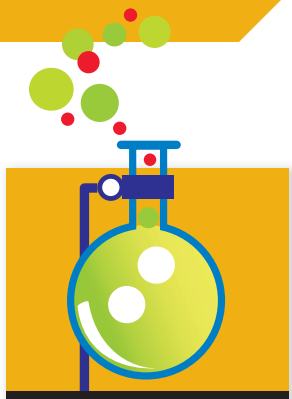
Unknown	Element
1	
2	
3	
4	

Procedure

1. Copy the data table in your lab notebook. Be sure that you have plenty of room for observations about each test.
2. Use the note cards to copy the information listed on each of the sample cards in the worksheets that your teacher has given you. If the word *observe* is listed, you will need to visually inspect the sample and then write the observation in the appropriate space.
3. Arrange the note cards of the known elements in a crude representation of the periodic table. In other words, all of the known elements from Group 1 should be arranged in the appropriate order. Arrange all of the other cards accordingly.
4. Once the cards of the known elements are in place, inspect the properties of the unknowns to see where their properties would best "fit" the trends of the elements of each group.
5. Assign the proper element name to each of the unknowns. Add the symbol for each one of the unknown elements to your data table.
6. Clean up your lab station, and return the leftover note cards and samples of the elements to your teacher. Do not pour any of the samples down the drain or in the trash unless your teacher directs you to do so. Wash your hands thoroughly before you leave the lab and after all your work is finished.

Conclusions

1. **Interpreting information** Summarize your group's reasoning for the assignment of each unknown. Explain in a few sentences exactly how you predicted the identity of the nine unknown elements.



7 Percent Composition of Hydrates

Objectives

- Demonstrate proficiency in using the balance and the Bunsen burner.
- Determine that all the water has been driven from a hydrate by heating your sample to a constant mass.
- Relate results to the law of conservation of mass and the law of multiple proportions.
- Perform calculations by using the molar mass.
- Analyze the results and determine the empirical formula of the hydrate and its percentage by mass of water.

Materials

- balance
- Bunsen burner
- crucible and cover
- crucible tongs
- $CuSO_4$, hydrated crystals
- desiccator
- distilled water
- dropper or micropipet
- ring and pipe-stem triangle
- ring stand
- spatula
- stirring rod, glass
- weighing paper

Introduction

You are a research chemist working for a company that is developing a new chemical moisture absorber and indicator. The company plans to seal the moisture absorber into a transparent, porous pouch attached to a cellophane window on the inside of packages for compact disc players. This way, moisture within the packages will be absorbed, and any package that has too much moisture can be quickly detected and dried out. Your company's efforts have focused on copper(II) sulfate, $CuSO_4$, which can absorb water to become a hydrate that shows a distinctive color change.

When many ionic compounds are crystallized from a water solution, they include individual water molecules as part of their crystalline structure. If the substances are heated, this water of crystallization may be driven off and leave behind the pure anhydrous form of the compound. Because the law of multiple proportions also applies to crystalline hydrates, the number of moles of water driven off per mole of the anhydrous compound should be a simple whole-number ratio. You can use this information to help you determine the formula of the hydrate.

To help your company decide whether $CuSO_4$ is the right substance for the moisture absorber and indicator, you will need to examine the hydrated and anhydrous forms of the compound and determine the following:

- the empirical formula of the hydrate, including its water of crystallization
- if the compound is useful as an indicator when it changes from the hydrated to the anhydrous form
- the mass of water absorbed by the 25 g of anhydrous compound, which the company proposes to use

Even if you can guess what the formula for the hydrate should be, carefully perform this lab so that you know how well your company's supply of $CuSO_4$ absorbs moisture.

Safety Procedures

- Wear safety goggles when working around chemicals, acids, bases, flames, or heating devices. Contents under pressure may become projectiles and cause serious injury.
- Never look directly at the sun through any optical device or use direct sunlight to illuminate a microscope.
- Avoid wearing contact lenses in the lab.
- If any substance gets in your eyes, notify your instructor immediately and flush your eyes with running water for at least 15 min.

- Secure loose clothing, and remove dangling jewelry. Don't wear open-toed shoes or sandals in the lab.
- Wear an apron or lab coat to protect your clothing when working with chemicals.
- If a spill gets on your clothing, rinse it off immediately with water for at least 5 min while notifying your instructor.

- If a chemical gets on your skin or clothing or in your eyes, rinse it immediately, and alert your instructor.
- If a chemical is spilled on the floor or lab bench, alert your instructor, but do not clean it up yourself unless your teacher says it is OK to do so.

- Always use caution when working with chemicals.
- Never mix chemicals unless specifically directed to do so.
- Never taste, touch, or smell chemicals unless specifically directed to do so.
- Add acid or base to water; never do the opposite.
- Never return unused chemicals to the original container.
- Never transfer substances by sucking on a pipette or straw; use a suction bulb.
- Follow instructions for proper disposal.

- Avoid wearing hair spray or hair gel on lab days.
- Whenever possible, use an electric hot plate as a heat source instead of an open flame.
- When heating materials in a test tube, always angle the test tube away from yourself and others.
  Glass containers used for heating should be made of heat-resistant glass.
- Know your school's fire-evacuation routes.

- Check the condition of glassware before and after using it. Inform your teacher of any broken, chipped, or cracked glassware, because it should not be used.
- Do not pick up broken glass with your bare hands. Place broken glass in a specially designated disposal container.

- Clean and decontaminate all work surfaces and personal protective equipment as directed by your instructor.
- Dispose of all sharps (broken glass and other contaminated sharp objects) and other contaminated materials (biological and chemical) in special containers as directed by your instructor.

Data Table 1

Mass of empty crucible and cover
Initial mass of sample, crucible, and cover
Mass of sample, crucible, and cover after first heating
Mass of sample, crucible, and cover after second heating
Constant mass of sample, crucible, and cover

Procedure

1. Copy Data Table 1 in your lab notebook. Be sure that you have plenty of room for observations about each test.

2. Make sure that your equipment is very clean so that you will get the best possible results. Once you have heated the crucible and cover, do not touch them with your bare hands. Remember that you will need to cool the heated crucible in the desiccator before you measure its mass. Never put a hot crucible on a balance; it will damage the balance.

3. Place the crucible and cover on the triangle with the lid slightly tipped, as shown in **Figure A.** The small opening will allow gases to escape. Heat the crucible and cover until the crucible glows slightly red. Use the tongs to transfer the crucible and cover to the desiccator, and allow them to cool for 5 min. Determine the mass of the crucible and cover to the nearest 0.01 g, and record the mass in your data table.

Figure A

4. Using a spatula, add approximately 5 g of copper sulfate hydrate crystals to the crucible. Break up any large crystals before placing them in the crucible. Determine the mass of the covered crucible and crystals to the nearest 0.01 g, and record the mass in your data table.

5. Place the crucible with the copper sulfate hydrate on the triangle, and again position the cover so there is only a small opening. If the opening is too large, the crystals may spatter as they are heated. Heat the crucible very gently on a low flame to avoid spattering. Increase the temperature gradually for 2 or 3 min, and then heat until the crucible glows red for at least 5 min. Be very careful not to raise the temperature of the crucible and its contents too suddenly. You will observe a color change, which is normal, but if the substance remains yellow after cooling, it was overheated and has begun to decompose. Allow the crucible, cover, and contents to cool for 5 min in the desiccator, and then measure their mass. Record the mass in your data table.

6. Heat the covered crucible and contents to redness again for 5 min. Allow the crucible, cover, and contents to cool in the desiccator, and then determine their mass and record it in the data table. If the two mass measurements differ by no more than 0.01 g, you may assume that all of the water has been driven off. Otherwise, repeat the process until the mass no longer changes, which indicates that all of the water has evaporated. Record this constant mass in your data table.

7. After recording the constant mass, set aside a part of your sample on a piece of weighing paper. Using the dropper or pipet, as shown in **Figure B,** put a few drops of water onto this sample to rehydrate the crystals. Record your observations in your lab notebook.

Figure B

8. Clean all apparatus and your lab station. Make sure to completely shut off the gas valve before leaving the laboratory. Remember to wash your hands thoroughly. Place the rehydrated and anhydrous chemicals in the disposal containers designated by your teacher.

Analysis

1. **Explaining events**
Why do you need to heat the clean crucible before using it in this lab? Why do the tongs used throughout this lab need to be especially clean?

2. **Explaining events**
Why do you need to use a cover for the crucible? Could you leave the cover off each time you measure the mass of the crucible and its contents and still get accurate results? Explain your answer.

3. **Examining data**
Calculate the mass of anhydrous copper sulfate (the residue that remains after heating to constant mass) by subtracting the mass of the empty crucible and cover from the mass of the crucible, cover, and heated $CuSO_4$. Use the molar mass for $CuSO_4$, determined from the periodic table, to calculate the number of moles present.

4. **Analyzing data**
Calculate the mass and moles of water originally present in the hydrate by using the molar mass determined from the periodic table.

Conclusions

5. **Interpreting information** Explain why the mass of the sample decreased after it was heated, despite the law of conservation of mass.

6. **Drawing conclusions** Using your answers from items 3 and 4, determine the empirical formula for the copper sulfate hydrate.

7. **Analyzing results** What is the percentage by mass of water in the original hydrated compound?

8. **Applying conclusions** How much water could 25 g of anhydrous $CuSO_4$ absorb?

9. **Applying conclusions** When you rehydrated the small amount of anhydrous copper sulfate, what were your observations? Explain whether this substance would make a good indicator of moisture.

10. **Applying conclusions** Some cracker tins include a glass vial of drying material in the lid. This is often a mixture of magnesium sulfate and cobalt chloride. As the mixture absorbs moisture to form hydrated compounds, the cobalt chloride changes from blue-violet $CoCl_2 \cdot 2H_2O$ to pink $CoCl_2 \cdot 6H_2O$. When this hydrated mixture becomes totally pink, it can be restored to the dihydrate form by being heated in the oven. Write equations for the reactions that occur when this mixture is heated.

11. **Drawing conclusions** Three pairs of students obtained the results in the table below when they heated a solid. In each case, the students observed that when they began to heat the solid, drops of a liquid formed on the sides of the test tube.
    a. Could the solid be a hydrate? Explain how you could find out.
    b. If the solid has a molar mass of 208 g/mol after being heated, how many formula units of water are there in one formula unit of the unheated compound?

Data Table 2

Sample number	Mass before heating (g)	Constant mass after heating (g)
1	1.92	1.26
2	2.14	1.40
3	2.68	1.78

Extensions

12. **Designing experiments** Some electronic equipment is packaged for shipping with a small packet of drying material. You are interested in finding out whether the electronic equipment was exposed to moisture during shipping. How could you determine this?

Inquiry LAB
Design Your Own Experiment

7 Hydrates

Gypsum and Plaster of Paris

THE PROBLEM

Director of Research
CheMystery Labs, Inc.
52 Fulton Street
Springfield, VA 22150

Dear Director:

Lost Art Gypsum Mine previously sold its raw gypsum to a manufacturing company that used the gypsum to make anhydrous calcium sulfate, $CaSO_4$ (a desiccant), and plaster of Paris. That company has now gone out of business, and we are currently negotiating the purchase of the firm's equipment to process our own gypsum into $CaSO_4$ and plaster of Paris.

Your company has been recommended to plan the large-scale industrial process for our new plant. We will need a detailed report on the development of the process and formulas for these products. This report will be presented to the bank handling our loan for the new plant. As we discussed on the telephone today, we are willing to pay you $250,000 for the work, and the contract papers will arrive under separate cover today.

Sincerely,

Alex Farros

Alex Farros
Vice President
Lost Art Gypsum Mine

References

Review information about hydrates and water of crystallization. Gypsum and plaster of Paris are hydrated forms of calcium sulfate, $CaSO_4$. One of the largest gypsum mines in the world is located outside Paris, France. Plaster of Paris contains less water of crystallization than gypsum. Plaster of Paris is commonly used in plaster walls and art sculptures.

THE PLAN

CheMystery Labs, Inc.52 Fulton Street, Springfield, VA 22150

CheMystery Labs, Inc.
52 Fulton Street
Springfield, VA 22150

Memorandum

Date: February 10, 2004
To: Kenesha Smith
From: Martha Li-Hsien

Your team needs to develop a procedure to experimentally determine the correct empirical formulas for both hydrates of this anhydrous compound. You will use gypsum samples from the mine and samples of the plaster of Paris product.

As soon as possible, I need a preliminary report from you that includes the following:

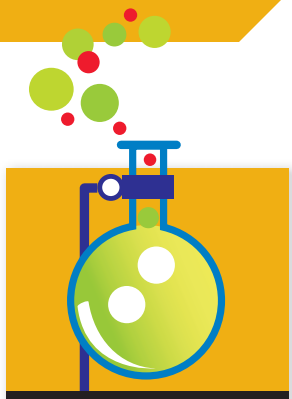
- a detailed one-page summary of your plan for the procedure, including all necessary data tables
- an itemized list of equipment

After you complete the analysis, prepare a two-page report that includes the following information:

- formulas for anhydrous calcium sulfate, plaster of Paris, and gypsum
- a summary of your procedure
- detailed and organized data and analysis sections that show calculations, along with estimates and explanations of any possible sources of error

Required Precautions

- Wear safety goggles when working around chemicals, acids, bases, flames, or heating devices. Contents under pressure may become projectiles and cause serious injury.
- Avoid wearing contact lenses in the lab.
- If any substance gets in your eyes, notify your instructor immediately and flush your eyes with running water for at least 15 min.
- Secure loose clothing, and remove dangling jewelry. Don't wear open-toed shoes or sandals in the lab.
- Wear an apron or lab coat to protect your clothing when working with chemicals.
- If a spill gets on your clothing, rinse it off immediately with water for at least 5 min while notifying your instructor.
- Always use caution when working with chemicals.
- Never taste, touch, or smell chemicals unless specifically directed to do so.
- Follow instructions for proper disposal.
- Whenever possible, use an electric hot plate as a heat source instead of an open flame.
- When heating materials in a test tube, always angle the test tube away from yourself and others.
- Know your school's fire-evacuation routes.
- Clean and decontaminate all work surfaces and personal protective equipment as directed by your instructor.
- Dispose of all sharps (broken glass and other contaminated sharp objects) and other contaminated materials (biological and chemical) in special containers as directed by your instructor.



9 Stoichiometry and Gravimetric Analysis

Objectives

- Observe the reaction between strontium chloride and sodium carbonate, and write a balanced equation for the reaction.
- Demonstrate proficiency with gravimetric methods.
- Measure the mass of insoluble precipitate formed.
- Relate the mass of precipitate formed to the mass of reactants before the reaction.
- Calculate the mass of sodium carbonate in a solution of unknown concentration.

Materials

- balance
- beaker tongs
- beakers, 250 mL (3)
- distilled water
- drying oven
- filter paper
- glass funnel or Büchner funnel
- glass stirring rod
- graduated cylinder, 100 mL
- Na_2CO_3 solution (15 mL)
- ring and ring stand
- rubber policeman
- spatula
- $SrCl_2$ solution, 0.30 M (45 mL)
- water bottle

Introduction

You are working for a company that makes water-softening agents for homes with hard water. Recently, there was a mix-up on the factory floor, and sodium carbonate solution was mistakenly mixed in a vat with an unknown quantity of distilled water. You must determine the amount of Na_2CO_3 in the vat in order to predict the percentage yield of the water-softening product.

When chemists are faced with problems that require them to determine the quantity of a substance by mass, they often use a technique called gravimetric analysis. In this technique, a small sample of the material undergoes a reaction with an excess of another reactant. The chosen reaction is one that almost always provides a yield near 100%. If the mass of the product is carefully measured, you can use stoichiometry calculations to determine how much of the reactant of unknown amount was involved in the reaction. Then by comparing the size of the analysis sample with the size of the original material, you can determine exactly how much of the substance is present.

This procedure involves a double-displacement reaction between strontium chloride, $SrCl_2$, and sodium carbonate, Na_2CO_3. In general, this reaction can be used to determine the amount of any carbonate compound in a solution.

You will react an unknown amount of sodium carbonate with an excess of strontium chloride. After purifying the product, you will determine the following:

- how much product is present
- how much Na_2CO_3 must have been present to produce that amount of product
- how much Na_2CO_3 is contained in the 575 L of solution

Safety Procedures

- Wear safety goggles when working around chemicals, acids, bases, flames, or heating devices. Contents under pressure may become projectiles and cause serious injury.
- Never look directly at the sun through any optical device or use direct sunlight to illuminate a microscope.
- Avoid wearing contact lenses in the lab.
- If any substance gets in your eyes, notify your instructor immediately and flush your eyes with running water for at least 15 min.

- Secure loose clothing, and remove dangling jewelry. Do not wear open-toed shoes or sandals in the lab.
- Wear an apron or lab coat to protect your clothing when working with chemicals.
- If a spill gets on your clothing, rinse it off immediately with water for at least 5 min while notifying your instructor.

- Always use caution when working with chemicals.
- Never mix chemicals unless specifically directed to do so.
- Never taste, touch, or smell chemicals unless specifically directed to do so.
- Add acid or base to water; never do the opposite.
- Never return unused chemicals to the original container.
- Never transfer substances by sucking on a pipette or straw; use a suction bulb.
- Follow instructions for proper disposal.

- Avoid wearing hair spray or hair gel on lab days.
- Whenever possible, use an electric hot plate as a heat source instead of an open flame.
- When heating materials in a test tube, always angle the test tube away from yourself and others.
- Glass containers used for heating should be made of heat-resistant glass.
- Know your school's fire-evacuation routes.

- Clean and decontaminate all work surfaces and personal protective equipment as directed by your instructor.
- Dispose of all sharps (broken glass and other contaminated sharp objects) and other contaminated materials (biological and chemical) in special containers as directed by your instructor.

Data Table 1

Volume of Na_2CO_3 solution added
Volume of $SrCl_2$ solution added
Mass of dry filter paper
Mass of beaker with paper towel
Mass of beaker with paper towel, filter paper, and precipitate
Mass of precipitate

Procedure

1. Organizing Data
Copy the data table in your lab notebook. Be sure that you have plenty of room for observations about each test.

2. Clean all of the necessary lab equipment with soap and water. Rinse each piece of equipment with distilled water.

3. Measure the mass of a piece of filter paper to the nearest 0.01 g, and record this value in your data table.

4. Refer to page 764 to set up a filtering apparatus, either a Büchner funnel or a gravity filtration, depending on what equipment is available.

