

STUDENT EDITION

CHEMISTRY
FORENSICS
LABORATORY MANUAL



Glencoe

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A GLENCOE PROGRAM



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To the Student

What is forensic science? Forensic science uses scientific knowledge and methods to help determine the cause of a crime or accident and identify criminals.

You may have seen television shows or movies in which a coroner uses forensic science to determine the cause of death in a homicide. You may also have seen fire investigators examine the scene of a fire to determine what started the blaze and whether or not it is arson. Fingerprints may be taken to see whether they match those of a suspect. All of this is part of forensic science.

But forensic science involves much more. Forensic chemists work with the tiniest bits of hair, skin, fibers from clothing or rugs, blood, or other materials that the untrained eye might overlook. Sometimes, local forensic experts can examine evidence and find the information they need. However, evidence often is sent to one of several hundred crime labs around the United States and Canada. These labs are fully equipped with the latest computerized testing equipment, such as electron microscopes, and staffed with highly trained personnel who examine evidence. Some laboratories work solely on evidence in cases concerning violation of federal or state laws. They may identify pollutants, test imported materials or products sold to the public, or verify that a particular substance is an illegal drug.

As time progresses, so does the accuracy of forensic science. Forensic scientists can compare more than 30 characteristics of human tissue. A paint chip from a car can identify the make of the car and perhaps the year it was manufactured. The composition of water in the lungs of a drowning victim can narrow down the site of the drowning. Charred documents from a fire can be analyzed. Forgeries can be distinguished from original works of art. Skeletons can be analyzed and a likeness of the person reconstructed. Blood, saliva, and other body fluids found at the scene of a crime can be analyzed for the unique DNA that cells contain.

You are now to become a forensic scientist. Several labs accompany each of the crimes described in this book. Your lab results will be applied to the crime. You will then examine evidence and draw conclusions as to what caused the crime and, in some cases, identify the guilty party.

Objectives

You will:

- learn and apply basic chemistry concepts.
- understand the nature of science.
- develop and practice science process skills.
- incorporate technology as a tool for collecting and analyzing data.
- demonstrate good lab practices.
- recognize how chemistry relates to your life in an authentic way.

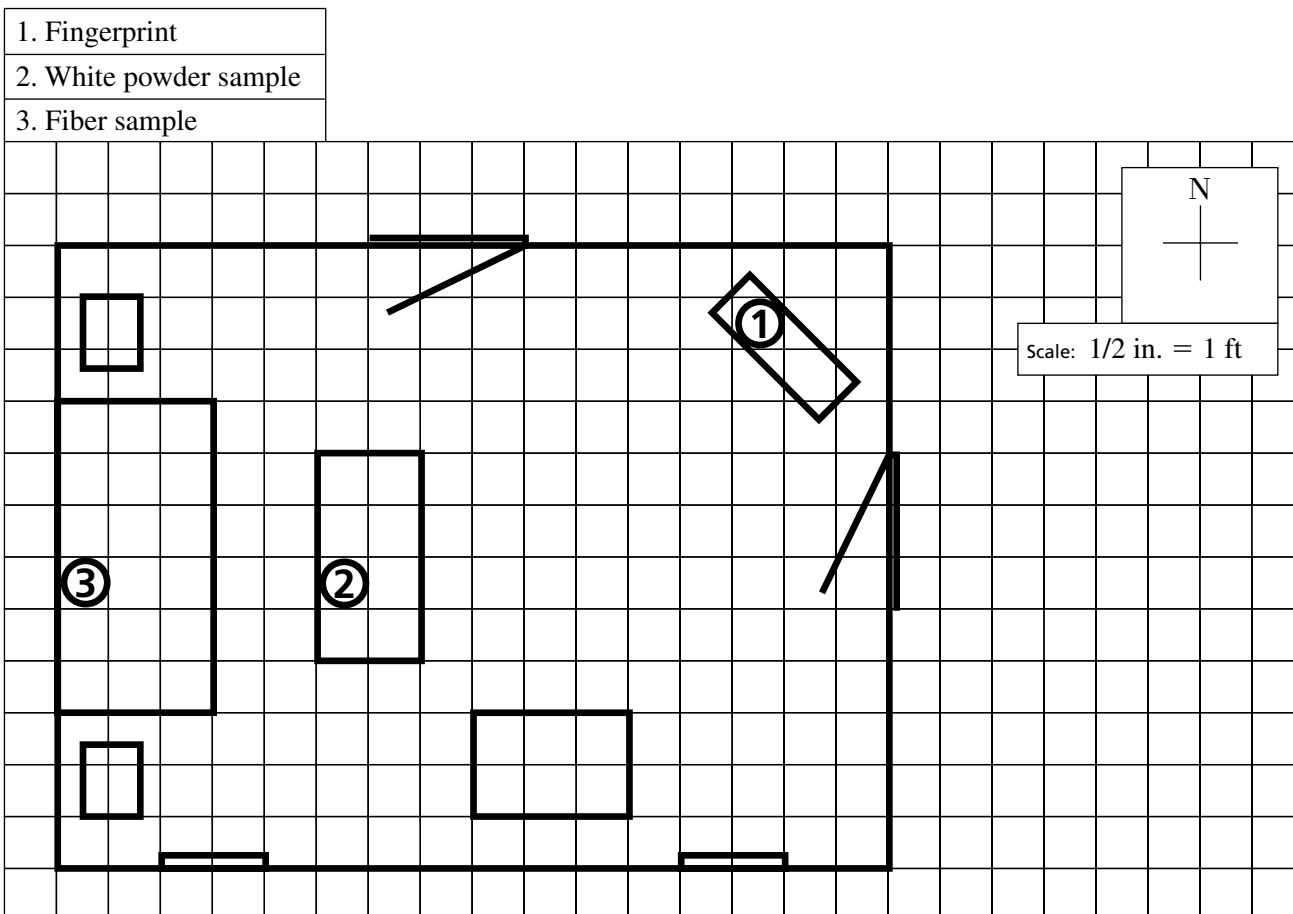
Forensic Skills

The next several pages include general forensic skills. These skills do not relate to a specific crime but are used whenever they are needed in solving any crime.