5. Label a paper towel with your name, your class, and the date. Place the towel in a clean, dry 250 mL beaker, and measure and record the mass of the towel and beaker to the nearest 0.01 g.

6. Measure about 15 mL of the Na_2CO_3 solution into the graduated cylinder. Record this volume to the nearest 0.5 mL in your data table. Pour the Na_2CO_3 solution into a clean, empty 250 mL beaker. Carefully wash the graduated cylinder, and rinse it with distilled water.

7. Measure about 25 mL of the 0.30 M $SrCl_2$ solution into the graduated cylinder. Record this volume to the nearest 0.5 mL in your data table. Pour the $SrCl_2$ solution into the beaker with the Na_2CO_3 solution, as shown in **Figure A.** Gently stir the solution and precipitate with a glass stirring rod.

Figure A
Graduated cylinder pouring solution into beaker.

8. Carefully measure another 10 mL of $SrCl_2$ into the graduated cylinder. Record the volume to the nearest 0.5 mL in your data table. Slowly add it to the beaker. Repeat this step until no more precipitate forms.

9. Once the precipitate has settled, slowly pour the mixture into the funnel. Be careful not to overfill the funnel because some of the precipitate could be lost between the filter paper and the funnel. Use the rubber policeman to transfer as much of the precipitate into the funnel as possible.

10. Rinse the rubber policeman into the beaker with a small amount of distilled water, and pour this solution into the funnel. Rinse the beaker several more times with small amounts of distilled water, as shown in **Figure B.** Pour the rinse water into the funnel each time.

Figure B
Washing a beaker with water bottle

11. After all of the solution and rinses have drained through the funnel, slowly rinse the precipitate on the filter paper in the funnel with distilled water to remove any soluble impurities.

12. Carefully remove the filter paper from the funnel, and place it on the paper towel that you have labeled with your name. Unfold the filter paper, and place the paper towel, filter paper, and precipitate in the rinsed beaker. Then place the beaker in the drying oven. For best results, allow the precipitate to dry overnight.

13. Using beaker tongs, remove your sample from the drying oven, and allow it to cool. Measure and record the mass of the beaker with paper towel, filter paper, and precipitate to the nearest 0.01 g.

14. Dispose of the precipitate in a designated waste container. Pour the filtrate in the other 250 mL beaker into the designated waste container. Clean up the lab and all equipment after use, and dispose of substances according to your teacher's instructions. Wash your hands thoroughly after all lab work is finished and before you leave the lab.

Analysis

1. Organizing Data

Write a balanced equation for the reaction. What is the precipitate? Write its empirical formula. (Hint: It was a double-displacement reaction.)

2. Examining Data

Calculate the mass of the dry precipitate. Calculate the number of moles of precipitate produced in the reaction. (Hint: Use the results from step 13.)

3. Examining Data

How many moles of Na_2CO_3 were present in the 15 mL sample?

Conclusions

4. Evaluating Methods

There was 0.30 mol of $SrCl_2$ in every liter of solution. Calculate the number of moles of $SrCl_2$ that were added. Determine whether $SrCl_2$ or Na_2CO_3 was the limiting reactant. Would this experiment have worked if the other reactant had been chosen as the limiting reactant? Explain why or why not.

5. Evaluating Methods

Why was the precipitate rinsed in step 11? What soluble impurities could have been on the filter paper along with the precipitate? How would the calculated results vary if the precipitate had not been completely dry? Explain your answer.

6. Applying Conclusions

How many grams of Na_2CO_3 were present in the 15 mL sample?

7. Applying Conclusions

How many grams of Na_2CO_3 are present in the 575 L? (Hint: Create a conversion factor to convert from the sample, with a volume of 15 mL, to the entire solution, with a volume of 575 L.)

8. Evaluating Methods

Ask your teacher for the theoretical mass of Na_2CO_3 in the sample, and calculate your percentage error.

Extensions

1. Designing Experiments

What possible sources of error can you identify with your procedure? If you can think of ways to eliminate them, ask your teacher to approve your plan, and run the procedure again.

9 Gravimetric Analysis

Hard Water Testing

Inquiry LAB
Design Your Own Experiment

THE PROBLEM

March 3, 2004

George Taylor, Director of Analysis
CheMystery Labs, Inc.
52 Fulton Street
Springfield, VA 22150

Dear Mr. Taylor:

The city's Public Works Department is investigating new sources of water. One proposal involves drilling wells into a nearby aquifer that is protected from brackish water by a unique geological formation. Unfortunately, this formation is made of calcium minerals. If the concentration of calcium ions in the water is too high, the water will be "hard," and treating it to meet local water standards would be too expensive for us.

Water containing more than 120 mg of calcium per liter is considered hard. I have enclosed a sample of water that has been distilled from 1.0 L to its present volume. Please determine whether the water is of suitable quality.

We are seeking a firm to be our consultant for the entire testing process. Interested firms will be evaluated based on this water analysis. We look forward to receiving your report.

Sincerely,

Dana Rubio

Dana Rubio
City Manager

References

Review the "Stoichiometry" chapter for information about mass-mass stoichiometry. In this investigation, you will use a double-displacement reaction, but Na_2CO_3 will be used as a reagent to identify how much calcium is present in a sample. Like strontium and other Group 2 metals, calcium salts react with carbonate-containing salts to produce an insoluble precipitate.

THE PLAN

CheMystery Labs, Inc. 52 Fulton Street, Springfield, VA 22150

CheMystery Labs, Inc.
52 Fulton Street
Springfield, VA 22150

Memorandum

Date: March 4, 2004
To: Shane Thompson
From: George Taylor

We can solve the city's problem by doing some careful gravimetric analysis, because calcium salts and carbonate compounds undergo double-displacement reactions to yield insoluble calcium carbonate as a precipitate.

Before you begin your work, I will need the following information from you so that I can create our bid:

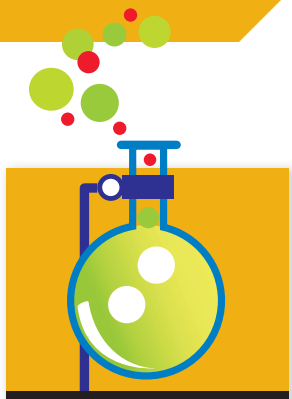
- a detailed one-page summary of your plan for the procedure as well as all necessary data tables
- a description of necessary calculations
- an itemized list of equipment

After you complete the analysis, prepare a two-page report for Dana Rubio. Make sure to include the following items:

- a calculation of calcium concentration in mg/L for the water from the aquifer
- an explanation of how you determined the amount of calcium in the sample, including measurements and calculations
- a balanced chemical equation for the reaction
- explanations and estimations for any possible sources of error

Required Precautions

- Wear safety goggles when working around chemicals, acids, bases, flames, or heating devices. Contents under pressure may become projectiles and cause serious injury.
- Avoid wearing contact lenses in the lab.
- If any substance gets in your eyes, notify your instructor immediately and flush your eyes with running water for at least 15 min.
- Secure loose clothing, and remove dangling jewelry. Don't wear open-toed shoes or sandals in the lab.
- Wear an apron or lab coat to protect your clothing when working with chemicals.
- If a spill gets on your clothing, rinse it off immediately with water for at least 5 min while notifying your instructor.
- Always use caution when working with chemicals.
- Never taste, touch, or smell chemicals unless specifically directed to do so.
- Follow instructions for proper disposal.
- Whenever possible, use an electric hot plate as a heat source instead of an open flame.
- When heating materials in a test tube, always angle the test tube away from yourself and others.
- Know your school's fire-evacuation routes.
- Clean and decontaminate all work surfaces and personal protective equipment as directed by your instructor.
- Dispose of all sharps (broken glass and other contaminated sharp objects) and other contaminated materials (biological and chemical) in special containers as directed by your instructor.



Objectives

- **Demonstrate** proficiency in the use of calorimeters and related equipment.
- **Relate** temperature changes to enthalpy changes.
- **Determine** the heat of reaction for several reactions.
- **Demonstrate** that the heat of reaction can be additive.

Materials

- balance
- distilled water
- glass stirring rod
- graduated cylinder, 100 mL
- HCl solution, 0.50 M (100 mL)
- HCl solution, 1.0 M (50 mL)
- NaOH pellets (4 g)
- NaOH solution, 1.0 M (50 mL)
- plastic-foam cups (or calorimeters)
- spatula
- thermometer
- watch glass

Optional Equipment

- CBL unit
- graphing calculator with link cable
- Vernier temperature probe

10 Calorimetry and Hess's Law

Introduction

A man working for a cleaning firm was told by his employer to pour some old cleaning supplies into a glass container for disposal. Some of the supplies included muriatic (hydrochloric) acid, HCl(*aq*), and a drain cleaner containing lye, NaOH(*s*). When the substances were mixed, the container shattered, spilling the contents onto the worker's arms and legs. The worker claims that the hot spill caused burns, and he is therefore suing his employer. The employer claims that the worker is lying because the solutions were at room temperature before they were mixed. The employer says that a chemical burn is unlikely because tests after the accident revealed that the mixture had a neutral pH, indicating that the HCl and NaOH were neutralized. The court has asked you to evaluate whether the worker's story is supported by scientific evidence.

Chemicals can be dangerous because of their special storage needs. Chemicals that are mixed and react are even more dangerous because many reactions release large amounts of heat. Glass is heat-sensitive and can shatter if there is a sudden change in temperature due to a reaction. Some glassware, such as Pyrex, is heat-conditioned but can still fracture under extreme heat conditions, especially if scratched.

You will measure the amount of heat released by mixing the chemicals in two ways. First you will break the reaction into steps and measure the heat change of each step. Then you will measure the heat change of the reaction when it takes place all at once. When you are finished, you will be able to use the calorimetry equation from the chapter "Causes of Change" to determine the following:

- the amount of heat evolved during the overall reaction
- the amount of heat for each step
- the amount of heat for the reaction in kilojoules per mole
- whether this heat could have raised the temperature of the water in the solution high enough to cause a burn

Safety Procedures

- Wear safety goggles when working around chemicals, acids, bases, flames, or heating devices. Contents under pressure may become projectiles and cause serious injury.
- Never look directly at the sun through any optical device or use direct sunlight to illuminate a microscope.
- Avoid wearing contact lenses in the lab.
- If any substance gets in your eyes, notify your instructor immediately and flush your eyes with running water for at least 15 min.

- Secure loose clothing, and remove dangling jewelry. Don't wear open-toed shoes or sandals in the lab.
- Wear an apron or lab coat to protect your clothing when working with chemicals.
- If a spill gets on your clothing, rinse it off immediately with water for at least 5 min while notifying your instructor.

- If a chemical gets on your skin or clothing or in your eyes, rinse it immediately, and alert your instructor.
  If a chemical is spilled on the floor or lab bench, alert your instructor, but do not clean it up yourself unless your teacher says it is OK to do so.

- Always use caution when working with chemicals.
- Never mix chemicals unless specifically directed to do so.
- Never taste, touch, or smell chemicals unless specifically directed to do so.
- Add acid or base to water; never do the opposite.
- Never return unused chemicals to the original container.
- Never transfer substances by sucking on a pipette or straw; use a suction bulb.
- Follow instructions for proper disposal.

- Check the condition of glassware before and after using it. Inform your teacher of any broken, chipped, or cracked glassware, because it should not be used.
- Do not pick up broken glass with your bare hands. Place broken glass in a specially designated disposal container.

- Clean and decontaminate all work surfaces and personal protective equipment as directed by your instructor.
- Dispose of all sharps (broken glass and other contaminated sharp objects) and other contaminated materials (biological and chemical) in special containers as directed by your instructor.

Procedure

1. Copy the data table below in your lab notebook. Reactions 1 and 3 will each require two additional spaces to record the mass of the empty watch glass and the mass of the watch glass with NaOH.

2. If you are not using a plastic-foam cup as a calorimeter, ask your teacher for instructions on using the calorimeter. At various points in the procedure, you will need to measure the temperature of the solution within the calorimeter.

Thermometer procedure continues on page 796.

Data Table 1

	Reaction 1	Reaction 2	Reaction 3
Total volumes of liquid(s)			
Initial temperature			
Final temperature			
Mass of empty watch glass			
Mass of watch glass with NaOH			

CBL and Sensors

3. Connect the CBL to the graphing calculator with the unit-to-unit link cable using the I/O ports located on each unit. Connect the temperature probe to the CH1 port. Turn on the CBL and the graphing calculator. Start the program CHEMBIO on the graphing calculator.
   a. Select option *SET UP PROBES* from the MAIN MENU. Enter 1 for the number of probes. Select the temperature probe from the list. Enter 1 for the channel number. Select *USE STORED* from the CALIBRATION menu.
   b. Select the *COLLECT DATA* option from the MAIN MENU. Select the *TRIGGER* option from the DATA COLLECTION menu.

4. Measure the temperature by gently inserting the Vernier temperature probe into the hole in the calorimeter lid.

Reaction 1: Dissolving NaOH

5. Pour about 100 mL of distilled water into a graduated cylinder. Measure and record the volume of the water to the nearest 0.1 mL. Pour the water into your calorimeter.

6. Using the temperature probe, measure the temperature of the water. Press TRIGGER on the CBL to collect the temperature reading. Record this temperature in your data table. Select *STOP* from the TRIGGER menu on the graphing calculator. Leave the probe in the calorimeter.

7. Select the *COLLECT DATA* option from the MAIN MENU. Select the *TIME GRAPH* option from the DATA COLLECTION menu. Enter 6 for the time between samples, in seconds. Enter 99 for the number of samples (the CBL will collect data for 9.9 min). Press ENTER. Select *USE TIME SETUP* to continue. If you want to change the number of samples or the time between samples, select *MODIFY SETUP.* Enter 0 for *Ymin,* enter 100 for *Ymax,* and enter 5 for *Yscl.*

8. Determine and record the mass of a clean and dry watch glass to the nearest 0.01 g. Remove the watch glass from the balance. While wearing gloves, obtain about 2 g of NaOH pellets, and put them on the watch glass. Use forceps when handling NaOH pellets. Measure and record the mass of the watch glass and the pellets to the nearest 0.01 g. **It is important that this step be done quickly because NaOH is hygroscopic. It absorbs moisture from the air, and its mass increases as long as it remains exposed to the air.**

9. Press ENTER on the graphing calculator to begin collecting the temperature readings for the water in the calorimeter.

10. Immediately place the NaOH pellets in the calorimeter cup, and gently stir the solution with a stirring rod. Place the lid on the calorimeter.

11. When the CBL displays DONE, use the arrow keys to trace the graph. Time in seconds in graphed on the *x*-axis, and the temperature readings are graphed on the *y*-axis. Record the highest temperature reading from the CBL in your data table.

12. When the reaction is finished, pour the solution into the container designated by your teacher for disposal of basic solutions.

13. Be sure to clean all equipment and rinse it with distilled water before continuing with the next procedure.

Reaction 2: NaOH and HCl in solution

14. Pour about 50 mL of 1.0 M HCl into a graduated cylinder. Measure and record the volume of the HCl solution to the nearest 0.1 mL. Pour the HCl solution into your calorimeter.

15. Select the *COLLECT DATA* option from the MAIN MENU. Select the *TRIGGER* option from the DATA COLLECTION menu. Using the temperature probe, measure the temperature of the HCl solution. Press TRIGGER on the CBL to collect the temperature reading. Record this temperature in your data table.

16. Pour about 50 mL of 1.0 M NaOH into a graduated cylinder. Measure and record the volume of the NaOH solution to the nearest 0.1 mL. **For this step only, rinse the temperature probe in distilled water.** Using the temperature probe, measure the temperature of the NaOH solution. Press TRIGGER on the CBL to collect the temperature reading. Record this temperature in your data table. Select *STOP* from the TRIGGER menu on the graphing calculator. Put the probe in the calorimeter.

17. Select the *COLLECT DATA* option from the MAIN MENU. Select the *TIME GRAPH* option from the DATA COLLECTION menu. Enter 6 for the time between samples, in seconds. Enter 99 for the number of samples. Press ENTER. Select *USE TIME SETUP* to continue. If you want to change the number of samples or the time between samples, select *MODIFY SETUP.* Enter 0 for *Ymin,* enter 100 for *Ymax,* and enter 5 for *Yscl.* Press ENTER on the calculator to begin collecting temperature readings.

18. Pour the NaOH solution into the calorimeter cup, and stir gently. Place the lid on the calorimeter.

19. When the CBL displays DONE, use the arrow keys to trace the graph. Time in seconds in graphed on the *x*-axis, and the temperature readings are graphed on the *y*-axis. Record the highest temperature reading from the CBL in your data table.

Figure A

20. Pour the solution into the container designated by your teacher for disposal of mostly neutral solutions. Clean and rinse all equipment before continuing with the next procedure.

Reaction 3: Solid NaOH and HCl in solution

21. Pour about 100 mL of 0.50 M HCl into a graduated cylinder. Measure and record the volume to the nearest 0.1 mL. Pour the HCl solution into your calorimeter, as shown in **Figure A.**

22. Select the *COLLECT DATA* option from the MAIN MENU. Select the *TRIGGER* option from the DATA COLLECTION menu. Using the temperature probe, measure the temperature of the HCl solution. Press TRIGGER on the CBL to collect the temperature reading. Record this temperature in your data table. Select *STOP* from the TRIGGER menu on the graphing calculator.

23. Select the *COLLECT DATA* option from the MAIN MENU. Select the *TIME GRAPH* option from the DATA COLLECTION menu. Enter 6 for the time between samples, in seconds. Enter 99 for the number of samples. Press ENTER. Select *USE TIME SETUP* to continue. If you want to change the number of samples or the time between samples, select *MODIFY SETUP.* Enter 0 for *Ymin,* enter 100 for *Ymax,* and enter 5 for *Yscl.* Press ENTER on the calculator to begin collecting temperature readings.

24. Measure the mass of a clean and dry watch glass, and record it in your data table. Obtain approximately 2 g of NaOH. Place it on the watch glass, and record the total mass to the nearest 0.01 g. **It is important that this step be done quickly because NaOH is hygroscopic.**

25. Press ENTER on the graphing calculator to begin collecting the temperature readings for the water in the calorimeter.

26. Immediately place the NaOH pellets in the calorimeter, and gently stir the solution. Place the lid on the calorimeter.