Observing the Scene and Collecting Data

The first task in a forensic investigation is to secure the scene. A secure site means that it is marked off and no one can enter without permission. Nothing should be touched or altered in any way.

Sketch the scene and take photographs. The form on the following page is typical of one used to record where evidence was collected and photographs were taken at a crime scene. The numbered items at the top of the page provide necessary identification facts. The spaces numbered 1 through 18 are used to identify items or photographs whose locations are labeled on the grid. When you take a photograph, record the number of the picture and the location of the scene. When you collect fingerprints or any other evidence, the sample should be placed in an evidence bag and carefully marked for identification. Number the sample and label its location on your sketch and on a line item at the top of the page. The following figure shows an example of how evidence and photographs are recorded on such a form. Always keep in mind that your evidence may have to stand up to close scrutiny in a courtroom.

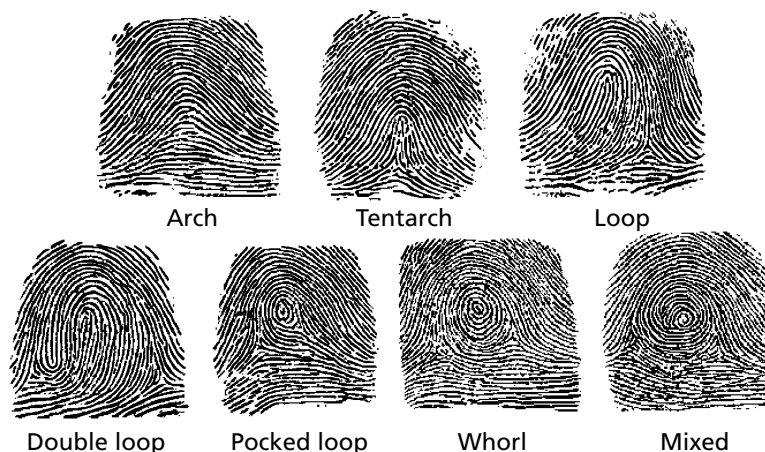


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Fingerprints

Fingerprints are some of the most important and useful pieces of forensic evidence collected by the forensic scientist. Individual prints are unique. Fingerprint types are inherited, but exact patterns are not. Compare your prints to those of your parents and siblings. No two persons' fingerprints are alike, not even identical twins. This fact allows a person's fingerprints to be considered as direct evidence for identification.

Three main fingerprint patterns are found in the human population—arch, loop, and whorl. Approximately 69% of all prints are loops. The rarest type of fingerprint is the arch, making up approximately 6% of the total population. That leaves about 25% of the population as whorls. Each of these groups is subdivided. Look at the following examples.



Arches

The plain arch consists of simple ridges that flow from left to right, with a rise or hill in the center. The tented arch appears to have a ridge that supports the arches like the center post in a tent.



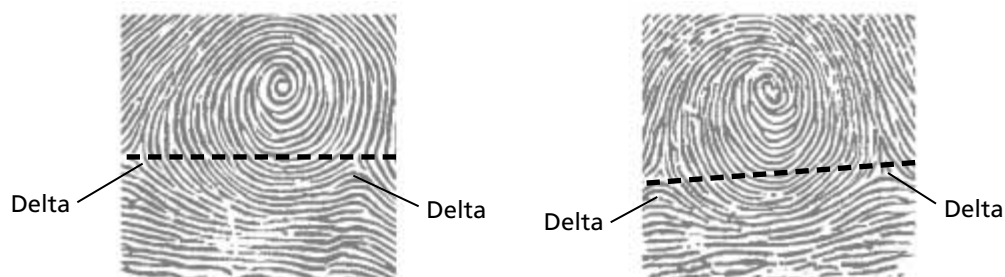
Loops

There are three parts of a loop pattern: deltas, typelines, and looping. Loop patterns always develop ridges that separate to form a delta. All loops must have at least one delta. The ridges that separate or diverge at the delta are typelines. The third part of a loop pattern is the looping. Loops must have at least one curving and returning ridge. They may have as many as 20. In a loop pattern, ridges flow from one side with a rise. Then, they curve and return to the same side from which they started.

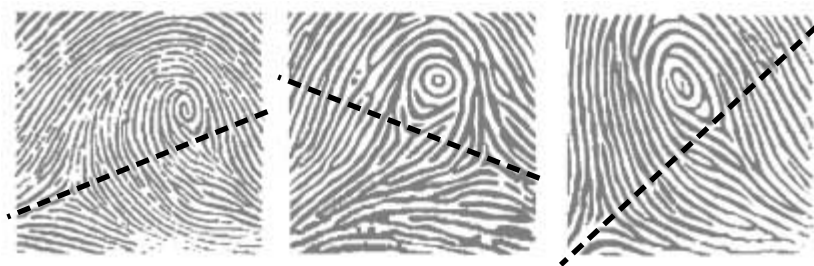
Whorls

Unlike arches and loops, whorls are often unique. Whorls are ridge patterns that have a minimum of two deltas.

Plain whorls are target-shaped patterns with two deltas. An imaginary line connecting the two deltas must cross at least one circle.