27. When the CBL displays DONE, use the arrow keys to trace the graph. Time in seconds in graphed on the *x*-axis, and the temperature readings are graphed on the *y*-axis. Record the highest temperature reading from the CBL in your data table.

28. When the reaction is finished, pour the solution into the container designated by your teacher for disposal of basic solutions.

29. Clean all apparatus and your lab station. Check with your teacher for the proper disposal procedures. Any excess NaOH pellets should be disposed of in the designated container. Always wash your hands thoroughly after cleaning up the lab area and equipment.

Thermometer

3. Measure the temperature by gently inserting the thermometer into the hole in the calorimeter lid, as shown in **Figure B.** The thermometer takes time to reach the same temperature as the solution inside the calorimeter, so wait to be sure you have an accurate reading. **Thermometers break easily, so be careful with them, and do not use them to stir a solution.**

Figure B

Reaction 1: Dissolving NaOH

4. Pour about 100 mL of distilled water into a graduated cylinder. Measure and record the volume of the water to the nearest 0.1 mL. Pour the water into your calorimeter. Measure and record the water temperature to the nearest 0.1°C.

5. Determine and record the mass of a clean and dry watch glass to the nearest 0.01 g. Remove the watch glass from the balance. While wearing gloves, obtain about 2 g of NaOH pellets, and put them on the watch glass. Use forceps when handling NaOH pellets. Measure and record the mass of the watch glass and the pellets to the nearest 0.01 g. **It is important that this step be done quickly because NaOH is hygroscopic. It absorbs moisture from the air, and increases its mass as long as it remains exposed to the air.**

6. Immediately place the NaOH pellets in the calorimeter cup, and gently stir the solution with a stirring rod. **Do not stir with a thermometer.** Place the lid on the calorimeter. Watch the thermometer, and record the highest temperature in the data table. When the reaction is finished, pour the solution into the container designated by your teacher for disposal of basic solutions.

7. Be sure to clean all equipment and rinse it with distilled water before continuing with the next procedure.

Reaction 2: NaOH and HCl in solution

8. Pour about 50 mL of 1.0 M HCl into a graduated cylinder. Measure and record the volume of the HCl solution to the nearest 0.1 mL. Pour the HCl solution into your calorimeter. Measure and record the temperature of the HCl solution to the nearest 0.1°C.

9. Pour about 50 mL of 1.0 M NaOH into a graduated cylinder. Measure and record the volume of the NaOH solution to the nearest 0.1 mL. **For this step only, rinse the thermometer in distilled water, and measure the temperature of the NaOH solution in the graduated cylinder to the nearest 0.1°C. Record the temperature in your data table, and then replace the thermometer in the calorimeter.**

10. Pour the NaOH solution into the calorimeter cup, and stir gently. Place the lid on the calorimeter. Watch the thermometer, and record the highest temperature in the data table. When finished with this reaction, pour the solution into the container designated by your teacher for disposal of mostly neutral solutions.

11. Clean and rinse all equipment before continuing with the next procedure.

Reaction 3: Solid NaOH and HCl in solution

12. Pour about 100 mL of 0.50 M HCl into a graduated cylinder. Measure and record the volume to the nearest 0.1 mL. Pour the HCl solution into your calorimeter, as shown in **Figure C.** Measure and record the temperature of the HCl solution to the nearest 0.1°C.

Figure C

13. Measure the mass of a clean and dry watch glass, and record it in your data table. Obtain approximately 2 g of NaOH. Place it on the watch glass, and record the total mass to the nearest 0.01 g. **It is important that this step be done quickly because NaOH is hygroscopic.**

14. Immediately place the NaOH pellets in the calorimeter, and gently stir the solution. Place the lid on the calorimeter. Watch the thermometer, and record the highest temperature in the data table. When finished with this reaction, pour the solution into the container designated by your teacher for disposal of mostly neutral solutions.

15. Clean all apparatus and your lab station. Check with your teacher for the proper disposal procedures. Any excess NaOH pellets should be disposed of in the designated container. Always wash your hands thoroughly after cleaning up the lab area and equipment.

Analysis

1. Organizing Data

Write a balanced chemical equation for each of the three reactions that you performed. (Hint: Be sure to include states of matter for all substances in each equation.)

2. Analyzing Results

Find a way to get the equation for the total reaction by adding two of the equations from Analysis and Interpretation item 1 and then canceling out substances that appear in the same form on both sides of the new equation. (Hint: Start with the equation whose product is a reactant in a second equation. Add those two equations together.)

3. Explaining Events

Explain why a plastic-foam cup makes a better calorimeter than a paper cup does.

4. Organizing Data

Calculate the change in temperature (Δt) for each of the reactions.

5. Organizing Data

Assuming that the density of the water and the solutions is 1.00 g/mL, calculate the mass, m, of liquid present for each of the reactions.

6. Analyzing Results

Using the calorimeter equation, calculate the heat released by each reaction. (Hint: Use the specific heat capacity of water in your calculations; $c_{p,H_2O} = 4.180$ J/g•°C.)

$$\text{Heat} = m \times \Delta t \times c_{p,H_2O}$$

7. Organizing Data

Calculate the moles of NaOH used in each of the reactions. (Hint: To find the number of moles in a solution, multiply the volume in liters by the molar concentration.)

8. Analyzing Results

Calculate the ΔH value in terms of kilojoules per mole of NaOH for each of the three reactions.

9. Analyzing Results

Using your answer to Analysis and Interpretation item 2 and your knowledge of Hess's law from the chapter "Causes of Change," explain how the enthalpies for the three reactions should be mathematically related.

10. Analyzing Results

Which of the following types of heat of reaction apply to the enthalpies calculated in Analysis and Interpretation item 8: heat of combustion, heat of solution, heat of reaction, heat of fusion, heat of vaporization, and heat of formation?

Conclusions

11. Evaluating Methods

Use your answers from Analysis and Interpretation items 7 and 8 to determine the ΔH value for the reaction of solid NaOH with HCl solution by direct measurement and by indirect calculation.

12. Drawing Conclusions

Third-degree burns can occur if skin comes into contact for more than 4 s with water that is hotter than 60°C (140°F). Suppose someone accidentally poured hydrochloric acid into a glass-disposal container that already contained the drain cleaner NaOH and the container shattered. The solution in the container was approximately 55 g of NaOH and 450 mL of hydrochloric acid solution containing 1.35 mol of HCl (a 3.0 M HCl solution). If the initial temperature of the solutions was 25°C, could a mixture hot enough to cause burns have resulted?

13. Applying Conclusions

For the reaction between the drain cleaner and HCl described in item 12, which chemical is the limiting reactant? How many moles of the other reactant remained unreacted?

14. Evaluating Results

When chemists make solutions from NaOH pellets, they often keep the solution in an ice bath. Explain why.

15. Evaluating Methods

You have worked with heats of solution for exothermic reactions. Could the same type of procedure be used to determine the temperature changes for endothermic reactions? How would the procedure stay the same? What would change about the procedure and the data?

16. Drawing Conclusions

Which is more stable, solid NaOH or NaOH solution? Explain your answer.

Extensions

1. Designing Experiments

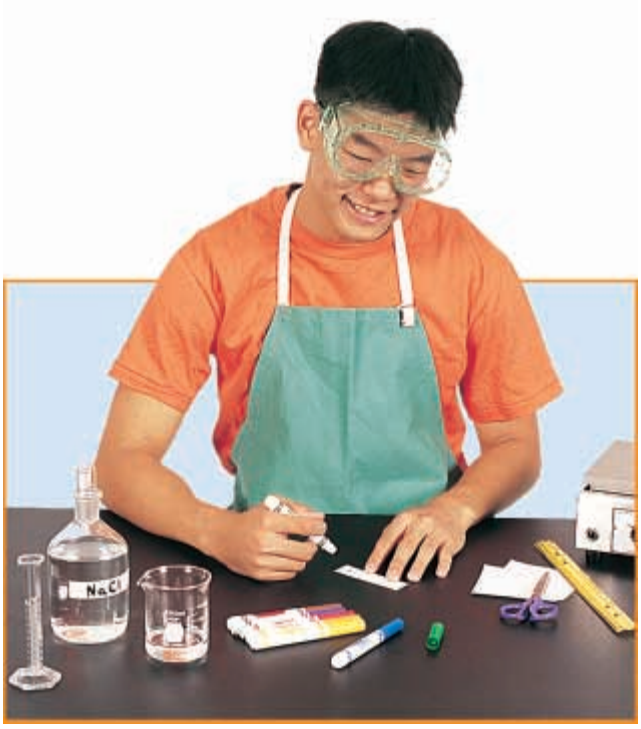
You have worked with heats of solution for exothermic reactions. Could the same type of procedure be used to determine the temperature changes for endothermic reactions? How would the procedure stay the same? What would change about the procedure and the data?

2. Designing Experiments

A chemical supply company is going to ship NaOH pellets to a very humid place, and you have been asked to give advice on packaging. Design a package for the NaOH pellets. Explain the advantages of your package's design and materials. (Hint: Remember that the reaction in which NaOH absorbs moisture from the air is exothermic and that NaOH reacts exothermically with other compounds as well.)

Skills Practice Lab

13 Paper Chromatography of Colored Markers



Objectives

- Conduct a paper chromatography experiment with three different water-soluble colored markers.
- Design a successful method to ensure that the chromatography paper remains vertical throughout the experiment.
- Observe the dye components of three different water-soluble markers.

Materials

- beaker, 250 mL
- chromatography paper
- developing solution: NaCl solution, 0.1% by mass
- graduated cylinder, 10 mL
- hot plate
- markers
- paper clips
- pencils
- ruler
- scissors

Introduction

There is a wide variety of marker products on the market today ranging in color and function. All of these markers contain different dye components that are responsible for their color.

Paper chromatography is an analytical technique that uses paper as a medium to separate the different dye components dissolved in a mixture. In this process, the mixture to be separated is placed on a piece of chromatography paper. A solvent is then allowed to soak up into the paper. As the solvent travels across the paper, some of the components of the mixture are carried with it. Particles of the same component group together. The components that are most soluble and least attracted to the paper travel farther than others. A color band is created and the different components can be seen separated on the paper. The success of chromatography hinges on the slight difference in the physical properties of the individual components.

In this activity you will use a paper chromatography to determine the components of the dyes found in water-soluble markers. Your goal is to use paper chromatography to determine the dye components of three different water-soluble markers. You will also need to design a simple method that will keep the chromatography paper vertical while it is in the developing solution.

Safety Procedures

- Wear safety goggles when working around chemicals, acids, bases, flames, or heating devices. Contents under pressure may become projectiles and cause serious injury.
- Never look directly at the sun through any optical device or use direct sunlight to illuminate a microscope.
- Avoid wearing contact lenses in the lab.
- If any substance gets in your eyes, notify your instructor immediately and flush your eyes with running water for at least 15 min.

- Secure loose clothing, and remove dangling jewelry. Don't wear open-toed shoes or sandals in the lab.
- Wear an apron or lab coat to protect your clothing when working with chemicals.
- If a spill gets on your clothing, rinse it off immediately with water for at least 5 min while notifying your instructor.

- Always use caution when working with chemicals.
- Never mix chemicals unless specifically directed to do so.
- Never taste, touch, or smell chemicals unless specifically directed to do so.
- Add acid or base to water; never do the opposite.
- Never return unused chemicals to the original container.
- Never transfer substances by sucking on a pipette or straw; use a suction bulb.
- Follow instructions for proper disposal.

- Clean and decontaminate all work surfaces and personal protective equipment as directed by your instructor.
- Dispose of all sharps (broken glass and other contaminated sharp objects) and other contaminated materials (biological and chemical) in special containers as directed by your instructor.

Procedure

1. Copy the data table below in your lab notebook.

Data Table 1

Marker Color	Dye Components

2. Obtain a clean 250 mL beaker and a 7.0 × 2.5 cm piece of chromatography paper.

3. Choose three different markers for this activity. Write the color of each marker in your data table.

4. Using a ruler, draw a horizontal line in pencil approximately 1.0 cm from one of the ends of the paper. Mark three small dots on this line, using a different marker for each dot.

Figure A

Figure B

5. Using a pencil, label each of the dots on the chromatography paper according to the color of the markers.

6. Measure out 7.0 mL of the developing solution in a 10 mL graduated cylinder.

7. Pour the 7.0 mL of solution in a 250 mL beaker, as shown in **Figure A.** Make sure the bottom of the beaker is completely covered. The level of the liquid must be below the marks on your chromatography paper.

8. You will need to design an experimental technique to ensure that your paper sample does not slide into the developing solution. The chromatography paper must remain vertical as the developing solution rises into the paper.

9. Carefully place your paper (with the dots at the bottom) into the liquid, as shown in **Figure B.**

10. When the level of the liquid has advanced through most of the paper, remove the paper from the developing solution. Hold up the paper and observe the colors.

11. The chromatography samples can be carefully dried on a hot plate.

12. You may repeat this process using overwrite or color-change markers.

13. Clean all apparatus and your lab station. Return equipment to its proper place. Dispose of chemicals and solutions in the containers designated by your teacher. Do not pour any chemicals down the drain or in the trash unless your teacher directs you to do so.

Analysis

1. Describing Events
What was the purpose of this experiment?

2. Explaining Events
Why were only water-soluble markers used in this experiment? Could permanent markers be used?

3. Explaining Events
Why must the spotted marks remain above the level of the liquid in the beaker?

Conclusions

4. Applying Conclusions
Why shouldn't you use a ballpoint pen when marking the initial line and spots on the chromatography paper? Explain.

5. Evaluating Results
Make observations about the dye components (colors) of each marker based on your results.

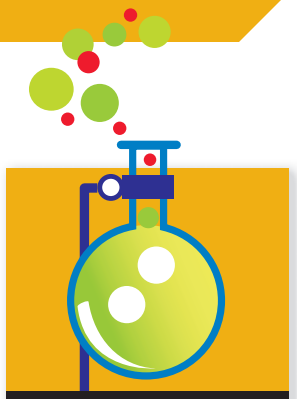
6. Applying Conclusions
Explain how law enforcement officials could use paper chromatography to identify a pen that was used in a ransom note.

7. Applying Conclusions
List some other applications for using paper chromatography.

8. Evaluating Methods
Compare your results with those of another lab group. Were the dye components found in other markers different from those found in yours?

Extensions

1. Research and Communications
Gasoline is a mixture of many different chemicals. Chemists can identify the different components of the mixture using chromatography. Research what gasoline is composed of and make a chart of the common components.



15A Drip-Drop Acid-Base Experiment

Objectives

- Translate word equations into chemical formulas.
- Count the number of drops of sodium hydroxide needed to completely react with different acid samples.
- Calculate the average number of drops of sodium hydroxide needed for each acid.
- Relate the number of drops to the coefficients in the balanced chemical equations.

Materials

- buret clamps
- burets (2)
- H_2SO_4, 0.1 M
- HCl, 0.1 M
- NaOH, 0.3 M
- phenolphthalein indicator
- pipets
- ring stands
- test tubes
- test-tube rack

Introduction

The purpose of this lab is to investigate the simple reaction between two different acids and a base. We will be counting the number of drops of sodium hydroxide that are needed to react completely with all of the acid. The starting acid and base solutions are colorless and clear, and the final products are colorless and clear.

To monitor the progress of the chemical reaction, the acid-base indicator phenolphthalein will be used. Phenolphthalein is colorless when acidic and pink in color when neutral or basic. In this activity, we will know that all of the acid has been consumed by the base when the test-tube solution starts to turn pink. We can monitor the progress of the reaction so that a single drop of the base results in a sudden change from colorless to pink. At that point, we will know that all of the acid has reacted with the base.

You will need to count the number of drops of sodium hydroxide that are necessary to neutralize two different acids. Find the relationship between the sodium hydroxide drops necessary and the coefficients in the balanced chemical equation.

Safety Procedures

- Wear safety goggles when working around chemicals, acids, bases, flames, or heating devices. Contents under pressure may become projectiles and cause serious injury.
- Never look directly at the sun through any optical device or use direct sunlight to illuminate a microscope.
- Avoid wearing contact lenses in the lab.
- If any substance gets in your eyes, notify your instructor immediately and flush your eyes with running water for at least 15 min.

- Secure loose clothing, and remove dangling jewelry. Don't wear open-toed shoes or sandals in the lab.
- Wear an apron or lab coat to protect your clothing when working with chemicals.
- If a spill gets on your clothing, rinse it off immediately with water for at least 5 min while notifying your instructor.

- Always use caution when working with chemicals.
- Never mix chemicals unless specifically directed to do so.
- Never taste, touch, or smell chemicals unless specifically directed to do so.
- Add acid or base to water; never do the opposite.
- Never return unused chemicals to the original container.
- Never transfer substances by sucking on a pipette or straw; use a suction bulb.
- Follow instructions for proper disposal.

- Check the condition of glassware before and after using it. Inform your teacher of any broken, chipped, or cracked glassware, because it should not be used.
- Do not pick up broken glass with your bare hands. Place broken glass in a specially designated disposal container.

- Clean and decontaminate all work surfaces and personal protective equipment as directed by your instructor.
- Dispose of all sharps (broken glass and other contaminated sharp objects) and other contaminated materials (biological and chemical) in special containers as directed by your instructor.

Procedure

1. Translate each of the word equations shown below into chemical equations.

hydrochloric acid + sodium hydroxide ⟶ sodium chloride + water

sulfuric acid + sodium hydroxide ⟶ sodium sulfate + water

2. Copy Data Tables 1 and 2 in your lab notebook. Be sure that you have plenty of room for observations about each test.

3. Clean six test tubes, and rinse them with distilled water. They do not need to be dry.

4. Obtain approximately 10 mL of sodium hydroxide solution in a small beaker.

Data Table 1

HCl volume (mL)	NaOH (drops)
2.00	
2.00	
4.00	
4.00	

Data Table 2

H_2SO_4 volume (mL)	NaOH (drops)
2.00	
2.00	

Figure A

Part I

5. Use a buret to put exactly 2.00 mL of hydrochloric acid directly into your test tube, as shown in **Figure A.**
6. Add two drops of phenolphthalein indicator solution to the test tube.
7. Use a pipet to add the sodium hydroxide solution dropwise to the test tube. Count the number of drops of sodium hydroxide as you add them. Gently shake the test tube from side to side after adding each drop. **Continue adding drops until the color just changes from colorless to pink.**
8. Record in your data table the total number of drops of sodium hydroxide needed to reach the color change. To obtain consistent results, repeat this trial.