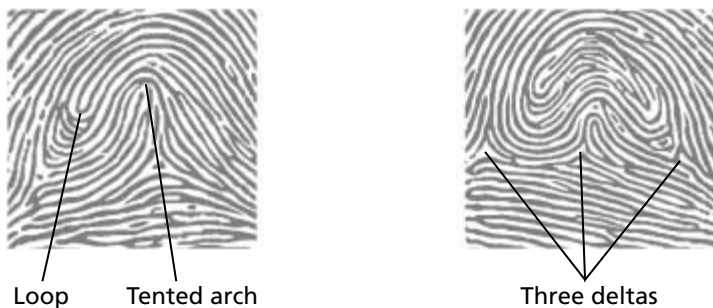
Central pocket loop whorls must have at least one circle and two deltas. An imaginary line connecting the two deltas must not cross the circle between the deltas.



Double loop whorls must have two separate loop formations inside two delta formations.



Accidental whorls are unusual patterns with three deltas or a combination of a loop and a tented arch.



Procedure for Lifting Fingerprints

The three types of fingerprints are visible, impressions, and latent. If liquids, such as paint or blood, are part of the crime scene, fingerprints may be visible. In this case, the investigator photographs the prints and catalogs the photograph as part of the evidence.

More frequently, fingerprints are not visible. Impressions can become visible if special lighting techniques are used. Then the prints can also be photographed. Latent prints, however, are hidden. Latent prints occur because fingers sweat, even if they feel cool and dry. Sweat is mostly water, which will evaporate, leaving behind organic compounds such as amino acids, glucose, lactic acid, and peptides or inorganic salts of potassium or sodium chloride. These trace compounds form latent prints.

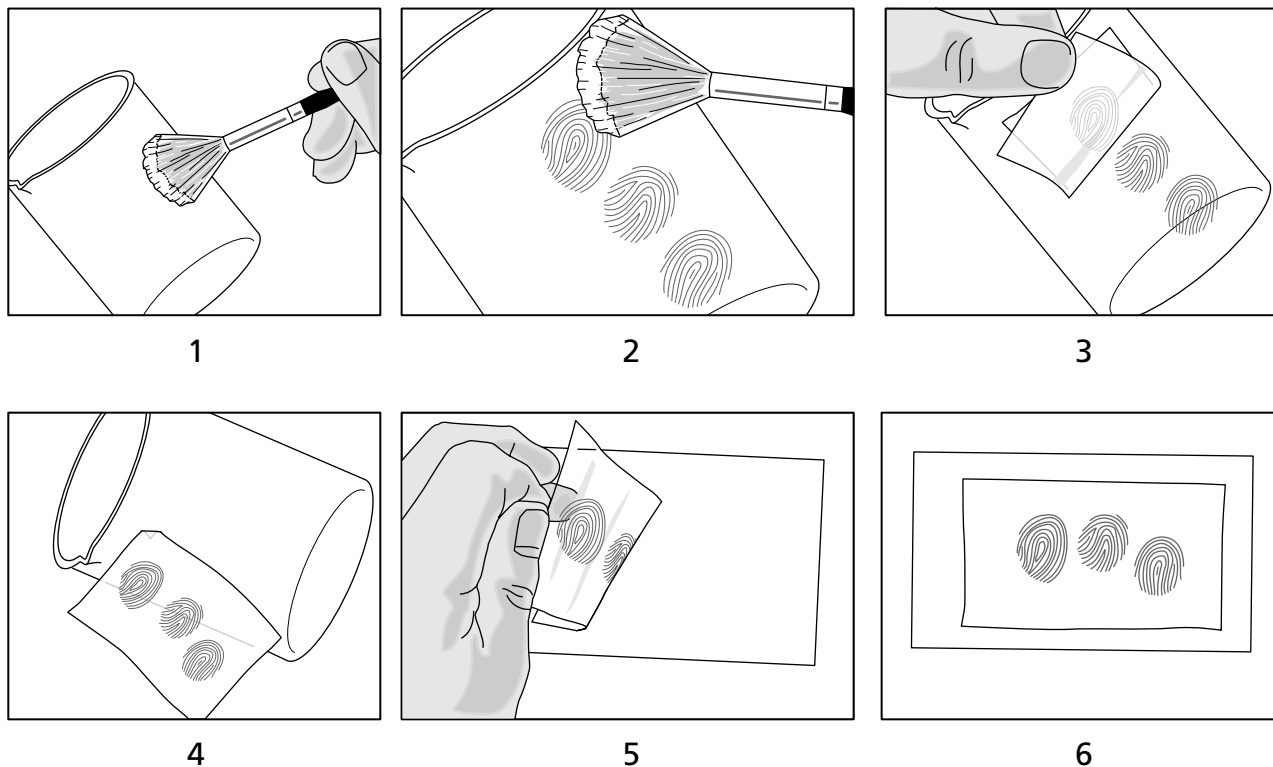
Method 1

The simplest and most frequently used method of revealing a fresh fingerprint is to dust it with a black powder. This powder is composed of a colorant and a resinous polymer or inorganic salt. The resinous polymer or inorganic salt is adsorbed by the moisture or oil of sweat, and the colorant is adsorbed on the resin or salt.

A black powder that can be used to dust for fingerprints can be prepared as follows.

1. Place 3 g of charcoal powder, 9 g of zinc carbonate, and 0.1 g of talcum powder in a mortar and pestle. Grind the mixture to a fine powder.
2. Add 20 g of fine iron filings and grind again.
3. Place the powder in a tightly sealed, labeled bottle.