Part II

9. Use a buret to add exactly 4.00 mL of hydrochloric acid directly into a clean test tube.
10. Add two drops of phenolphthalein indicator solution to the test tube.
11. Using a pipet, add one drop of sodium hydroxide solution at a time to the test tube. Count the number of drops of sodium hydroxide as you add them. Gently swirl the test tube after adding each drop. **Continue adding drops until the color just changes from colorless to a pink.**
12. Record in your data table the total number of drops of sodium hydroxide needed to reach the color change. Repeat this trial.

Part III Sulfuric Acid

13. Use a buret to add exactly 2.00 mL of sulfuric acid directly into your test tube.
14. Add two drops of phenolphthalein indicator solution to the test tube.
15. Using a pipet, add one drop of sodium hydroxide solution at a time to the test tube. Count the number of drops of sodium hydroxide as you add them. Gently swirl the test tube after adding each drop. **Continue adding drops until the color just changes from colorless to pink.**
16. Record in your data table the total number of drops of sodium hydroxide needed to reach the color change. Repeat this trial.
17. Clean all apparatus and your lab station. Return equipment to its proper place. Dispose of chemicals and solutions in the containers designated by your teacher. Do not pour any chemicals down the drain or in the trash unless your teacher directs you to do so. Wash your hands thoroughly after all work is finished and before you leave the lab.

Analysis

1. Examining Data

What was the average number of drops of sodium hydroxide required to consume 2.00 mL of HCl? Show your work. 4.00 mL of HCl? Show your work.

2. Examining Data

What was the average number of drops of sodium hydroxide required to consume 2.00 mL of H_2SO_4? Show your work.

3. Analyzing Results

Compare your responses to Analysis item 1. Is there a difference in the average number of drops? What is the ratio between these two numbers? Is it 1:1, 1:2, 2:1, or 1:3? Explain the "chemistry" behind this ratio.

4. Analyzing Results

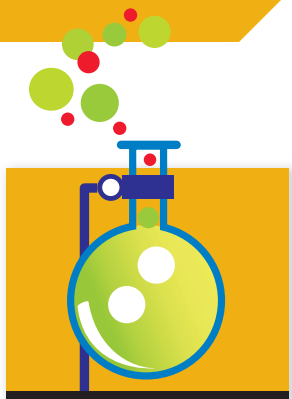
Now compare your responses to Analysis and Interpretation items 1 and 2. Is there a difference in the average number of drops? What is the ratio between these two numbers? Is it 1:1, 1:2, 1:3, etc? Explain the "chemistry" behind this ratio.

Conclusions

5. Applying Conclusions

Based on your observed results, how many drops of sodium hydroxide would be needed to react completely with a 2.00 mL sample of HNO_3?

$$HNO_3 + NaOH \longrightarrow NaNO_3 + H_2O$$



15B Acid-Base Titration of an Eggshell

Objectives

- Determine the amount of calcium carbonate present in an eggshell.
- Relate experimental titration measurements to a balanced chemical equation.
- Infer a conclusion from experimental data.
- Apply reaction-stoichiometry concepts.

Materials

- balance
- beaker, 100 mL
- bottle, 50 mL or small Erlenmeyer flask
- desiccator (optional)
- distilled water
- drying oven
- eggshell
- forceps
- graduated cylinder, 10 mL
- HCl, 1.00 M
- medicine droppers or thin-stemmed pipets (3)
- mortar and pestle
- NaOH, 1.00 M
- phenolphthalein solution
- weighing paper
- white paper or white background

Introduction

You are a scientist working with the Department of Agriculture. A farmer has brought a problem to you. In the past 10 years, his hens' eggs have become increasingly fragile. So many of them have been breaking that he is beginning to lose money. The farmer believes his problems are linked to a landfill upstream, which is being investigated for illegal dumping of PCBs and other hazardous chemicals. Your job is to find out if the PCBs are the cause of the hens' fragile eggs.

Birds have evolved a chemical process that allows them to rapidly produce the calcium carbonate, $CaCO_3$, required for eggshell formation. Research has shown that some chemicals, like DDT and PCBs, can decrease the amount of calcium carbonate in the eggshell, resulting in shells that are thin and fragile.

You need to determine how much calcium carbonate is in sample eggshells from chickens that were not exposed to PCBs. The farmer's eggshells contain about 78% calcium carbonate. The calcium carbonate content of eggshells can easily be determined by means of an acid-base back-titration. A carefully measured excess of a strong acid will react with the calcium carbonate. Because the acid is in excess, there will be some left over at the end of the reaction. The resulting solution will be titrated with a strong base to determine how much acid remained unreacted. Phenolphthalein will be used as an indicator to signal the endpoint of the titration. From this measurement, you can determine the following:

- the amount of excess acid that reacted with the eggshell
- the amount of calcium carbonate that was present to react with this acid

Safety Procedures

- Wear safety goggles when working around chemicals, acids, bases, flames, or heating devices. Contents under pressure may become projectiles and cause serious injury.
- Never look directly at the sun through any optical device or use direct sunlight to illuminate a microscope.
- Avoid wearing contact lenses in the lab.
- If any substance gets in your eyes, notify your instructor immediately and flush your eyes with running water for at least 15 minutes.

- Secure loose clothing, and remove dangling jewelry. Don't wear open-toed shoes or sandals in the lab.
- Wear an apron or lab coat to protect your clothing when working with chemicals.
- If a spill gets on your clothing, rinse it off immediately with water for at least 5 min while notifying your instructor.

- If a chemical gets on your skin or clothing or in your eyes, rinse it immediately, and alert your instructor.
- If a chemical is spilled on the floor or lab bench, alert your instructor, but do not clean it up yourself unless your teacher says it is OK to do so.

- Always use caution when working with chemicals.
- Never mix chemicals unless specifically directed to do so.
- Never taste, touch, or smell chemicals unless specifically directed to do so.
- Add acid or base to water; never do the opposite.
- Never return unused chemicals to the original container.
- Never transfer substances by sucking on a pipette or straw; use a suction bulb.
- Follow instructions for proper disposal.

- Whenever possible, use an electric hot plate as a heat source instead of an open flame.
- When heating materials in a test tube, always angle the test tube away from yourself and others.
- Glass containers used for heating should be made of heat-resistant glass.
- Know your school's fire-evacuation routes.

- Clean and decontaminate all work surfaces and personal protective equipment as directed by your instructor.
- Dispose of all sharps (broken glass and other contaminated sharp objects) and other contaminated materials (biological and chemical) in special containers as directed by your instructor.

Procedure

1. Make data and calculation tables like the following tables.

Data Table 1

Total volume of acid drops	
Average volume of each drop	
Total volume of base drops	
Average volume of each drop	

Data Table 2

Titration Steps	
Mass of entire eggshell	
Mass of ground eggshell sample	
Number of drops of 1.00 M HCl added	150
Volume of 1.00 M HCl added	
Number of drops of 1.00 M NaOH added	
Volume of 1.00 M NaOH added	
Volume of HCl reacting with NaOH	
Volume of HCl reacting with eggshell	
Number of moles of HCl reacting with eggshell	
Number of moles of $CaCO_3$ reacting with HCl	
Mass of $CaCO_3$	
Percentage of $CaCO_3$ in eggshell sample	

Data Table 3 **Graduated Cylinder Readings (Pipet Calibration: Steps 3–5)**

Trial	Initial acid pipet	Final acid pipet	Initial base pipet	Final base pipet
1				
2				
3				

Figure A

Figure B

Figure C

Figure D

2. Remove the white and the yolk from the egg, as shown in **Figure A.** Dispose of these according to your teacher's directions. Wash the shell with distilled water, and carefully peel all the membranes from the inside of the shell. Discard the membranes. Place ALL of the shell in a premassed beaker, and dry the shell in the drying oven at 110°C for about 15 min.

3. Put exactly 5.0 mL of water in the 10.0 mL graduated cylinder. Record this volume in the data table in your lab notebook. Fill the first dropper or pipet with water. This dropper should be labeled "Acid." **Do not use this dropper for the base solution.** Holding the dropper vertical, add 20 drops of water to the cylinder. For the best results, keep the sizes of the drops as even as possible throughout this investigation. Record the new volume of water in the first data table as Trial 1.

4. Without emptying the graduated cylinder, add an additional 20 drops from the dropper, as you did in step 3, and record the new volume as the final volume for Trial 2. Repeat this procedure once more for Trial 3.

5. Repeat steps 3 and 4 for the second thin-stemmed dropper. Label this dropper "Base." **Do not use this dropper for the acid solution.**

6. Make sure that the three trials produce data that are similar to each other. If one is greatly different from the others, perform steps 3–5 over again. If you're still waiting for the eggshell in the drying oven, calculate and record in the first data table the total volume of the drops and the average volume per drop.

7. Remove the eggshell and beaker from the oven. Cool them in a desiccator. Record the mass of the entire eggshell in the second data table. Place half the shell in a clean mortar, and grind it to a very fine powder, as shown in **Figure B.** This will save time when dissolving the eggshell. (If time permits, dry the crushed eggshell again, and cool it in the desiccator.)

8. Measure the mass of a piece of weighing paper. Transfer about 0.1 g of ground eggshell to a piece of weighing paper, and measure the eggshell's mass as accurately as possible. Record the mass in the second data table. Place this eggshell sample in a clean 50 mL bottle or Erlenmeyer flask. A flask will make it easier to swirl the mixture when needed.

9. Fill the acid dropper with the 1.00 M HCl acid solution, and then empty the dropper into an extra 100 mL beaker. Label the beaker "Waste." Fill the base dropper with the 1.00 M NaOH base solution, and then empty the dropper into the 100 mL beaker.

10. Fill the acid dropper once more with 1.00 M HCl. Using the acid dropper, add exactly 150 drops of 1.00 M HCl to the bottle (or flask) with the eggshell, as shown in **Figure C.** Swirl gently for 3–4 minutes. Rinse the sides of the flask with about 10 mL of distilled water. Using a third dropper, add two drops of phenolphthalein solution. Record the number of drops of HCl used in the second data table.

11. Fill the base dropper with the 1.00 M NaOH. Slowly add NaOH from the base dropper into the bottle or flask with the eggshell mixture until a faint pink color persists, even after it is swirled gently, as shown in **Figure D.** It may help to use a white piece of paper as a background so you will be able to see the color as soon as possible. **Be sure to add the base drop by drop, and be certain the drops end up in the reaction mixture and not on the side of the bottle or flask. Keep a careful count of the number of drops used.** Record the number of drops of base used in the second data table.

12. Clean all apparatus and your lab station. Return the equipment to its proper place. Dispose of chemicals and solutions in the containers designated by your teacher. Do not pour any chemicals down the drain or in the trash unless your teacher directs you to do so. Wash your hands thoroughly before you leave the lab and after all work is finished.

Analysis

1. Explaining Events

The calcium carbonate in the eggshell sample undergoes a double-replacement reaction with the hydrochloric acid in step 10. Then the carbonic acid that was formed decomposes. Write a balanced chemical equation for these reactions. (Hint: The gas observed was carbon dioxide.)

2. Explaining Events

Write the balanced chemical equation for the acid-base neutralization of the excess unreacted HCl with the NaOH.

3. Organizing Data

Make the necessary calculations from the first data table to find the number of milliliters in each drop. Using this milliliter/drop ratio, convert the number of drops of each solution in the second data table to volumes in milliliters.

4. Analyzing Results

Using the relationship between the molarity and volume of acid and the molarity and volume of base needed to neutralize the acid, calculate the volume of the HCl solution that was neutralized by the NaOH. Then subtract this amount from the initial volume of HCl to determine how much HCl reacted with $CaCO_3$.

Conclusions

5. Evaluating Data

Use the stoichiometry of the reaction in Analysis and Interpretation item 1 to calculate the number of moles of $CaCO_3$ that reacted with the HCl, and record this number in your table.

6. Evaluating Data

Workers in a lab in another city have also tested eggs, and they found that a normal eggshell is about 97% $CaCO_3$. Calculate the percent error for your measurement.

Extensions

1. Building Models

Calculate an estimate of the mass of $CaCO_3$ present in the entire eggshell, based on your results. (Hint: Apply the percent composition of your sample to the mass of the entire eggshell.)

2. Designing Experiments

What possible sources of error can you identify in this procedure? If you can think of ways to eliminate them, ask your teacher to approve your plan, and run the procedure again.

Inquiry LAB
Design Your Own Experiment

15B Acid-Base Titration

THE PROBLEM

DELIVER BY OVERNIGHT COURIER
Date: April 21, 2004
To: EPA National Headquarters
From: Anthony Wong, Plant Supervisor
Re: Vacaville Bleachex Corp. Plant Spill

As a result of last night's earthquake, the Bleachex plant in the industrial park south of Vacaville was severely damaged. The safety control measures failed because of the magnitude of the earthquake.

Bleachex manufactures a variety of products using concentrated acids and bases. Plant officials noticed a large quantity of liquid, which was believed to be either sodium hydroxide or hydrochloric acid solution, flowing through the loading bay doors. An Emergency Toxic Spill Response Team attempted to determine the source and identity of the unknown liquid. A series of explosions and the presence of chlorine gas forced the team to abandon its efforts. The unknown liquid continues to flow into the nearly full containment ponds.

We are sending a sample of the liquid to you by overnight courier, and we hope that you can quickly and accurately identify the liquid and notify us of the proper method for cleanup and disposal. We need your answer as soon as possible.

Sincerely,

Anthony Wong

Anthony Wong

THE PLAN

CheMystery Labs, Inc. 52 Fulton Street, Springfield, VA 22150

Memorandum

Date: April 22, 2004
To: Cicely Jackson
From: Marissa Bellinghausen

This project is a high priority. First we must determine the pH of the unknown so that we know whether it is an acid or a base. Then titrate the unknown using a standard solution to determine its concentration so that we can advise Bleachex on the amount of neutralizing agents that will be needed for the three containment ponds.

I need the following items:

- a detailed one-page plan for your procedure that includes all necessary data tables (include multiple trials)
- a detailed list of the equipment and materials you will need

When you have completed your experiment, prepare a report in the form of a two-page letter that we can fax to Anthony Wong. The letter must include the following:

- the identity of the unknown and its concentration
- the pH of the unknown and an explanation of how you determined the pH
- paragraph summarizing how you titrated the sample to determine its concentration
- a detailed and organized data table
- a detailed analysis section, including calculations, a discussion of the multiple trials, and a statistical analysis of your precision
- your proposed method for cleanup and disposal, including the amount of neutralizing agents that will be needed

Required Precautions

- Wear safety goggles when working around chemicals, acids, bases, flames, or heating devices. Contents under pressure may become projectiles and cause serious injury.
- Avoid wearing contact lenses in the lab.
- If any substance gets in your eyes, notify your instructor immediately and flush your eyes with running water for at least 15 min.
- Secure loose clothing, and remove dangling jewelry. Don't wear open-toed shoes or sandals in the lab.
- Wear an apron or lab coat to protect your clothing when working with chemicals.
- If a spill gets on your clothing, rinse it off immediately with water for at least 5 min while notifying your instructor.
- Always use caution when working with chemicals.
- Never taste, touch, or smell chemicals unless specifically directed to do so.
- Follow instructions for proper disposal.
- Whenever possible, use an electric hot plate as a heat source instead of an open flame.
- When heating materials in a test tube, always angle the test tube away from yourself and others.
- Know your school's fire-evacuation routes.
- Clean and decontaminate all work surfaces and personal protective equipment as directed by your instructor.
- Dispose of all sharps (broken glass and other contaminated sharp objects) and other contaminated materials (biological and chemical) in special containers as directed by your instructor.

Skills Practice Lab

16 Reaction Rates

Introduction

Executive "toys" are a big business. Your company has been contacted by a toy company that wants technical assistance in designing a new executive desk gadget. The company wants to investigate a reaction that turns a distinctive color in a specific amount of time. Although it will not be easy to determine the precise combination of chemicals that will work, the profit the company stands to make would be worthwhile in the end.

In this experiment you will determine the rate of an *oxidation-reduction,* or *redox,* reaction. Reactions of this type are discussed in the chapter "Electrochemistry." The net equation for the reaction you will study is as follows:

$$3Na_2S_2O_5(aq) + 2KIO_3(aq) + 3H_2O(l) \xrightarrow{H^+} 2KI(aq) + 6NaHSO_4(aq)$$

One way to study the rate of this reaction is to observe how fast $Na_2S_2O_5$ is used up. After all the $Na_2S_2O_5$ solution has reacted, the concentration of iodine, I_2, an intermediate in the reaction, builds up. A starch indicator solution added to the reaction mixture will signal when this happens. The colorless starch will change to a blue-black color in the presence of I_2.

In the experiment, the concentrations of the reactants are given in terms of drops of Solution A and drops of Solution B. Solution A contains $Na_2S_2O_5$, the starch-indicator solution, and dilute sulfuric acid to supply the hydrogen ions needed to catalyze the reaction. Solution B contains KIO_3. You will run the reaction with several different concentrations of the reactants and record the time it takes for the blue-black color to appear.

To determine the best conditions and concentrations for the reaction, you will determine the following:

- how changes in reactant concentrations affect the reaction outcome
- how much time elapses for each reaction
- a rate law for the reaction that will allow you to predict the results with other combinations

Objectives

- Prepare and observe several different reaction mixtures.
- Demonstrate proficiency in measuring reaction rates.
- Analyze the results and relate experimental results to a rate law that you can use to predict the results of various combinations of reactants.

USING SCIENTIFIC METHODS

Materials

- 8-well microscale reaction strips (2)
- distilled or deionized water
- fine-tipped dropper bulbs or small micro-tip pipets (3)
- solution A
- solution B
- stopwatch or clock with second hand

Safety Procedures

- Wear safety goggles when working around chemicals, acids, bases, flames, or heating devices. Contents under pressure may become projectiles and cause serious injury.
- Never look directly at the sun through any optical device or use direct sunlight to illuminate a microscope.
- Avoid wearing contact lenses in the lab.
- If any substance gets in your eyes, notify your instructor immediately and flush your eyes with running water for at least 15 min.

- Secure loose clothing, and remove dangling jewelry. Don't wear open-toed shoes or sandals in the lab.
- Wear an apron or lab coat to protect your clothing when working with chemicals.
- If a spill gets on your clothing, rinse it off immediately with water for at least 5 min while notifying your instructor.