Test your product by taking a clean, dry beaker and pressing your fingers around the outside. Dip a small brush into your powder, and lightly dust the prints. You may either photograph or lift the print. To lift a fingerprint, take a wide piece of clear tape and press it firmly over a print. Rub the back of the tape, then carefully lift it. Fasten the tape to a 3" × 5" index card.



Method 2

If the print is older and most of the water and oils have evaporated, you still may be able to find a latent print. Ninhydrin is an organic compound that reacts with amino acids to form a deep purple complex. Make a solution of ninhydrin by mixing 0.5 g ninhydrin with 30 mL of ethanol. Pour the solution into a spray bottle. Hold the bottle about 15 cm away from where you think the print might be, and spray a light coat on the area. Wait a few moments until much of the ethanol evaporates, then spray again. Allow the area to dry completely. The print will appear only when the area is completely dry. You may use a hair dryer to help dry the area. This method works well on papers, such as on forged checks, where latent prints are normally difficult to lift.

Blood Identification

A criminal investigator makes numerous observations when viewing a crime scene. After the initial observation and photographing and sketching of the scene, the investigator must test some of the observations. Stains at the scene may be from blood. A number of other substances, such as tomato juice or ketchup, can make a stain that might be confused with bloodstains. The stain might be on a colored fabric that camouflages its color. Before the investigator jumps to conclusions, tests must be performed to provide data to support the claims that the stain is indeed blood.

To make bloodstains to use in class to test for blood from a crime, press some beef or pork blood on an object to be left at the crime scene. For practice in class, prepare index cards or swatches of cloth containing bloodstains several days ahead so that the samples will be completely dry. You may also use synthetic blood from biological suppliers. An alternative is to use ketchup with a little rust or horseradish. Do not use human blood.

Before touching anything that might involve blood, put on rubber gloves. This protects yourself from anything that might be present in the blood and protects the stain from contamination. Then, use one of the following methods to test for blood.

Method 1

Animal blood possesses an enzyme that breaks down hydrogen peroxide. One by-product of this reaction reacts with reduced phenolphthalein to change the colorless solution to pink.

Prepare a reduced phenolphthalein solution. In a 1-L beaker, add 1 g of phenolphthalein, 10 g of sodium hydroxide, 5 g of zinc powder, and 250 mL of distilled water. Using a stirring hot plate, mix and heat until the solution loses its pink color. Do not boil. This process may take 2 to 3 hours. Decant the liquid into a 500-mL graduated cylinder. Add ethanol to make 300 mL of solution. Add a small amount of zinc powder to a brown bottle, and pour the phenolphthalein solution into this bottle. Label, date, and store the bottle in a refrigerator. When you are ready to conduct the lab, pour a small amount into a dropper bottle.

Using a piece of filter paper or paper towel, rub the stain suspected to be blood to collect a sample. If the stain is dry, you may moisten the paper slightly with distilled water. You will not see a visible blood stain on your filter paper.

Lay the paper out so that the spot that you rubbed is exposed. Add 1 drop of ethanol to the center of the paper. Follow this with 1 drop of reduced phenolphthalein and 1 drop of 3% hydrogen peroxide. If a pink color appears within 5 s, a positive test should be recorded. No pink color within 5 s is a negative test result and should be recorded as such.

False readings can occur. It is typical for tested filter paper to turn pink after an extended amount of time. Do not consider this in your test results. A pink color after phenolphthalein has been applied but before hydrogen peroxide has been applied normally indicates a false positive due to an oxidant being present. Rust could cause a false reading of this type.

Method 2

There are times when you may not actually see blood, but traces still remain. The heme group of hemoglobin possesses a peroxidase-like activity that catalyzes the breakdown of an oxidizing agent into free oxygen radicals. These oxygen radicals can reduce luminol reagent and produce light much like a glow stick. Because you most likely have only a small amount of heme, the glow will be faint.

Prepare the luminol solution just before testing. It is not stable and will not last more than a few hours. To make the solution, add 0.5 g luminol (5-amino-2,3 dihydro-1,4 phthalazine-dione), 25 g Na_2CO_3 , and 3.5 g $\text{NaBO}_3 \cdot 4\text{H}_2\text{O}$ to 500 mL distilled water. Pour into a spray bottle. Make the area around the test site as dark as possible. Spray a thin film of the luminol and watch for a faint glow. If your sample is small, an alternative to a darkened room is to put the sample in a box with a small peephole.

This test is extremely sensitive; 1 part blood in 100 000 000 parts can be detected. In one reported case, a room thought to be the murder scene had actually been repainted. When the room was sprayed with luminol, the blood was visible.

Safety in the Laboratory











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





1. The chemistry laboratory is a place for serious work. Do not perform activities without your teacher's permission. **Never** work alone in the laboratory. Work only when your teacher is present.
2. Study your lab activity **before** you come to the lab. If you are in doubt about any procedures, ask your teacher for help.
3. Safety goggles and a laboratory apron must be worn whenever you work in the lab. Gloves should be worn whenever you use chemicals that cause irritations or can be absorbed through the skin.
4. Contact lenses should not be worn in the lab, even if goggles are worn. Lenses can absorb vapors and are difficult to remove in an emergency.
5. Long hair should be tied back to reduce the possibility of it catching fire.
6. Avoid wearing dangling jewelry or loose, draping clothing. The loose clothing may catch fire and either the clothing or jewelry could catch on chemical apparatus.
7. Wear shoes that cover the feet at all times. Bare feet or sandals are not permitted in the lab.
8. Know the location of the fire extinguisher, safety shower, eyewash, fire blanket, and first-aid kit. Know how to use the safety equipment provided for you.
9. Report any accident, injury, incorrect procedure, or damaged equipment immediately to your teacher.
10. Handle chemicals carefully. *Check the labels of all bottles **before** removing the contents.* Read the labels three times: before you pick up the container, when the container is in your hand, and when you put the bottle back.
11. Do **not** return unused chemicals to reagent bottles.
12. Do **not** take reagent bottles to your work area unless specifically instructed to do so. Use test tubes, paper, or beakers to obtain your chemicals. Take only small amounts. It is easier to get more than to dispose of excess.
13. Do **not** insert droppers into reagent bottles. Pour a small amount of the chemical into a beaker.
14. **Never** taste any chemical substance. **Never** draw any chemicals into a pipette with your mouth. Eating, drinking, chewing gum, and smoking are prohibited in the laboratory.
15. If chemicals come into contact with your eyes or skin, flush the area immediately with large quantities of water. Immediately inform your teacher of the nature of the spill.
16. Keep combustible materials away from open flames. (Alcohol and acetone are combustible.)

17. Handle toxic and combustible gases only under the direction of your teacher. Use the fume hood when such materials are present.
18. When heating a substance in a test tube, be careful not to point the mouth of the tube at another person or yourself. Never look down the mouth of a test tube.
19. Use caution and the proper equipment when handling hot apparatus or glassware. Hot glass looks the same as cool glass.
20. Dispose of broken glass, unused chemicals, and products of reactions only as directed by your teacher.
21. Know the correct procedure for preparing acid solutions. *Always add the acid slowly to the water.*
22. Keep the balance area clean. Never weigh chemicals directly on the pan of the balance.
23. Do **not** heat graduated cylinders, burettes, or pipettes with a laboratory burner.
24. After completing an activity, clean and put away your equipment. Clean your work area. Make sure the gas and water are turned off. Wash your hands with soap and water before you leave the lab.

CHEMISTRY FORENSICS LABORATORY MANUAL

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

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

	Eye Safety Proper eye protection should be worn at all times by anyone performing or observing science activities.
	Clothing Protection This symbol appears when substances could stain or burn clothing.
	Radioactivity This symbol appears when radioactive materials are used.
	Handwashing After the lab, wash hands with soap and water before removing goggles.



The Counterfeit Coin Caper

Counterfeiting money is one of the oldest types of crime. In some ancient cultures, penalties for counterfeiting ranged from hand amputations to death sentences. In the Roman Empire, counterfeiters were burned at the stake.

Historically, counterfeiting money has been a problem in the United States. In the 1800s, each bank issued its own currency. With approximately 1600 different banks producing 7000 different types of paper money, counterfeiting money was easy to do and difficult to detect. It is estimated that by the 1860s, approximately one-third of all circulating currency was counterfeit.

To solve this problem, a national currency was adopted in 1863. Counterfeiters still were at work, and the United States Secret Service was established in 1865 to eliminate counterfeiting. Many counterfeiters are caught and prosecuted, but this crime remains a problem. The importance of detection has increased, as criminals no longer limit themselves to reproducing money, but also counterfeit such things as credit cards, identification papers, and tickets for transportation or entertainment.

Methods to detect currency counterfeiting include investigating the detail used in legal currency. For example, some of the printing on paper currency is raised. Much counterfeit currency is missing the fine detail present in

legal currency, such as detail in faces and outer borders or, in coins, even and distinct corrugated outer edges. Investigators also check for repeated serial numbers in paper currency. One common coin-counterfeiting scheme involves altering the date, or mint mark, on a coin, changing it to a date or mint location that has more value than the one on the original coin.

Detection methods also include investigating the materials used by counterfeiters. Genuine paper currency uses a certain type of paper that is illegal for use by anyone except those authorized to produce paper money. Paper used for currency contains tiny, embedded red and blue fibers. Counterfeit coins might contain alloys that differ in composition from those in official coins.

As times change and counterfeiting methods improve, so do methods of prevention and detection. You may be familiar with the new paper money that contains a hidden image, which is difficult to counterfeit, and is printed on paper that turns a certain color when marked with a special marker. Scientists also have many methods of analysis that can determine whether money is counterfeit or not. In this set of labs, you will use several methods that will help you investigate evidence and determine facts about a crime involving counterfeiting.

Scene of the Crime

The police discovered a coin counterfeiting ring and arrested several people. The detectives discovered an old warehouse where they think the coins were being made. Although no suspects were found at the scene, the detectives collected evidence for analysis. Evidence collected included metal cylinders and some powder of unknown composition, including two different white powders. After questioning Mr. Skittle, the owner of the warehouse, and

people in the neighborhood, the detectives identified four suspects. Once laboratory chemists identified the evidence, it was compared to evidence taken from each suspect, and the guilty party was identified and arrested. Your task is to analyze the samples and prepare an evidence report for the scheduled trial. This project may include fingerprint techniques described by your teacher.

What Metal Can It Be?

Problem

How can the physical properties of specific heat and density be used to identify an unknown metal?

Objectives

- **Determine** the specific heat and density of a metal.
- **Identify** an unknown metal by using specific heat and density data.

Materials

metal sample	100-mL graduated cylinder
plastic-foam cup	thermometer
lid to fit the cup, with a hole for the thermometer	laboratory balance
400-mL beaker	hot plate
250-mL beaker	tongs

Safety Precautions



- Always wear safety goggles and a lab apron.
- Use caution when handling hot water.
- Never use a thermometer as a stirrer.
- Use caution when using the hot plate.