- If a chemical gets on your skin or clothing or in your eyes, rinse it immediately, and alert your instructor.
- If a chemical is spilled on the floor or lab bench, alert your instructor, but do not clean it up yourself unless your teacher says it is OK to do so.

- Always use caution when working with chemicals.
- Never mix chemicals unless specifically directed to do so.
- Never taste, touch, or smell chemicals unless specifically directed to do so.
- Add acid or base to water; never do the opposite.
- Never return unused chemicals to the original container.
- Never transfer substances by sucking on a pipette or straw; use a suction bulb.
- Follow instructions for proper disposal.

- Clean and decontaminate all work surfaces and personal protective equipment as directed by your instructor.
- Dispose of all sharps (broken glass and other contaminated sharp objects) and other contaminated materials (biological and chemical) in special containers as directed by your instructor.

Procedure

1. Copy the data table below in your lab notebook.

Data Table 1

	Well 1	Well 2	Well 3	Well 4	Well 5
Time reaction began					
Time reaction stopped					
Drops of A					
Drops of B					
Drops of H_2O					

Figure A

Figure B

2. Obtain three dropper bulbs or small microtip pipets, and label them "A," "B," and "H_2O."

3. Fill bulb or pipet A with solution A, fill bulb or pipet B with solution B, and fill the bulb or pipet for H_2O with distilled water.

4. Using the first 8-well strip, place five drops of Solution A into each of the first five wells, as shown in **Figure A.** (Disregard the remaining three wells.) Record the number of drops in the appropriate places in your data table. For best results, try to make all of the drops about the same size.

5. In the second 8-well reaction strip, place one drop of Solution B in the first well, two drops in the second well, three drops in the third well, four drops in the fourth well, and five drops in the fifth well. Record the number of drops in the appropriate places in your data table.

6. In the second 8-well strip that contains drops of Solution B, add four drops of water to the first well, three drops to the second well, two drops to the third well, and one drop to the fourth well. Do not add any water to the fifth well.

7. Carefully invert the second strip. The surface tension should keep the solutions from falling out of the wells. Place the second strip well-to-well on top of the first strip, as shown in **Figure B.**

8. Holding the strips tightly together, record the exact time or set the stopwatch as you shake the strips. This procedure should effectively mix the upper solutions with each of the corresponding lower ones.

9. Observe the lower wells. Note the sequence in which the solutions react, and record the number of seconds it takes for each solution to turn a blue-black color.

10. Dispose of the solutions in the container designated by your teacher. Wash your hands thoroughly after cleaning up the area and equipment.

Analysis

1. Organizing Data
Calculate the time elapsed for the complete reaction of each combination of Solution A and Solution B.

2. Constructing Graphs
Make a graph of your results. Label the x-axis "Number of drops of Solution B." Label the y-axis "Time elapsed." Make a similar graph for drops of Solution B versus rate (1/time elapsed).

3. Analyzing Data
Which mixture reacted the fastest? Which mixture reacted the slowest?

4. Explaining Events
Why was it important to add the drops of water to the wells that contained fewer than five drops of Solution B? (Hint: Figure out the total number of drops in each of the reaction wells.)

Conclusions

5. Evaluating Methods
How can you be sure that each of the chemical reactions began at about the same time? Why is this important?

6. Evaluating Results
Of the following variables that can affect the rate of a reaction, which is tested in this experiment: temperature, catalyst, concentration, surface area, or nature of reactants? Explain your answer.

7. Analyzing Graphs
Use your data and graphs to determine the relationship between the concentration of Solution B and the rate of the reaction. Describe this relationship in terms of a rate law.

8. Evaluating Data
Share your data with other lab groups, and calculate a class average for the rate of the reaction for each concentration of B. Compare the results from other groups with your results. Explain why there are differences in the results.

9. Evaluating Methods
What are some possible sources of error in this procedure? If you can think of ways to eliminate them, ask your teacher to approve your plan and run your procedure again.

10. Making Predictions
How would your data be different if the experiment were repeated but Solution A was diluted with one part solution for every seven parts distilled water?

Extensions

1. Designing Experiments
What combination of drops of Solutions A and B would you use if you wanted the reaction to last exactly 2.5 min? Design an experiment to test your answer. If your teacher approves your plan, perform the experiment, and record these results. Make another graph that includes both the old and new data.

2. Designing Experiments
How would you determine the smallest interval of time during which you could distinguish a clock reaction? Design an experiment to find out. If your teacher approves your plan, perform your experiment.

3. Designing Experiments
How would the results of this experiment be affected if the reaction took place in a cold environment? Design an experiment to test your answer using materials available. If your teacher approves your plan, perform your experiment and record the results. Make another graph, and compare it with your old data.

4. Designing Experiments
Devise a plan to determine the effect of Solution A on the rate law. If your teacher approves your plan, perform your experiment, and determine the rate law for this reaction.

5. Building Models
If Solution B contains 0.02 M KIO_3, calculate the value for the constant, k, in the expression below. (Hint: Remember that Solution B is diluted when it is added to Solution A.)

$$\text{rate} = k[KIO_3]$$

Skills Practice Lab

17 Redox Titration

Introduction

You are a chemist working for a chemical analysis firm. A large pharmaceutical company has hired you to help salvage some products that were damaged by a small fire in their warehouse. Although there was only minimal smoke and fire damage to the warehouse and products, the sprinkler system ruined the labeling on many of the pharmaceuticals. The firm's best-selling products are iron tonics used to treat low-level anemia. The tonics are produced from hydrated iron(II) sulfate, $FeSO_4 \cdot 7H_2O$. The different types of tonics contain different concentrations of $FeSO_4$. You have been hired to help the pharmaceutical company figure out the proper label for each bottle of tonic.

In the chapter "Acids and Bases" you studied acid-base titrations in which an unknown amount of acid is titrated with a carefully measured amount of base. In this procedure a similar approach called a redox titration is used. In a redox titration, the reducing agent, Fe^{2+}, is oxidized to Fe^{3+} by the oxidizing agent, MnO_4^-. When this process occurs, the Mn in MnO_4^- changes from a +7 to a +2 oxidation state and has a noticeably different color. You can use this color change in the same way that you used the color change of phenolphthalein in acid-base titrations—to signify a redox reaction end point. When the reaction is complete, any excess MnO_4^- added to the reaction mixture will give the solution a pink or purple color. The volume data from the titration, the known molarity of the $KMnO_4$ solution, and the mole ratio from the following balanced redox equation will give you the information you need to calculate the molarity of the $FeSO_4$ solution.

$$5Fe^{2+}(aq) + MnO_4^-(aq) + 8H^+(aq) \longrightarrow 5Fe^{3+}(aq) + Mn^{2+}(aq) + 4H_2O(l)$$

To determine how to label the bottles, you must determine the concentration of iron(II) ions in the sample from an unlabeled bottle from the warehouse by answering the following questions:

- How can the volume data obtained from the titration and the mole ratios from the balanced redox reaction be used to determine the concentration of the sample?
- Which tonic is in the sample, given information about the concentration of each tonic?

Objectives

- Demonstrate proficiency in performing redox titrations and recognizing the end point of a redox reaction.
- Determine the concentration of a solution using stoichiometry and volume data from a titration.

Materials

- beaker 250 mL (2)
- beaker 400 mL
- burets (2)
- distilled water
- double buret clamp
- Erlenmeyer flask, 125 mL (4)
- $FeSO_4$ solution
- graduated cylinder, 100 mL
- H_2SO_4, 1.0 M
- $KMnO_4$, 0.0200 M
- ring stand
- wash bottle

Safety Procedures

- Wear safety goggles when working around chemicals, acids, bases, flames, or heating devices. Contents under pressure may become projectiles and cause serious injury.
- Never look directly at the sun through any optical device or use direct sunlight to illuminate a microscope.
- Avoid wearing contact lenses in the lab.
- If any substance gets in your eyes, notify your instructor immediately and flush your eyes with running water for at least 15 min.

- Secure loose clothing, and remove dangling jewelry. Don't wear open-toed shoes or sandals in the lab.
- Wear an apron or lab coat to protect your clothing when working with chemicals.
- If a spill gets on your clothing, rinse it off immediately with water for at least 5 min while notifying your instructor.

- If a chemical gets on your skin or clothing or in your eyes, rinse it immediately, and alert your instructor.
- If a chemical is spilled on the floor or lab bench, alert your instructor, but do not clean it up yourself unless your teacher says it is OK to do so.

- Always use caution when working with chemicals.
- Never mix chemicals unless specifically directed to do so.
- Never taste, touch, or smell chemicals unless specifically directed to do so.
- Add acid or base to water; never do the opposite.
- Never return unused chemicals to the original container.
- Never transfer substances by sucking on a pipette or straw; use a suction bulb.
- Follow instructions for proper disposal.

- Check the condition of glassware before and after using it. Inform your teacher of any broken, chipped, or cracked glassware, because it should not be used.
- Do not pick up broken glass with your bare hands. Place broken glass in a specially designated disposal container.

- Clean and decontaminate all work surfaces and personal protective equipment as directed by your instructor.
- Dispose of all sharps (broken glass and other contaminated sharp objects) and other contaminated materials (biological and chemical) in special containers as directed by your instructor.

Data Table 1

Trial	Initial $KMnO_4$ volume	Final $KMnO_4$ volume	Initial $FeSO_4$ volume	Final $FeSO_4$ volume
1				
2				
3				

Procedure

1. Organizing Data

Copy the data table above in your lab notebook.

2. Clean two 50 mL burets with a buret brush and distilled water. Rinse each buret at least three times with distilled water to remove any contaminants.

3. Label two 250 mL beakers "0.0200 M $KMnO_4$," and "$FeSO_4$ solution." Label three of the flasks 1, 2, and 3. Label the 400 mL beaker "Waste." Label one buret "$KMnO_4$" and the other "$FeSO_4$."

4. Measure approximately 75 mL of 0.0200 M $KMnO_4$, and pour it into the appropriately labeled beaker. Obtain approximately 75 mL of $FeSO_4$ solution, and pour it into the appropriately labeled beaker.

5. Rinse one buret three times with a few milliliters of 0.0200 M $KMnO_4$ from the appropriately labeled beaker. Collect these rinses in the

Figure A

Figure B

waste beaker. Rinse the other buret three times with small amounts of $FeSO_4$ solution from the appropriately labeled beaker. Collect these rinses in the waste beaker.

6. Set up the burets as shown in **Figure A.** Fill one buret with approximately 50 mL of the 0.0200 M $KMnO_4$ from the beaker, and fill the other buret with approximately 50 mL of the FeSO4 solution from the other beaker.

7. With the waste beaker underneath its tip, open the $KMnO_4$ buret long enough to be sure the buret tip is filled. Repeat for the $FeSO_4$ buret.

8. Add 50 mL of distilled water to one of the 125 mL Erlenmeyer flasks, and add one drop of 0.0200 M $KMnO_4$ to the flask. Set this aside to use as a color standard, as shown in **Figure B,** to compare with the titration and to determine the end point.

9. Record the initial buret readings for both solutions in your data table. Add 10.0 mL of the hydrated iron(II) sulfate, $FeSO_4 \cdot 7H_2O$, solution to flask 1. Add 5 mL of 1.0 M H_2SO_4 to the $FeSO_4$ solution in this flask. The acid will help keep the Fe^{2+} ions in the reduced state, allowing you time to titrate.

10. Slowly add $KMnO_4$ from the buret to the $FeSO_4$ in the flask while swirling the flask, as shown in **Figure C.** When the color of the solution matches the color standard you prepared in step 8, record the final readings of the burets in your data table.

11. Empty the titration flask into the waste beaker. Repeat the titration procedure in steps 9 and 10 with flasks 2 and 3.

12. Always clean up the lab and all equipment after use. Dispose of the contents of the waste beaker in the container designated by your teacher. Also pour the contents of the color-standard flask into this container. Wash your hands thoroughly after cleaning up the area and equipment.

Figure C

Analysis

1. Analyzing Data
Calculate the number of moles of MnO_4^- reduced in each trial.

2. Analyzing Data
Calculate the number of moles of Fe^{2+} oxidized in each trial.

3. Analyzing Data
Calculate the average concentration (molarity) of the iron tonic.

4. Explaining Events
Explain why it was important to rinse the burets with $KMnO_4$ or $FeSO_4$ before adding the solutions. (Hint: Consider what would happen to the concentration of each solution if it were added to a buret that had been rinsed only with distilled water.)

Conclusions

5. Evaluating Data
The company makes three different types of iron tonics: Feravide A, with a concentration of 0.145 M $FeSO_4$; Feravide Extra-Strength, with 0.225 M $FeSO_4$; and Feravide Jr., with 0.120 M $FeSO_4$. Which tonic is your sample?

6. Evaluating Methods
What possible sources of error can you identify with this procedure? If you can think of ways to eliminate them, ask your teacher to approve your plan, and run the procedure again.

Extensions

1. Research and Communication
Blueprints are based on a photochemical reaction. The paper is treated with a solution of iron(III) ammonium citrate and potassium hexacyanoferrate(III) and dried in the dark. When a tracing-paper drawing is placed on the blueprint paper and exposed to light, Fe^{3+} ions are reduced to Fe^{2+} ions, which react with hexacyanoferrate(III) ions in the moist paper to form the blue color on the paper. The lines of the drawing block the light and prevent the reduction of Fe^{3+} ions, resulting in white lines. Find out how sepia prints are made, and report on this information.

2. Building Models
Electrochemical cells are based on the process of electron flow in a system with varying potential differences. Batteries are composed of such systems and contain different chemicals for different purposes and price ranges. You can make simple experimental batteries using metal wires and items such as lemons, apples, and potatoes. What are some other "homemade" battery sources, and what is the role of these food items in producing electrical energy that can be measured as battery power? Explain your answers.

17 Redox Titration

Mining Feasibility Study

Inquiry LAB
Design Your Own Experiment

THE PROBLEM

May 11, 2004

George Taylor
Director of Analytical Services
CheMystery Labs, Inc.
52 Fulton Street
Springfield, VA 22150

Dear Mr. Taylor:

Because of the high quality of your firm's work in the past, Goldstake is again asking that you submit a bid for a mining feasibility study. A study site in New Mexico has yielded some promising iron ore deposits, and we are evaluating the potential yield.

Your bid should include the cost of evaluating the sample we are sending with this letter and the fees for 20 additional analyses to be completed over the next year. The sample is a slurry extracted from the mine using a special process that converts the iron ore into iron(II) sulfate, $FeSO_4$, dissolved in water. The mine could produce up to 1.0×10^5 L of this slurry daily, but we need to know how much iron is in that amount of slurry before we proceed.

The contract for the other analyses will be awarded based on the accuracy of this analysis and the quality of the report. Your report will be used for two purposes: to evaluate the site for quantity of iron and to determine who our analytical consultant will be if the site is developed into a mining operation. I look forward to reviewing your bid proposal.

Sincerely,

Lynn L. Brown

Lynn L. Brown
Director of Operations
Goldstake Mining Company

References

Review more information on redox reactions. Remember to add a small amount of sulfuric acid, H_2SO_4, so the iron will stay in the Fe^{2+} form. Calculate your disposal costs based on the mass of potassium permanganate, $KMnO_4$, and $FeSO_4$ in your solutions, as well as the mass of the H_2SO_4 solution.

THE PLAN

CheMystery Labs, Inc. 52 Fulton Street, Springfield, VA 22150

Memorandum

Date: May 12, 2004
To: Crystal Sievers
From: George Taylor

Good news! The quality of our work has earned us a repeat customer, Goldstake Mining Company. This analysis could turn into a long-term contract. Perform the analysis more than one time so that we can be confident of our accuracy. Before you begin your analysis, send Ms. Brown the following items:

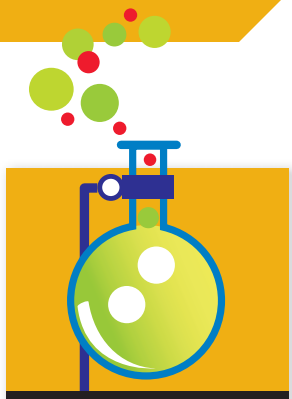
- a detailed, one-page plan for the procedure and all necessary data tables
- a detailed sheet that lists all of the equipment and materials you plan to use

When you have completed the laboratory work, please prepare a report in the form of a two-page letter to Ms. Brown. Include the following information:

- moles and grams of $FeSO_4$ in 10 mL of sample
- moles, grams, and percentage of iron(II) in 10 mL of the sample
- the number of kilograms of iron that the company could extract from the mine each year, assuming that 1.0×10^5 L of slurry could be mined per day, year round
- a balanced equation for the redox equation
- a detailed and organized data and analysis section showing calculations of how you determined the moles, grams, and percentage of iron(II) in the sample (include calculations of the mean, or average, of the multiple trials)

Required Precautions

- Wear safety goggles when working around chemicals, acids, bases, flames, or heating devices. Contents under pressure may become projectiles and cause serious injury.
- Avoid wearing contact lenses in the lab.
- If any substance gets in your eyes, notify your instructor immediately and flush your eyes with running water for at least 15 min.
- Secure loose clothing, and remove dangling jewelry. Don't wear open-toed shoes or sandals in the lab.
- Wear an apron or lab coat to protect your clothing when working with chemicals.
- If a spill gets on your clothing, rinse it off immediately with water for at least 5 min while notifying your instructor.
- Always use caution when working with chemicals.
- Never taste, touch, or smell chemicals unless specifically directed to do so.
- Follow instructions for proper disposal.
- Whenever possible, use an electric hot plate as a heat source instead of an open flame.
- When heating materials in a test tube, always angle the test tube away from yourself and others.
- Know your school's fire-evacuation routes.
- Clean and decontaminate all work surfaces and personal protective equipment as directed by your instructor.
- Dispose of all sharps (broken glass and other contaminated sharp objects) and other contaminated materials (biological and chemical) in special containers as directed by your instructor.



19 Polymers and Toy Balls

Objectives

- Synthesize two different polymers.
- Prepare a small toy ball from each polymer.
- Observe the similarities and differences between the two types of balls.
- Measure the density of each polymer.
- Compare the bounce height of the two balls.

Materials

- acetic acid solution (vinegar), 5% (10 mL)
- beaker, 2 L, or plastic bucket or tub
- distilled water
- ethanol solution, 50% (3 mL)
- gloves
- graduated cylinder, 10 mL
- graduated cylinder, 25 mL
- liquid latex (10 mL)
- meterstick
- paper cups, 5 oz (2)
- paper towels
- sodium silicate solution (12 mL)
- wooden stick

Introduction

Your company has been contacted by a toy company that specializes in toy balls made from vulcanized rubber. Recent legislation has increased the cost of disposing of the sulfur and other chemical byproducts of the manufacturing process for this type of rubber. The toy company wants you to research some other materials.

Rubber is a polymer of covalently bonded atoms. When rubber is vulcanized, it is heated with sulfur. The sulfur atoms form bonds between adjacent molecules of rubber, which increases its strength and making it more elastic.

Latex rubber is a colloidal suspension that can be made synthetically or found naturally in plants. Latex is composed of approximately 60% water, 35% hydrocarbon monomers, 2% proteins, and some sugars and inorganic salts.

The polymer formed from ethanol, C_2H_5OH, and a solution of sodium silicate, mostly in the form of $Na_2Si_3O_7$, also has covalent bonds. When the polymer is formed, water is also a product.

Latex rubber and the ethanol–sodium silicate polymer are the two materials you will become familiar with as you do the following:

- Synthesize each polymer.
- Make a ball 2–3 cm in diameter from each polymer.
- Make observations about the physical properties of each polymer.
- Measure how well each ball bounces.

Safety Procedures

- Wear safety goggles when working around chemicals, acids, bases, flames, or heating devices. Contents under pressure may become projectiles and cause serious injury.
- Never look directly at the sun through any optical device or use direct sunlight to illuminate a microscope.
- Avoid wearing contact lenses in the lab.
- If any substance gets in your eyes, notify your instructor immediately and flush your eyes with running water for at least 15 min.

- Secure loose clothing, and remove dangling jewelry. Don't wear open-toed shoes or sandals in the lab.
- Wear an apron or lab coat to protect your clothing when working with chemicals.
- If a spill gets on your clothing, rinse it off immediately with water for at least 5 min while notifying your instructor.

- If a chemical gets on your skin or clothing or in your eyes, rinse it immediately, and alert your instructor.
- If a chemical is spilled on the floor or lab bench, alert your instructor, but do not clean it up yourself unless your teacher says it is OK to do so.

- Always use caution when working with chemicals.
- Never mix chemicals unless specifically directed to do so.
- Never taste, touch, or smell chemicals unless specifically directed to do so.
- Add acid or base to water; never do the opposite.
- Never return unused chemicals to the original container.
- Never transfer substances by sucking on a pipette or straw; use a suction bulb.
- Follow instructions for proper disposal.

- Use flammable liquids only in small amounts.
- When working with flammable liquids, be sure that no one else in the lab is using a lit Bunsen burner or plans to use one. Make sure there are no other heat sources present.

Data Table 1

Trial	Height (cm)	Mass (g)	Diameter (cm)
1			
2			
3			

Procedure

1. Copy Data Table 1 above in your lab notebook. Be sure that you have plenty of room for observations about each test.

Organizing Data

2. Fill the 2 L beaker, bucket, or tub about half full with distilled water.
3. Using a clean 25 mL graduated cylinder, measure 10 mL of liquid latex and pour it into one of the paper cups.
4. Thoroughly clean the 25 mL graduated cylinder with soap and water, and then rinse it with distilled water.
5. Measure 10 mL of distilled water. Pour it into the paper cup with the latex.
6. Measure 10 mL of the 5% acetic acid solution, and pour it into the paper cup with the latex and water.
7. Immediately stir the mixture by using the wooden stick.
8. As you continue stirring, a polymer "lump" will form around the wooden stick. Pull the stick with the polymer lump from the paper cup, and immerse the lump in the 2 L beaker, bucket, or tub.

9. While wearing gloves, gently pull the lump from the wooden stick. Be sure to keep the lump immersed in the water, as shown in **Figure A.**

10. Keep the latex rubber underwater, and use your gloved hands to mold the lump into a ball, as shown in **Figure B.** Squeeze the lump several times to remove any unused chemicals. You may remove the latex rubber from the water as you roll it in your hands to smooth the ball.

11. Set aside the latex-rubber ball to dry. While it is drying, begin to make a ball from the ethanol and sodium silicate solutions.

12. In a clean 25 mL graduated cylinder, measure 12 mL of sodium silicate solution and pour it into the other paper cup.

13. In a clean 10 mL graduated cylinder, measure 3 mL of 50% ethanol. Pour the ethanol into the paper cup with the sodium silicate, and mix with the wooden stick until a solid substance is formed.

14. While wearing gloves, remove the polymer that forms and place it in the palm of one hand, as shown in **Figure C.** Gently press it with the palms of both your hands until a ball that does not crumble is formed. This process takes a little time and patience. The liquid that comes out of the ball is a combination of ethanol and water. Occasionally moisten the ball by letting a small amount of water from a faucet run over it. When the ball no longer crumbles, you are ready to go on to the next step.

15. Observe as many physical properties of the balls as possible, and record your observations in your lab notebook.

16. Drop each ball several times, and record your observations.

17. Drop each ball from a height of 1 m, and measure its bounce. Perform three trials for each ball, and record the values in your data table.

18. Measure the diameter and the mass of each ball, and record the values in your data table.

19. Clean all apparatus and your lab station. Dispose of any extra solutions in the containers indicated by your teacher. Clean up your lab area. Remember to wash your hands thoroughly when your lab work is finished.

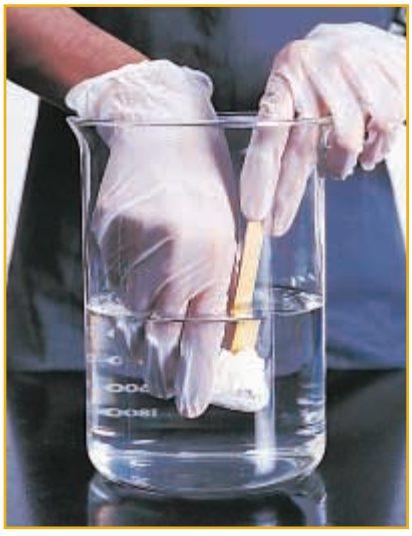


Figure A

Figure B

Figure C

Analysis

1. **Analyzing data** Give the chemical formula for the latex (isoprene) monomer and the ethanol–sodium silicate polymer.

2. **Analyzing data** List at least three observations you made of the properties of the two different balls.

3. **Explaining events** Explain how your observations in item 2 indicate that the polymers in each ball are not ionically bonded.

4. **Organizing data** Calculate the average height of the bounce for each type of ball.

5. **Organizing data** Calculate the volume for each ball. Even though the balls may not be perfectly spherical, assume that they are. (Hint: The volume of a sphere is equal to $\frac{4}{3} \times \pi \times r^3$, where r is the radius of the sphere, which is one-half of the diameter.)

6. **Organizing data** Using your measurements for the volumes from item 5 and the recorded mass, calculate the density of each ball.

Conclusions

7. **Evaluating data** Which polymer would you recommend for the toy company's new toy balls? Explain your reasoning.

8. **Evaluating results** Using the table shown below, calculate the unit cost, that is, the amount of money it costs to make a single ball. (Hint: Calculate how much of each reagent is needed to make a single ball.)

Data Table 2

Reagent	Price (dollars per liter)
Acetic acid solution	1.50
Ethanol solution	9.00
Latex solution	20.00
Sodium silicate solution	10.00

9. **Evaluating results** What are some other possible practical applications for each of the polymers you made?

10. **Making predictions** When a ball bounces up, kinetic energy of motion is converted into potential energy. With this in mind, explain which will bounce higher, a perfectly symmetrical, round sphere or an oblong shape that vibrates after it bounces.

11. **Evaluating methods** Explain why you didn't measure the volume of the balls by submerging them in water.

Extensions

1. **Research and communication** Polymers are used in our daily lives. Describe or list the polymers you come into contact with during a one-day period in your life.

2. **Designing experiments** Design a mold for a polymer ball that will make it symmetrical and smooth. If your teacher approves of your design, try the procedure again with the mold.

APPENDIX A

A Chemical Reference Handbook

TABLE A-1 SI MEASUREMENT

Prefix	Symbol	Factor of Base Unit	Prefix	Symbol	Factor of Base Unit
giga	G	1 000 000 000	***centi***	c	0.01
mega	M	1 000 000	***milli***	m	0.001
kilo	k	1 000	***micro***	μ	0.000 001
hecto	h	100	***nano***	n	0.000 000 001
deka	da	10	***pico***	p	0.000 000 000 001
deci	d	0.1			

TABLE A-2 UNIT ABBREVIATIONS

amu	=	atomic mass unit (mass)	**mol**	=	mole (quantity)
atm	=	atmosphere (pressure, non-SI)	**M**	=	molarity (concentration)
Bq	=	becquerel (nuclear activity)	**N**	=	newton (force)
°C	=	degree Celsius (temperature)	**Pa**	=	pascal (pressure)
J	=	joule (energy)	**s**	=	second (time)
K	=	kelvin (temperature, thermodynamic)	**V**	=	volt (electric potential difference)

TABLE A-3 SYMBOLS

Symbol		Meaning	Symbol		Meaning
α	=	helium nucleus (also ${}^{4}_{2}\mathrm{He}$) emission from radioactive materials	ΔG^0	=	standard free energy of reaction
β	=	electron (also ${}^{0}_{-1}e$) emission from radioactive materials	ΔG^0_f	=	standard molar free energy of formation
γ	=	high-energy photon emission from radioactive materials	H	=	enthalpy
Δ	=	change in a given quantity (e.g., ΔH for change in enthalpy)	ΔH^0	=	standard enthalpy of reaction
c	=	speed of light in vacuum	ΔH^0_f	=	standard molar enthalpy of formation
c_p	=	specific heat capacity (at constant pressure)	K_a	=	ionization constant (acid)
D	=	density	K_b	=	dissociation constant (base)
E_a	=	activation energy	K_{eq}	=	equilibrium constant
E^0	=	standard electrode potential	K_{sp}	=	solubility-product constant
E^0_{cell}	=	standard potential of an electrochemical cell	KE	=	kinetic energy
G	=	Gibbs free energy	m	=	mass
			N_A	=	Avogadro's number
			n	=	number of moles
			P	=	pressure

TABLE A-3 CONTINUED

Symbol		Meaning	Symbol		Meaning
pH	=	measure of acidity ($-\log[H_3O^+]$)	T	=	temperature (thermodynamic, in kelvins)
R	=	ideal gas law constant	t	=	temperature (in degrees Celsius)
S	=	entropy	V	=	volume
S^0	=	standard molar entropy	v	=	velocity or speed

TABLE A-4 PHYSICAL CONSTANTS

Quantity	Symbol	Value
Atomic mass unit	amu	$1.660\ 5402 \times 10^{-27}$ kg
Avogadro's number	N_A	$6.022\ 137 \times 10^{23}$/mol
Electron rest mass	m_e	$9.109\ 3897 \times 10^{-31}$ kg 5.4858×10^{-4} amu
Ideal gas law constant	R	8.314 L•kPa/mol•K 0.0821 L•atm/mol•K
Molar volume of ideal gas at STP	V_M	22.414 10 L/mol
Neutron rest mass	m_n	$1.674\ 9286 \times 10^{-27}$ kg 1.008 665 amu
Normal boiling point of water	T_b	373.15 K = 100.0°C
Normal freezing point of water	T_f	273.15 K = 0.00°C
Planck's constant	h	$6.626\ 076 \times 10^{-34}$ J•s
Proton rest mass	m_p	$1.672\ 6231 \times 10^{-27}$ kg 1.007 276 amu
Speed of light in a vacuum	c	$2.997\ 924\ 58 \times 10^8$ m/s
Temperature of triple point of water		273.16 K = 0.01°C

TABLE A-5 PROPERTIES OF COMMON ELEMENTS

Name	Form/color	Density (g/cm^3)	Melting point (°C)	Boiling point (°C)	Common oxidation states
Aluminum	silver metal	2.702	660.37	2467	3+
Arsenic	gray metalloid	5.72714	817 (28 atm)	613 (sublimes)	3–, 3+, 5+
Barium	bluish white metal	3.51	725	1640	2+
Bromine	red-brown liquid	3.119	27.2	58.78	1–, 1+, 3+, 5+, 7+
Calcium	silver metal	1.54	839 ± 2	1484	2+
Carbon	diamond	3.51	3500 (63.5 atm)	3930	2+, 4+
	graphite	2.25	3652 (sublimes)	—	
Chlorine	green-yellow gas	3.214*	2100.98	234.6	1–, 1+, 3+, 5+, 7+
Chromium	gray metal	7.2028	1857 ± 20	2672	2+, 3+, 6+

continued on next page

TABLE A-5 CONTINUED

Name	Form/color	Density (g/cm^3)	Melting point (°C)	Boiling point (°C)	Common oxidation states
Cobalt	gray metal	8.9	1495	2870	2+, 3+
Copper	red metal	8.92	1083.4 ± 0.2	2567	1+, 2+
Fluorine	yellow gas	1.69‡	2219.62	2188.14	1–
Germanium	gray metalloid	5.32325	937.4	2830	4+
Gold	yellow metal	19.31	1064.43	2808 ± 2	1+, 3+
Helium	colorless gas	0.1785*	2272.2 (26 atm)	2268.9	0
Hydrogen	colorless gas	0.0899*	2259.34	2252.8	1–, 1+
Iodine	blue-black solid	4.93	113.5	184.35	1–, 1+, 3+, 5+, 7+
Iron	silver metal	7.86	1535	2750	2+, 3+
Lead	bluish white metal	11.343716	327.502	1740	2+, 4+
Lithium	silver metal	0.534	180.54	1342	1+
Magnesium	silver metal	1.745	648.8	1107	2+
Manganese	gray-white metal	7.20	1244 ± 3	1962	2+, 3+, 4+, 6+, 7+
Mercury	silver liquid metal	13.5462	238.87	356.58	1+, 2+
Neon	colorless gas	0.9002*	2248.67	2245.9	0
Nickel	silver metal	8.90	1455	2730	2+, 3+
Nitrogen	colorless gas	1.2506*	2209.86	2195.8	3–, 3+, 5+
Oxygen	colorless gas	1.429*	2218.4	2182.962	2–
Phosphorus	yellow solid	1.82	44.1	280	3–, 3+, 5+
Platinum	silver metal	21.45	1772	3827 ± 100	2+, 4+
Potassium	silver metal	0.86	63.25	760	1+
Silicon	gray metalloid	2.33 ± 0.01	1410	2355	2+, 4+
Silver	white metal	10.5	961.93	2212	1+
Sodium	silver metal	0.97	97.8	882.9	1+
Strontium	silver metal	2.6	769	1384	2+
Sulfur	yellow solid	1.96	119.0	444.674	2–, 4+, 6+
Tin	white metal	7.28	231.88	2260	2+, 4+
Titanium	white metal	4.5	1660 ± 10	3287	2+, 3+, 4+
Uranium	silver metal	19.05 ± 0.0225	1132.3 ± 0.8	3818	3+, 4+, 6+
Zinc	blue-white metal	7.14	419.58	907	2+

* Densities of gases given in g/L at STP
† Densities obtained at 20°C unless otherwise noted (superscript)
‡ Density of fluorine given in g/L at 1 atm and 15°C

TABLE A-6 KEY OF ATOM COLORS USED IN MOLECULAR MODELS IN *HOLT CHEMISTRY*

Element	Color
Hydrogen, H	
Helium, He	
Carbon, C	
Nitrogen, N	
Oxygen, O	
Flourine, F	
Neon, Ne	
Sodium, Na (similar color used for all Group 1 metals)	
Magnesium, Mg (similar color used for all Group 2 metals)	
Aluminum, Al	
Silicon, Si	
Phosphorus, P	
Sulfur, S	
Chlorine, Cl	
Argon, Ar	
Iron, Fe	
Copper, Cu	
Bromine, Br	
Silver, Ag	
Iodine, I	

TABLE A-7 COMMON IONS

Cation	Symbol	Cation	Symbol	Anion	Symbol	Anion	Symbol
Aluminum	Al^{3+}	Lead(II)	Pb^{2+}	Acetate	CH_3COO^-	Hydrogen sulfate	HSO_4^-
Ammonium	NH_4^+	Magnesium	Mg^{2+}	Bromide	Br^-	Hydroxide	OH^-
Arsenic(III)	As^{3+}	Mercury(I)	Hg_2^{2+}	Carbonate	CO_3^{2-}	Hypochlorite	ClO^-
Barium	Ba^{2+}	Mercury(II)	Hg^{2+}	Chlorate	ClO_3^-	Iodide	I^-
Calcium	Ca^{2+}	Nickel(II)	Ni^{2+}	Chloride	Cl^-	Nitrate	NO_3^-
Chromium(II)	Cr^{2+}	Potassium	K^+	Chlorite	ClO_2^-	Nitrite	NO_2^-
Chromium(III)	Cr^{3+}	Silver	Ag^+	Chromate	CrO_4^{2-}	Oxide	O_2^-
Cobalt(II)	Co^{2+}	Sodium	Na^+	Cyanide	CN^-	Perchlorate	ClO_4^-
Cobalt(III)	Co^{3+}	Strontium	Sr^{2+}	Dichromate	$Cr_2O_7^{2-}$	Permanganate	MnO_4^-
Copper(I)	Cu^+	Tin(II)	Sn^{2+}	Fluoride	F^-	Peroxide	O_2^{2-}
Copper(II)	Cu^{2+}	Tin(IV)	Sn^{4+}	Hexacyanoferrate(II)	$Fe(CN)_6^{4-}$	Phosphate	PO_4^{3-}
Hydronium	H_3O^+	Titanium(III)	Ti^{3+}	Hexacyanoferrate(III)	$Fe(CN)_6^{3-}$	Sulfate	SO_4^{2-}
Iron(II)	Fe^{2+}	Titanium(IV)	Ti^{4+}	Hydride	H^-	Sulfide	S^{2-}
Iron(III)	Fe^{3+}	Zinc	Zn^{2+}	Hydrogen carbonate	HCO_3^-	Sulfite	SO_3^{2-}

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TABLE A-8 PREFIXES FOR NAMING COVALENT COMPOUNDS

Prefix	Number of Atoms	Example	Name	Prefix	Number of Atoms	Example	Name
mono-	1	CO	carbon monoxide	*hexa-*	6	CeB_6	cerium hexaboride
di-	2	SiO_2	silicon dioxide	*hepta-*	7	IF_7	iodine heptafluoride
tri-	3	SO_3	sulfur trioxide	*octa-*	8	Np_3O_8	trineptunium octoxide
tetra-	4	SCl_4	sulfur tetrachloride	*nona-*	9	I_4O_9	tetraiodine nonoxide
penta-	5	$SbCl_5$	antimony pentachloride	*deca-*	10	S_2F_{10}	disulfur decafluoride

TABLE A-9 ACTIVITY SERIES OF THE ELEMENTS

Activity of Metals		Activity of Halogens
Li Rb K Ca Ba Sr Ca Na	react with cold H_2O and acids, replacing hydrogen; react with oxygen, forming oxides	F_2
Mg Al Mn Zn Cr Fe Cd	react with steam (but not cold water) and acids; replacing hydrogen; react with oxygen, forming oxides	Cl_2
Co Ni Sn Pb	do not react with water; react with acids, replacing hydrogen; react with oxygen, forming oxides	Br_2
H_2 Sb Bi Cu Hg	react with oxygen, forming oxides	I_2
Ag Pt Au	fairly unreactive, forming oxides only indirectly.	