Pre-Lab

1. What is a physical property?
2. List three physical properties.
3. Why isn't the ability to burn a physical property?
4. Describe how to find the average of three numbers.
5. Read the entire laboratory activity. Form a hypothesis about how the physical properties of a substance can be used to identify it. Record your hypothesis on page 3.

Tools of the Trade

Specific Heat To change the temperature of a substance such as water, heat must be added or removed. Some substances require little heat to cause a change in temperature. Other substances require a great deal of heat to cause the same temperature change. For example, it requires 4.184 J of heat to raise the temperature of 1 g of water one Celsius degree. Joule (J) is a unit commonly used to measure energy. It requires 0.902 J to raise the temperature of 1 g of aluminum one degree Celsius. The heat required to raise one gram of a substance one degree Celsius is called the specific heat (c_p) of the substance. The subscript p indicates that the temperature measurement is made at constant pressure.

Specific heat is a characteristic physical property of a substance. Every substance has its own value for

specific heat. Therefore, specific heat can be used to identify an unknown substance. For example, if substance A has a specific heat of $c_p = 0.920 \text{ J}/(\text{g}^\circ\text{C})$ and substance B has a specific heat of $c_p = 0.710 \text{ J}/(\text{g}^\circ\text{C})$, you can conclude that A and B are not the same substance.

The law of conservation of energy states that any heat lost by something must be gained by something else. Transfer of energy takes place between two things that are at different temperatures until the two reach the same temperature. The amount of energy transferred from or to a sample of matter can be calculated from the relationship

$$q = m \times \Delta T \times c_p,$$

where q is the quantity of heat gained or lost, m is the mass in grams, ΔT is the change in temperature, and c_p is the specific heat.

In this experiment, you will determine the specific heat of a metal. A heated sample of this metal will be placed into cool water contained in a covered plastic-foam cup. Because foam is a good insulator, heat cannot easily escape to the surroundings. Shortly after mixing, the water and the metal will be the same temperature. Therefore, the heat lost by the metal is equal to the heat gained by the water.

The specific heat of water is known, $c_{p,\text{water}} = 4.184 \text{ J}/(\text{g}^\circ\text{C})$. The temperature changes of the water and of the metal can be measured, as can the mass of

the water and the mass of the metal. Using this data, the specific heat of the metal can be calculated using the following equation.

$$m_{\text{water}} \times \Delta T_{\text{water}} \times c_{p,\text{water}} = m_{\text{metal}} \times \Delta T_{\text{metal}} \times c_{p,\text{metal}}$$

This equation can be rearranged to solve for $c_{p,\text{metal}}$:

$$c_{p,\text{metal}} = \frac{m_{\text{water}} \times \Delta T_{\text{water}} \times c_{p,\text{water}}}{m_{\text{metal}} \times \Delta T_{\text{metal}}}$$

Density An object made of cork feels lighter than a lead object of the same size. What you are actually comparing in such cases is how massive objects are compared with their size. This property is called density. Density is the ratio of mass to volume.

$$D = m/V$$

Density is a characteristic physical property of a substance. Density does not depend on the size of the sample because as the sample's mass increases, its volume increases proportionally. The ratio of mass to volume for a substance is constant at a specific temperature. Therefore, density can be used to identify a substance. For example, if substance A has a density of 0.86 g/mL and substance B also has a density of 0.86 g/mL, you can conclude that A and B may be the same substance.

Procedure

Part A: Specific Heat

1. Add 250 mL of tap water to a 400-mL beaker. Place the beaker on a hot plate and bring the water to a slow boil. While the water is heating, proceed to step 2.
2. Measure the mass of a metal sample. Record this mass in Part A of the Data and Observations section.
3. Place the metal sample in the boiling water for at least 10 minutes. Proceed to step 4 while the metal is heating.
4. Carefully measure 100.0 mL of distilled water in a graduated cylinder, and pour the water into a plastic-foam cup. Place the cup in a 250-mL beaker for support.

5. After the metal has been heating for at least 10 minutes, record the temperature of the water in the cup. Record this value as the initial temperature for water in **Data Table 1**.
6. Assuming the temperature of the metal is the same as that of the boiling water, measure the temperature of the boiling water and record it as the initial temperature of the metal.
7. Using tongs, carefully remove the metal from the boiling water. Immediately add the metal to the water in the cup. Place the lid on the cup, and put the thermometer into the cup through the hole in the lid. Gently swirl the cup and its contents. Note the temperature after it stops changing. Record this temperature as the final temperature for both the water and the metal in **Data Table 1**.
8. Repeat the experiment. If time permits, perform a third trial. Be sure you use the same metal sample for all trials.

Part B: Density

1. Record the mass of the metal sample in **Data Table 2**.
2. Add 50.0 mL of water to a 100-mL graduated cylinder. Record this initial volume in **Data Table 2**.
3. Add the metal to the 50.0 mL of water in the graduated cylinder. Measure the volume, and record this value as the final volume in **Data Table 2**.
4. Repeat steps 1–3 for two more trials.

Hypothesis

Cleanup and Disposal

1. Dry the metal samples for reuse.
2. Dry all equipment and return it to its proper place.
3. Be sure the hot plate is turned off and unplugged.

Data and Observations**Part A: Specific Heat**

Volume of water added to the cup for each trial: _____ mL

Mass of metal: _____ g

Data Table 1						
	Trial 1		Trial 2		Trial 3	
	metal	water	metal	water	metal	water
Initial temperature (°C)						
Final temperature (°C)						
Temperature change, ΔT (°C)						
Heat capacity, c_p (J/(g°C))						

Part B: Density

Data Table 2			
	Trial 1	Trial 2	Trial 3
Mass of metal (g)			
Final volume of metal + water (mL)			
Initial volume of water (mL)			
Volume of metal (mL)			
Density of metal (g/mL)			

Analyze and Conclude**Part A: Specific Heat****1. Measuring and Using Numbers**

- Calculate the changes in temperature of the water (ΔT) for each trial. Record the values in **Data Table 1**.
- Calculate the changes in temperature of the metal (ΔT_1) for each trial. Record the values in **Data Table 1**.
- Record c_p for water in **Data Table 1**.