TABLE A-10 STATE SYMBOLS AND REACTION CONDITIONS

Symbol	Meaning
(s), (l), (g)	substance in the solid, liquid, or gaseous state
(aq)	substance in aqueous solution (dissolved in water)
$\longrightarrow$	"produces" or "yields," indicating the result of a reaction
$\rightleftarrows$	reversible reaction in which products can reform into reactants; final result is a mixture of products and reactants
$\xrightarrow{\Delta}$ or $\xrightarrow{\text{heat}}$	reactants are heated; temperature is not specified
$\xrightarrow{\text{Pd}}$	name or chemical formula of a catalyst, added to speed a reaction
(c), $\downarrow$	product is a solid precipitate
$\uparrow$	product is a gas

TABLE A-11 THERMODYNAMIC DATA

Substance	ΔH_f^0 (kJ/mol)	S^0 (J/mol•K)	ΔG_f^0 (kJ/mol)
$Ag(s)$	0.0	42.7	0.0
$AgCl(s)$	–127.1	96.2	–109.8
$AgNO_3(s)$	–124.4	140.9	–33.5
$Al(s)$	0.0	28.3	0.0
$AlCl_3(s)$	–705.6	110.7	–628.9
$Al_2O_3(s,\ corundum)$	–1676.0	51.0	–1582.4
$Br_2(l)$	0.0	152.2	0.0
$Br_2(g)$	30.9	245.5	30.9
C $(s,\ diamond)$	1.9	2.4	2.90
C $(s,\ graphite)$	0.0	5.7	0.0
$CCl_4(l)$	–132.8	216.2	–65.3
$CCl_4(g)$	–95.8	309.9	–60.2
$CH_3OH(l)$	–239.1	127.2	–166.4
$CH_4(g)$	–74.9	186.3	–50.8
$CO(g)$	–110.5	197.6	–137.2
$CO_2(g)$	–393.5	213.8	–394.4
$CS_2(g)$	117.1	237.8	67.2
$C_2H_6(g)$	–83.8	229.1	32.9
$C_2H_4(g)$	52.5	219.3	68.1
$C_2H_5OH(l)$	–277.0	161.0	–174.9
$C_3H_8(g)$	–104.7	270.2	–24.3
$C_4H_{10}(g,\ n\text{-}butane)$	–125.6	310.1	–16.7
$C_4H_{10}(g,\ isobutane)$	–134.2	294.6	–20.9
$C_6H_{14}(g,\ n\text{-}hexane)$	–167.1	388.4	0.0
$C_7H_{16}(g,\ n\text{-}heptane)$	–187.7	427.9	8.0
$C_8H_{18}(g,\ n\text{-}octane)$	–208.6	466.7	16.3
$C_8H_{18}(g,\ iso\text{-}octane)$	–224.0	423.2	12.6
$CaCO_3(s)$	–1206.9	92.9	–1128.8
$CaCl_2(s)$	–795.8	108.4	–748.1
$Ca(OH)_2(s)$	–986.1	83.4	–898.6
$Ca(s)$	0.0	41.6	0.0
$CaO(s)$	–634.9	38.2	–604.04
$Cl_2(g)$	0.0	223.1	0.0
$Cu(s)$	0.0	33.2	0.0
$CuCl_2(s)$	–220.1	108.1	–175.7
$CuSO_4(s)$	–770.0	109.3	–661.9
$F_2(g)$	0.0	202.8	0.0
$Fe(s)$	0.0	27.3	0.0
$FeCl_3(s)$	–399.4	142.3	–334.05
$Fe_2O_3(s,\ hematite)$	–824.8	87.4	–742.2
$Fe_3O_4(s,\ magnetite)$	–1120.9	145.3	–1015.5
$H_2(g)$	0.0	130.7	0.0
$HBr(g)$	–36.4	198.6	–53.4
$HCl(g)$	–92.3	186.8	–95.3
$HCN(g)$	135.1	201.7	124.7
$HCOOH(l)$	–425.1	129.0	–361.4

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TABLE A-11 CONTINUED

Substance	ΔH_f^0 (kJ/mol)	S^0 (J/mol•K)	ΔG_f^0 (kJ/mol)	Substance	ΔH_f^0 (kJ/mol)	S^0 (J/mol•K)	ΔG_f^0 (kJ/mol)
$HF(g)$	–272.5	173.8	–273.2	$NO_2(g)$	33.1	240.0	51.3
$HNO_3(g)$	–134.3	266.4	–74.8	$N_2O(g)$	82.4	220.0	104.2
$H_2O(g)$	–241.8	188.7	–228.6	$N_2O_4(g)$	9.1	304.4	97.8
$H_2O(l)$	–285.8	70.0	–237.2	$Na(s)$	0.0	51.5	0.0
$H_2O_2(l)$	–187.8	109.6	–120.4	$NaCl(s)$	–411.2	72.1	–384.2
$H_2S(g)$	–20.5	205.7	–33.6	$NaOH(s)$	–425.9	64.4	–379.5
$H_2SO_4(l)$	–814.0	156.9	–690.1	$O_2(g)$	0.0	205.0	0.0
$K(s)$	0.0	64.7	0.0	$O_3(g)$	142.7	238.9	163.2
$KCl(s)$	–436.7	82.6	–409.2	$Pb(s)$	0.0	64.8	0.0
$KNO_3(s)$	–494.6	133.0	–394.9	$PbCl_2(s)$	–359.4	136.2	–317.9
$KOH(s)$	–424.7	78.9	–379.1	$PbO(s, red)$	–219.0	66.3	–188.95
$Li(s)$	0.0	29.1	0.0	$S(s)$	0.0	32.1	0.0
$LiCl(s)$	–408.6	59.3	–384.4	$SO_2(g)$	–296.8	248.1	–300.2
$LiOH(s)$	–484.9	42.8	–439.0	$SO_3(g)$	–395.8	256.8	–371.1
$Mg(s)$	0.0	32.7	0.0	$Si(s)$	0.0	18.8	0.0
$MgCl_2(s)$	–641.6	89.6	–591.8	$SiCl_4(g)$	–657.0	330.9	–617.0
$Hg(l)$	0.0	76.0	0.0	$SiO_2(s, quartz)$	–910.9	41.5	–856.7
$Hg_2Cl_2(s)$	–264.2	192.5	–210.8	$Sn(s, white)$	0.0	51.6	0.0
$HgO(s, red)$	–90.8	70.3	–55.6	$Sn(s, gray)$	–2.1	44.1	0.13
$N_2(g)$	0.0	191.6	0.0	$SnCl_4(l)$	–511.3	258.6	–440.2
$NH_3(g)$	–45.9	192.8	–16.5	$Zn(s)$	0.0	41.6	0.0
$NH_4Cl(s)$	–314.4	94.6	–203.0	$ZnCl_2(s)$	–415.0	111.5	–369.4
$NO(g)$	90.3	210.8	86.6	$ZnO(s)$	–348.3	43.6	–318.32

TABLE A-12 HEAT OF COMBUSTION

Formula	ΔH_c(kJ/mol)	Formula	ΔH_c(kJ/mol)	Formula	ΔH_c(kJ/mol)
$H_2(g)$	–285.8	$C_6H_{14}(l)$	–4163.2	$C_{10}H_8(s)$	–5156.3
$C(s, graphite)$	–393.5	$C_7H_{16}(l)$	–4817.0	$C_{14}H_{10}(s)$	–7076.5
$CO(g)$	–283.0	$C_8H_{18}(l)$	–5470.5	$CH_3OH(l)$	–726.1
$CH_4(g)$	–890.8	$C_2H_4(g)$	–1411.2	$C_2H_5OH(l)$	–1366.8
$C_2H_6(g)$	–1560.7	$C_3H_6(g)$	–2058.0	$(C_2H_5)_2O(l)$	–2751.1
$C_3H_8(g)$	–2219.2	$C_2H_2(g)$	–1301.1	$CH_2O(g)$	–570.7
$C_4H_{10}(g)$	–2877.6	$C_6H_6(l)$	–3267.6	$C_6H_{12}O_6(s)$	–2803.0
$C_5H_{12}(g)$	–3535.6	$C_7H_8(l)$	–3910.3	$C_{12}H_{22}O_{11}(s)$	–5640.9

TABLE A-13 WATER-VAPOR PRESSURE

Temperature (°C)	Pressure (mm Hg)	Pressure (kPa)	Temperature (°C)	Pressure (mm Hg)	Pressure (kPa)
0.0	4.6	0.61	23.0	21.1	2.81
5.0	6.5	0.87	23.5	21.7	2.90
10.0	9.2	1.23	24.0	22.4	2.98
15.0	12.8	1.71	24.5	23.1	3.10
15.5	13.2	1.76	25.0	23.8	3.17
16.0	13.6	1.82	26.0	25.2	3.36
16.5	14.1	1.88	27.0	26.7	3.57
17.0	14.5	1.94	28.0	28.3	3.78
17.5	15.0	2.00	29.0	30.0	4.01
18.0	15.5	2.06	30.0	31.8	4.25
18.5	16.0	2.13	35.0	42.2	5.63
19.0	16.5	2.19	40.0	55.3	7.38
19.5	17.0	2.27	50.0	92.5	12.34
20.0	17.5	2.34	60.0	149.4	19.93
20.5	18.1	2.41	70.0	233.7	31.18
21.0	18.6	2.49	80.0	355.1	47.37
21.5	19.2	2.57	90.0	525.8	70.12
22.0	19.8	2.64	95.0	633.9	84.53
22.5	20.4	2.72	100.0	760.0	101.32

TABLE A-14 DENSITIES OF GASES AT STP

Gas	Density (g/L)	Gas	Density (g/L)
Air, dry	1.293	Hydrogen	0.0899
Ammonia	0.771	Hydrogen chloride	1.639
Carbon dioxide	1.997	Hydrogen sulfide	1.539
Carbon monoxide	1.250	Methane	0.7168
Chlorine	3.214	Nitrogen	1.2506
Dinitrogen monoxide	1.977	Nitrogen monoxide (at 10°C)	1.340
Ethyne (acetylene)	1.165	Oxygen	1.429
Helium	0.1785	Sulfur dioxide	2.927

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TABLE A-15 DENSITY OF LIQUID WATER

Temperature (°C)	Density (g/cm^3)	Temperature (°C)	Density (g/cm^3)
0	0.999 84	25	0.997 05
2	0.999 94	30	0.995 65
3.98 (maximum)	0.999 973	40	0.992 22
4	0.999 97	50	0.988 04
6	0.999 94	60	0.983 20
8	0.999 85	70	0.977 77
10	0.999 70	80	0.971 79
14	0.999 24	90	0.965 31
16	0.998 94	100	0.958 36
20	0.998 20		

TABLE A-16 MEASURES OF CONCENTRATION

Name	Symbol	Units	Areas of application
Molarity	M	$\frac{\text{mol solute}}{\text{L solution}}$	in solution stoichiometry calculations
Molality	m	$\frac{\text{mol solute}}{\text{kg solvent}}$	boiling-point elevation and freezing-point depression calculations
Mole fraction	X	$\frac{\text{mol solute}}{\text{total mol solution}}$	in solution thermodynamics
Volume percent	% V/V	$\frac{\text{volume solute}}{\text{volume solution}} \times 100$	with liquid-liquid mixtures
Mass or weight percent	% or %w/w	$\frac{\text{g solute}}{\text{g solution}} \times 100$	in biological research
Parts per million	ppm	$\frac{\text{g solute}}{\text{1 000 000 g solution}}$	to express small concentrations
Parts per billion	ppb	$\frac{\text{g solute}}{\text{1 000 000 000 g solution}}$	to express very small concentrations, as in pollutants or contaminants

TABLE A-17 SOLUBILITIES OF GASES IN WATER*

Gas	0°C	10°C	20°C	60°C
Air	0.029 18	0.022 84	0.018 68	0.012 16
Ammonia	1130	870	680	200
Carbon dioxide	1.713	1.194	0.878	0.359
Carbon monoxide	0.035 37	0.028 16	0.023 19	0.014 88
Chlorine	—	3.148	2.299	1.023
Hydrogen	0.021 48	0.019 55	0.018 19	0.016 00
Hydrogen chloride	512	475	442	339
Hydrogen sulfide	4.670	3.399	2.582	1.190
Methane	0.055 63	0.041 77	0.033 08	0.019 54
Nitrogen†	0.023 54	0.018 61	0.015 45	0.010 23
Nitrogen monoxide	0.073 81	0.057 09	0.047 06	0.029 54
Oxygen	0.048 89	0.038 02	0.031 02	0.019 46
Sulfur dioxide	79.789	56.647	39.374	—

* Volume of gas (in liters) at STP that can be dissolved in 1 L of water at the temperature (°C) indicated.
† Atmospheric nitrogen: 98.815% N_2, 1.185% inert gases

TABLE A-18 SOLUBILITY OF COMPOUNDS*

Formula	0°C	20°C	60°C	100°C
$Al_2(SO_4)_3$	31.2	36.4	59.2	89.0
NH_4Cl	29.4	37.2	55.3	77.3
NH_4NO_3	118	192	421	871
$(NH_4)_2SO_4$	70.6	75.4	88	103
$BaCl_2 \cdot 2H_2O$	31.2	35.8	46.2	59.4
$Ba(OH)_2$	1.67	3.89	20.94	$101.40^{80°}$
$Ba(NO_3)_2$	4.95	9.02	20.4	34.4
$Ca(HCO_3)_2$	16.15	16.60	17.50	18.40
$Ca(OH)_2$	0.189	0.173	0.121	0.076
$CuCl_2$	68.6	73.0	96.5	120
$CuSO_4 \cdot 5H_2O$	23.1	32.0	61.8	114
$PbCl_2$	0.67	1.00	1.94	3.20
$Pb(NO_3)_2$	37.5	54.3	91.6	133
$LiCl$	69.2	83.5	98.4	128
Li_2SO_4	36.1	34.8	32.6	$30.9^{90°}$
$MgSO_4$	22.0	33.7	54.6	68.3
$HgCl_2$	3.63	6.57	16.3	61.3

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TABLE A-18 CONTINUED

Formula	0°C	20°C	60°C	100°C
KBr	53.6	65.3	85.5	104
$KClO_3$	3.3	7.3	23.8	56.3
KCl	28.0	34.2	45.8	56.3
K_2CrO_4	56.3	63.7	70.1	$74.5^{90°}$
KI	128	144	176	206
KNO_3	13.9	31.6	106	245
K_2SO_4	7.4	11.1	18.2	24.1
$AgC_2H_3O_2$	0.73	1.05	1.93	$2.59^{80°}$
$AgNO_3$	122	216	440	733
$NaC_2H_3O_2$	36.2	46.4	139	170
$NaClO_3$	79.6	95.9	137	204
NaCl	35.7	35.9	37.1	39.2
$NaNO_3$	73.0	87.6	122	180
$C_{12}H_{22}O_{11}$	179.2	203.9	287.3	487.2

* Solubilities are given in grams of solute that can be dissolved in 100 g of water at the temperature (°C) indicated.

TABLE A-19 EXAMPLES OF COMPLEX IONS

Complex cation	Color	Complex cation	Color	Complex anion	Color
$[Co(NH_3)_6]^{3+}$	yellow-orange	$[Fe(H_2O)_5SCN]^{2+}$	deep red	$[Co(CN)_6]^{3-}$	pale yellow
$[Co(NH_3)_5(H_2O)]^{3+}$	bright red	$[Ni(NH_3)_6]^{2+}$	blue-violet	$[CoCl_4]^{2-}$	blue
$[Co(NH_3)_5Cl]^{2+}$	violet	$[Ni(H_2O)_6]^{2+}$	green	$[Cu_2Cl_6]^{2-}$	red
$[Co(H_2O)_6]^{2+}$	pink	$[Zn(NH_3)_4]^{2+}$	colorless	$[Fe(CN)_6]^{3-}$	red
$[Cu(NH_3)_4]^{2+}$	blue-purple	$[Zn(NH_3)_6]^{2+}$	colorless	$[Fe(CN)_6]^{4-}$	yellow
$[Cu(H_2O)_4]^{2+}$	light blue			$[Fe(C_2O_4)_3]^{3-}$	green

TABLE A-20 EQUILIBRIUM CONSTANTS

Equation	K_{eq} expression	Values	
$N_2(g) + 3H_2(g) \rightleftarrows 2NH_3(g)$	$\frac{[NH_3]^2}{[N_2][H_2]^3}$	3.3×10^8 (25°C)	4.2×10^1 (327°C)
$NH_3(aq) + H_2O(l) \rightleftarrows NH_4^+(aq) + OH^-(aq)$	$\frac{[NH_4^+][OH^-]}{[NH_3]}$	1.8×10^{-5} (25°C)	
$2NO_2(g) \rightleftarrows N_2O_4(g)$	$\frac{[N_2O_4]}{[NO_2]^2}$	1.25×10^3 (0°C) 2.0×10^1 (100°C)	1.65×10^2 (25°C)
$N_2(g) + O_2(g) \rightleftarrows 2NO(g)$	$\frac{[NO]^2}{[N_2][O_2]}$	4.5×10^{-31} (25°C)	6.7×10^{-10} (627°C)
$CO_2(g) + H_2(g) \rightleftarrows CO(g) + H_2O(g)$	$\frac{[CO][H_2O]}{[CO_2][H_2]}$	2.2 (1400°C)	4.6 (2000°C)
$H_2CO_3(aq) + H_2O(l) \rightleftarrows H_3O^+(aq) + HCO_3^-(aq)$	$\frac{[H_3O^+][HCO_3^-]}{[H_2CO_3]}$	4.3×10^{-7} (25°C)	
$HCO_3^-(aq) + H_2O(l) \rightleftarrows CO_3^{2-}(aq) + H_3O^+(aq)$	$\frac{[CO_3^{2-}][H_3O^+]}{[HCO_3^-]}$	4.7×10^{-11} (25°C)	
$H_2(g) + I_2(g) \rightleftarrows 2HI(g)$	$\frac{[HI]^2}{[H_2][I_2]}$	1.13×10^2 (250°C)	1.8×10^1 (1127°C)
$Hg^{2+}(aq) + Hg(l) \rightleftarrows Hg_2^{2+}(aq)$	$\frac{[Hg_2^{2+}]}{[Hg^{2+}]}$	8.1×10^1 (25°C)	

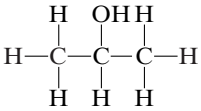
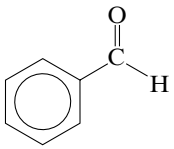
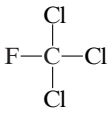
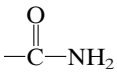
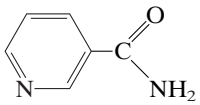
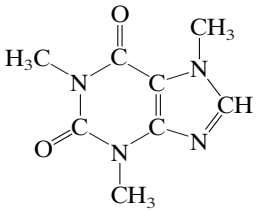
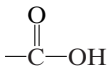
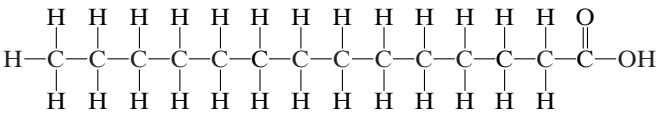
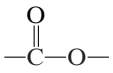
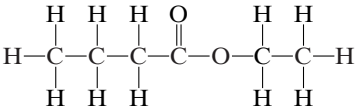
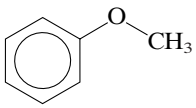
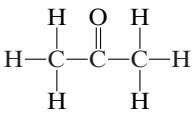
TABLE A-21 APPROXIMATE CONCENTRATION OF IONS IN OCEAN WATER

Ion	Concentration (mol/L)	Ion	Concentration (mol/L)
Cl^-	0.554	K^+	0.010
Na^+	0.470	Ca^{2+}	0.009
Mg^{2+}	0.047	CO_3^{2-}	0.002
SO_4^{2-}	0.015	Br^-	0.001

TABLE A-22 STANDARD ELECTRODE POTENTIALS

Electrode reaction	E° (V)
$Li^+(aq) + e^- \rightleftarrows Li(s)$	–3.0401
$K^+(aq) + e^- \rightleftarrows K(s)$	–2.931
$Ca^{2+}(aq) + 2e^- \rightleftarrows Ca(s)$	–2.868
$Na^+(aq) + e^- \rightleftarrows Na(s)$	–2.71
$Mg^{2+}(aq) + 2e^- \rightleftarrows Mg(s)$	–2.372
$Al^{3+}(aq) + 3e^- \rightleftarrows Al(s)$	–1.662
$Zn(OH)_2(s) + 2e^- \rightleftarrows Zn(s) + 2OH^-(aq)$	–1.249
$2H_2O(l) + 2e^- \rightleftarrows H_2(g) + 2OH^-(aq)$	–0.828
$Zn^{2+}(aq) + 2e^- \rightleftarrows Zn(s)$	–0.7618
$Fe^{2+}(aq) + 2e^- \rightleftarrows Fe(s)$	–0.447
$PbSO_4(s) + H_3O^+(aq) + 2e^- \rightleftarrows Pb(s) + HSO_4^-(aq) + H_2O(l)$	–0.42
$Cd^{2+}(aq) + 2e^- \rightleftarrows Cd(s)$	–0.4030
$Pb^{2+}(aq) + 2e^- \rightleftarrows Pb(s)$	–0.1262
$Fe^{3+}(aq) + 3e^- \rightleftarrows Fe(s)$	–0.037
$2H_3O^+(aq) + 2e^- \rightleftarrows H_2(g) + 2H_2O(l)$	0.000
$AgCl(s) + e^- \rightleftarrows Ag(s) + Cl^-(aq)$	+0.222
$Cu^{2+}(aq) + 2e^- \rightleftarrows Cu(s)$	+0.3419
$O_2(g) + 2H_2O(l) + 4e^- \rightleftarrows 4OH^-(aq)$	+0.401
$I_2(s) + 2e^- \rightleftarrows 2I^-(aq)$	+0.5355
$Fe^{3+}(aq) + e^- \rightleftarrows Fe^{2+}(aq)$	+0.771
$Hg_2^{2+}(aq) + 2e^- \rightleftarrows 2Hg(l)$	+0.7973
$Ag^+(aq) + e^- \rightleftarrows Ag(s)$	+0.7996
$Br_2(l) + 2e^- \rightleftarrows 2Br^-(aq)$	+1.066
$MnO_2(s) + 4H_3O^+(aq) + 2e^- \rightleftarrows Mn^{2+}(aq) + 6H_2O(l)$	+1.224
$O_2(g) + 4H_3O^+(aq) + 4e^- \rightleftarrows 6H_2O$	+1.229
$Cl_2(g) + 2e^- \rightleftarrows 2Cl^-(aq)$	+1.358
$PbO_2(s) + 4H_3O^+(aq) + 2e^- \rightleftarrows Pb^{2+}(aq) + 6H_2O(l)$	+1.455
$MnO_4^-(aq) + 8H_3O^+(aq) + 5e^- \rightleftarrows Mn^{2+}(aq) + 12H_2O(l)$	+1.507
$PbO_2(s) + HSO_4^-(aq) + 3H_3O^+(aq) + 2e^- \rightleftarrows PbSO_4(s) + 5H_2O(l)$	+1.691
$Ce^{4+}(aq) + e^- \rightleftarrows Ce^{3+}(aq)$	+1.72
$Ag_2O_2(s) + 4H^+(aq) + e^- \rightleftarrows 2Ag(s) + 2H_2O(l)$	+1.802
$F_2(g) + 2e^- \rightleftarrows 2F^-(aq)$	+2.866

TABLE A-23 SOME CLASSES OF ORGANIC COMPOUNDS

Class	Functional group	Example	Use
Alcohol	—OH	 **2-propanol**	disinfectant
Aldehyde		 **benzaldehyde**	almond flavor
Halide	—F, Cl, Br, I	 **trichlorofluoromethane (Freon-11)**	refrigerant
Amide		 **niacinamide (nicotinamide)**	nutrient
Amine		 **caffeine**	beverage ingredient
Carboxylic acid		 **tetradecanoic acid (myristic acid)**	soap-making ingredient
Ester		 **ethyl butanoate**	perfume ingredient
Ether	—O—	 **methyl phenyl ether (anisole)**	perfume ingredient
Ketone		 **propanone (acetone)**	solvent in nail-polish remover

APPENDIX A

TABLE A-24 SOLUBILITY PRODUCT CONSTANTS AT 25°C

Salt	K_{sp}	Salt	K_{sp}
Ag_2CO_3	8.4×10^{-12}	$FeCO_3$	3.1×10^{-11}
AgCl	1.8×10^{-10}	$Fe(OH)_2$	4.9×10^{-17}
Ag_2CrO_4	1.1×10^{-12}	$Fe(OH)_3$	2.6×10^{-39}
Ag_2S	1.1×10^{-49}	FeS	1.6×10^{-19}
AgBr	5.4×10^{-13}	$MgCO_3$	6.8×10^{-6}
AgI	8.5×10^{-17}	$Mg(OH)_2$	5.6×10^{-12}
$AlPO_4$	9.8×10^{-21}	$Mg_3(PO_4)_2$	9.9×10^{-25}
$BaSO_4$	1.1×10^{-10}	$MnCO_3$	2.2×10^{-11}
$CaCO_3$	5.0×10^{-9}	$Pb(OH)_2$	1.4×10^{-20}
$Ca(OH)_2$	4.7×10^{-7}	PbS	9.0×10^{-29}
$Ca_3(PO_4)_2$	2.1×10^{-33}	$PbSO_4$	1.8×10^{-8}
$CaSO_4$	7.1×10^{-5}	$SrSO_4$	3.4×10^{-7}
CuS	1.3×10^{-36}	$ZnCO_3$	1.2×10^{-10}
		ZnS	2.9×10^{-25}

Study Skills for Chemistry
Table of Contents

Succeeding in Your Chemistry Class

Your success in this course will depend on your ability to apply some basic study skills to learning the material. Studying chemistry can be difficult, but you can make it easier using simple strategies for dealing with the concepts and problems. Becoming skilled in using these strategies will be your keys to success in this and many other courses.

Reading the Text

- **Read the assigned material before class** so that the class lecture makes sense. Use a dictionary to help you interpret vocabulary. Remember while reading to figure out what information is important.

  Working together with others using Paired Reading and Discussion strategies can help you decide what is important and clarify the material. (For more discussion, see Other Reading Strategies on page 853.)
- **Select a quiet setting** away from distractions so that you can concentrate on what you are reading.
- **Have a pencil and paper nearby to jot down notes and questions** you may have. Be sure to get these questions answered in class. Power Notes (see page 849) can help you organize the notes you take and prepare you for class.
- **Use the Objectives in the beginning of each section as a list of what you need to know** from the section. Teachers generally make their tests based on the text objectives or their own objectives. Using the objectives to focus your reading can make your learning more efficient. Using the K/W/L strategy (see page 851) can help you relate new material to what you already know and what you need to learn.

Taking Notes in Class

- **Be prepared to take notes during class.** Have your materials organized in a notebook. Separate sheets of paper can be easily lost.
- **Don't write down everything your teacher says.** Try to tell which parts of the lecture are important and which are not. Reading the text before class will help in this. You will not be able to write down everything, so you must try to write down only the important things.
- **Recopying notes later is a waste of time** and does not help you learn material for a test. Do it right the first time. Organize your notes as you are writing them down so that you can make sense of your notes when you review them without needing to recopy them.

Reviewing Class Notes

- **Review your notes as soon as possible after class.** Write down any questions you may have about the material covered that day. Be sure to get these questions answered during the next class. You can work with friends to use strategies such as Paired Summarizing and L.I.N.K. (See page 853.)
- **Do not wait until the test to review.** By then you will have forgotten a good portion of the material.
- **Be selective about what you memorize.** You cannot memorize everything in a chapter. First of all, it is too time consuming. Second, memorizing and understanding are not the same thing. Memorizing topics as they appear in your notes or text does not guarantee that you will be able to correctly answer questions that require understanding of those topics. You should only memorize material that you understand. Concept Maps and other Reading Organizers, Sequencing/Pattern Puzzles, and Prediction Guides can help you understand key ideas and major concepts. (See pages 846, 852, and 854.)

Working Problems

In addition to understanding the concepts, the ability to solve problems will be a key to your success in chemistry. You will probably spend a lot of time working problems in class and at home. The ability to solve chemistry problems is a skill, and like any skill, it requires practice.

- **Always review the Sample Problems in the chapter.** The Sample Problems in the text provide road maps for solving certain types of problems. Cover the solution while trying to work the problem yourself.
- **The problems in the Chapter Review are similar to the Sample Problems.** If you can relate an assigned problem to one of the Sample Problems in the chapter, it shows that you understand the material.
- **The four steps: Gather information, Plan your work, Calculate, and Verify should be the steps you go through when working assigned problems.** These steps will allow you to organize your thoughts and help you develop your problem-solving skills.
- **Never spend more than 15 minutes trying to solve a problem.** If you have not been able to come up with a plan for the solution after 15 minutes, additional time spent will only cause you to become frustrated. What do you do? Get help! See your teacher or a classmate. Find out what it is that you do not understand.
- **Do not try to memorize the Sample Problems; spend your time trying to understand how the solution develops.** Memorizing a particular sample problem will not ensure that you understand it well enough to solve a similar problem.
- **Always look at your answer and ask yourself if it is reasonable and makes sense.** Check to be sure you have the correct units and numbers of significant figures.

Completing Homework

Your teacher will probably assign questions and problems from the Section Reviews and Chapter Reviews or assign Concept Review worksheets. The purpose of these assignments is to review what you have covered in class and to see if you can use the information to answer questions or solve problems. As in reviewing class notes, do your homework as soon after class as possible while the topics are still fresh in your mind. Do not wait until late at night, when you are more likely to be tired and to become frustrated.

Reviewing for an exam

- **Don't panic and don't cram!** It takes longer to learn if you are under pressure. If you have followed the strategies listed here and reviewed along the way, studying for the exam should be less stressful.
- When looking over your notes and concept maps, **recite ideas out loud.** There are two reasons for reciting:
  1. You are hearing the information, which is effective in helping you learn.
  2. If you cannot recite the ideas, it should be a clue that you do not understand the material, and you should begin rereading or reviewing the material again.
- **Studying with a friend provides a good opportunity for recitation.** If you can explain ideas to your study partner, you know the material.

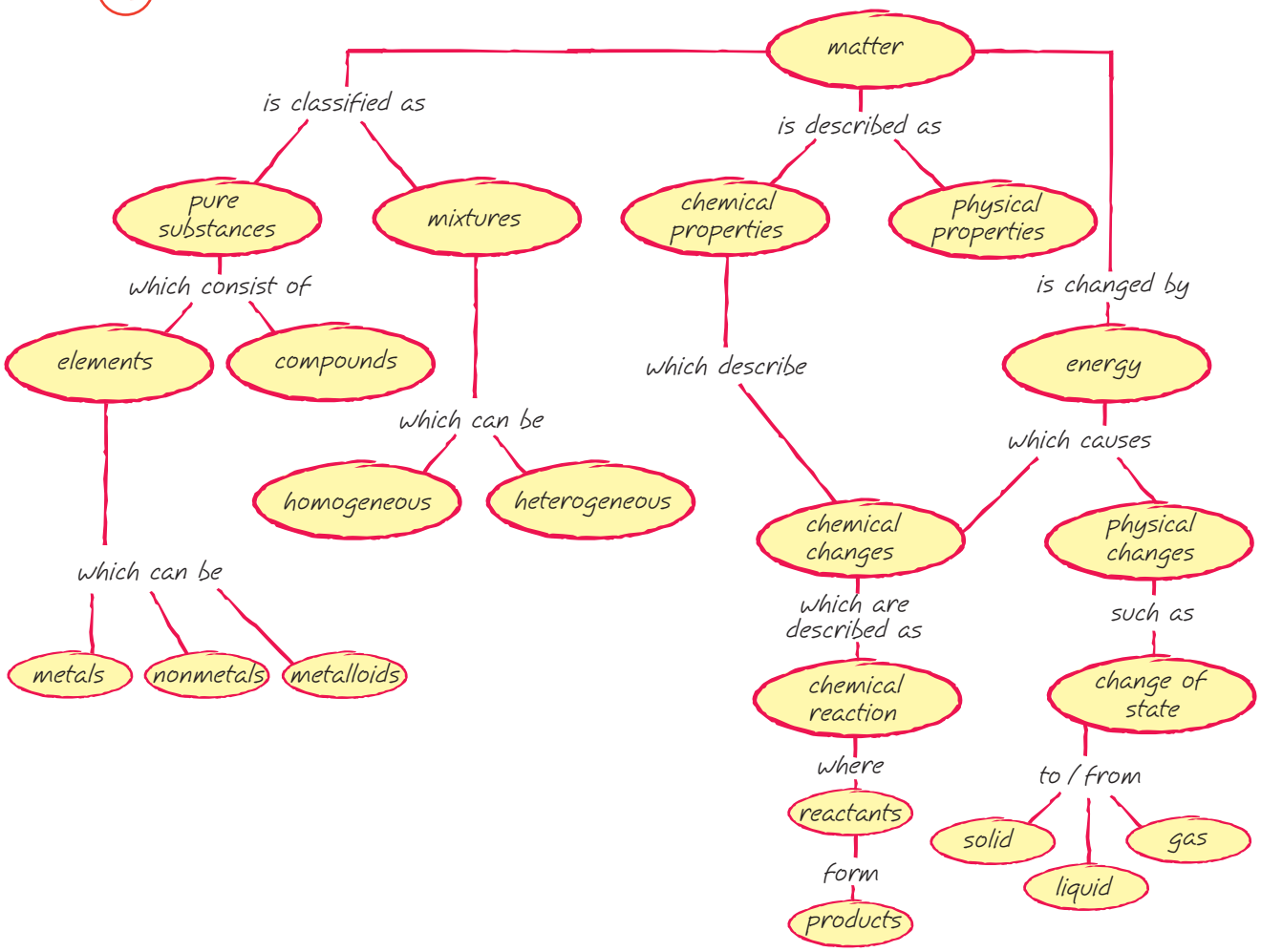
Taking an exam

- **Get plenty of rest before the exam** so that you can think clearly. If you have been awake all night studying, you are less likely to succeed than if you had gotten a full night of rest.
- **Start with the questions you know.** If you get stuck on a question, save it for later. As time passes and you work through the exam, you may recall the information you need to answer a difficult question or solve a difficult problem.

Good luck!

Making Concept Maps

MAP A



Making concept maps can help you decide what material in a chapter is important and how to efficiently learn that material. A concept map presents key ideas, meanings, and relationships for the concepts being studied. It can be thought of as a visual road map of the chapter. Learning happens efficiently when you use concept maps because you work with only the key ideas and how they fit together.

The concept map shown as **Map A** was made from vocabulary terms from the first few chapters of the book. Vocabulary terms are generally labels for concepts, and concepts are generally nouns. In a concept map, linking words are used to form propositions that connect concepts and give them meaning in context. For example, on the map above, "matter is described by physical properties" is a proposition.

Studies show that people are better able to remember materials presented visually. A concept map is better than an outline because you can see the relationships among many ideas. Because outlines are linear, there is no way of linking the ideas from various sections of the outline. Read through the map to become familiar with the information presented. Then look at the map in relation to all of the text pages in the first few chapters; which gives a better picture of the important concepts—the map or the full chapters?