2. Measuring and Using Numbers

- Remember that the heat gained by the water is equal to the heat lost by the metal. Use the data for ΔT , $c_{p,\text{water}}$ from **Data Table 1**, and the information in Tools of the Trade to calculate the specific heat of the metal for each trial. Record the values in **Data Table 1**.
 - Calculate your average value for the specific heat of the metal.
-

LAB A1 CHEMISTRY FORENSICS LABORATORY MANUAL

3. Drawing a Conclusion Compare the average specific heat for your unknown metal to the specific heats of the metals listed. Which metal do you believe to be the identity of your unknown?

Specific Heats of Metals	
Metal	Specific heat (J/g°C)
Aluminum	0.902
Copper	0.385
Iron	0.449
Lead	0.128
Tin	0.227
Zinc	0.388

Part B: Density

4. Measuring and Using Numbers

- a. Calculate the volume of metal for each trial by subtracting the initial volume from the final volume. Record these values in **Data Table 2**.
- b. Calculate the density of the metal for each trial. Record these values in **Data Table 2**.
- c. Calculate the average density.

5. Drawing a Conclusion Compare the average density for your unknown metal to the densities of the metals listed. Which metal do you believe to be the identity of your unknown?

Densities of Metals	
Metal	Density (g/mL)
Aluminum	2.70
Copper	8.92
Iron	7.87
Lead	11.3
Tin	7.27
Zinc	7.14

6. Error Analysis How do your answers for questions 3 and 5 compare? Explain possible causes of error.

Gathering the Evidence

Write about how the results of this lab apply to counterfeiting coins. Save the results of this lab until all labs relating to the crime are completed.

Separation of a Mixture

Problem

How can you separate a mixture of sodium chloride, sand, iron filings, copper shot, and benzoic acid and recover all five components in their dry, solid states?

Objectives

- **Design an experiment** to separate the components of a mixture.
- **Recover** the components of a mixture in their dry, solid state.

Materials

Mixture of sodium chloride, sand, iron filings, copper shot, and benzoic acid

The following materials will be available, but you may request additional materials if available.

alcohol
beakers
hot plate
filter paper
distilled water
stirring rods
funnels
ice
colander

Safety Precautions



- Always wear safety goggles and a lab apron.
- Use caution when handling hot materials.
- No open flames should be present when alcohol is being used.
- Benzoic acid is a skin irritant, slightly toxic if ingested, and is combustible.

Pre-Lab

1. Benzoic acid is a white solid that is soluble in hot water but relatively insoluble in cold water and insoluble in alcohol. List the physical properties of the other four components of the mixture listed under Materials.
2. Explain what the terms *soluble* and *insoluble* mean.
3. Read the entire laboratory activity. Form a hypothesis about how the component parts of a mixture of sodium chloride, sand, iron filings, copper shot, and benzoic acid can be separated. Record your hypothesis on page 7.

Tools of the Trade

One requirement of a hypothesis is that it be testable. Often, you follow procedure steps provided for you to perform an experiment to test a hypothesis. Other times, you may be required to design your own experiment to test your hypothesis. When you design your own experiment, it is important to remember several things. You should make a detailed list of the steps you will use. Your teacher should approve your procedure before you actually perform your experiment. Safety precautions should be noted and followed. You should be sure that the results expected from your experiment actually test the hypothesis. You will compare the experimental results to your hypothesis and note any sources of error. If necessary, revise your hypothesis and test the new one. In this laboratory activity, you will design an experiment to test the hypothesis you formed for this activity.

Procedure

1. Obtain a sample of the mixture to be separated from your teacher.
2. Considering the physical properties that you listed for each component of the mixture in the Pre-Lab, design a detailed procedure that you will use to separate and recover all five components in their dry, solid states. Include appropriate safety precautions in your procedure.
3. Prepare a list of the equipment you will need to conduct your procedure. Give your teacher a list of any additional equipment you need.
4. Have your teacher approve your procedure before beginning the lab.
5. After you have recovered all five components, show them to your teacher.

Hypothesis

Cleanup and Disposal

1. Dispose of or save the components of the mixture as instructed by your teacher.
2. Wash all equipment and return it to its proper place.

Analyze and Conclude

1. **Designing an Experiment/Identifying Variables** Prepare a written analysis of your separation procedure that includes the following:

- a. Purpose of the experiment

- b. Equipment list

- c. Flowchart diagramming your plan for separation

d. Detailed procedure in numbered steps

e. Conclusion, which you should compare to your hypothesis

2. **Error Analysis** Discuss the sources of error in your separation and recovery techniques and indicate what you would do differently to eliminate these errors.

3. **Acquiring and Analyzing Information** Discuss the following statement: “Separation techniques depend on one or more specified physical properties of the components being separated.” Include in your discussion at least five examples from this experiment.

Gathering the Evidence

Write about how the results of this lab apply to the way evidence might have been collected at the scene of the crime. Save the results of this lab until all labs relating to the crime are completed.

Analyzing and Identifying White Solids

Problem

How can the properties of certain white powders be used to identify an unknown white powder?

Objectives

- **Conduct** chemical and physical tests on a variety of white powders to determine unique sets of changes that identify each powder.
- **Identify** an unknown white powder by comparing its chemical and physical changes to those of the known powders.

Materials

24-well microplate	sodium chloride
iodine solution	unknown white solid
methanol	droppers
universal indicator	spatulas
3M HCl	toothpicks
baking soda	
sugar	
benzoic acid	
flour	

Safety Precautions



- Always wear safety goggles and a lab apron.
- Use caution when handling HCl and iodine. They can harm human tissue.
- Be sure no open flames are present in the laboratory when methanol is being used.

Pre-Lab

1. Read the entire laboratory activity.
 - a. Identify the evidence of physical changes you will observe.
 - b. Identify the evidence of chemical changes you will observe.
2. Assume you have one coarse, white solid and a different finely ground, white solid. You are given an unknown white solid that is finely ground. It is the same substance as one of the first two. Why can't you identify the solid on the basis of its appearance?
3. Form a hypothesis about how the properties of certain white powders can be used to identify an unknown white powder. Record your hypothesis on page 10.

Tools of the Trade

Chemistry is the study of matter and the changes it undergoes. These changes can be classified as either physical or chemical. The term *physical change* means that the process does not alter the chemical identity of the substance. Examples of physical changes include tearing, grinding, melting, boiling, dissolving, and crystallizing. The term *chemical change* means that the process alters the identity of the substance, thus creating one or more new substances. Chemical changes describe how a substance reacts with other substances. Examples of chemical changes include oxidation, production of a gas or precipitate, energy absorption or release, and change in color.

Procedure

1. Add a small sample of each white powder in the wells of the microplate as they are labeled in **Data Table 1**. Mark the columns, or set your microplate on the data table to keep track of which compound is in each well. Use small amounts of sample. Otherwise, you may not be able to notice changes.
2. Add 5 drops of water to each sample in the first row of wells. Stir each mixture with a clean toothpick. In **Data Table 1**, record whether the white powder is soluble (s), slightly soluble (ss), or insoluble (ins) in cold water. Record any additional observations in **Data Table 2**.
3. Add 1 drop of universal indicator to each of the wells containing your sample and water. Stir the solution and record the color of the resulting solution in the same cell of **Data Table 1** that you used in step 2.
4. Add 5 drops of HCl solution to each sample in the second row of wells. If a chemical reaction occurs, you should see gas bubbles being produced. Record a plus sign (+) for any well where you observe a positive reaction. Record a minus sign (–) for any well where no gas is produced. Although other reactions involving acids produce gases, in this lab a positive test indicates the presence of a carbonate.
5. Add 5 drops of methanol to each of the samples in the third row of wells. Stir each mixture with a clean toothpick. In **Data Table 1**, record whether the white powder is soluble (s), slightly soluble (ss), or insoluble (is) in methanol.
6. Add 5 drops of iodine solution to each sample in the last row of wells. If starch is present, the brown color of the iodine will change to dark blue or black. Record a “B” in **Data Table 1** if this color change occurs.
7. Using the results shown in **Data Table 1**, identify the unknown powder.

Hypothesis

Cleanup and Disposal

1. Dispose of the contents of the microplate and any unused solids as directed by your teacher.
2. Wash all equipment and return it to its proper place.

Data and Observations

Data Table 1						
	White Powders					
	Baking soda	Sugar	Benzoic acid	Flour	Sodium chloride	Unknown
Water + universal indicator						
HCl						
Methanol						
Iodine						

Data Table 2	
Observation	Physical or Chemical

Analyze and Conclude

- 1. Observing and Inferring** It is important that you not only record the requested information but also any other observations that might help you later. Describe physical and chemical properties that you observed in **Data Table 2**. You can add additional rows on another sheet of paper if necessary.
- 2. Drawing a Conclusion** What is your unknown? Describe the observations you used to identify your unknown powder.

- 3. Thinking Critically** If your sample accidentally got wet, how might it affect your results?

4. **Error Analysis** Why might the results not prove conclusively the identity of the unknown?

Gathering the Evidence

Write about how the results of this lab apply to the crime of the counterfeit coins.

The Final Analysis

Obtain an evidence box from your teacher. Contained in this box are a metal and a mixture of two white powders found at the crime scene. Other evidence might also be included. Use the investigative skills you learned in Labs A1–A3 to analyze the metal and the powder. When you have identified the guilty party, prepare an evidence report for the scheduled trial.



The Case of the Problem Patent

Virtually every product you use has at least one patent issued for it. The first patent on record was granted in Italy in 1421 for a barge with a hoist on it. In the 1700s, the new government of the United States considered patents to be of enough importance to mention them in Article I, Section 8 of the Constitution.

What is a patent? A patent is legal permission by the government to make, use, or sell a new product or process or an improvement in a currently patented item or process. Patent laws vary from country to country. The requirements to acquire a patent and the length of time the patent is effective vary considerably, depending on national patent laws. Patent applications can be complicated because applicants must show why a patent should be issued to them.

Patents can be issued for any item that is useful and is an advance over anything else that already has been patented. For example, the United States Patent Office has on file over 5000 patents related to elevators. They relate to a basic elevator itself and each improvement made over the years in the elevator's controls, appearance, and safety features. They might

also include improved methods of manufacturing or packaging related items. Over 1300 patents exist for compact discs and related products.

Why are patents important? The person or corporation holding a patent has control over the item or process for the length of the patent. No one else can produce or sell that exact item or use that exact process without the permission of the holder of the patent. Making and selling a product produces income. Having a patent to produce and sell an important product can produce millions of dollars in revenue.

It is not unusual for two people or groups of people to invent the same item or process at the same time. The one who acquires a patent for the item or process is the one who has permission to manufacture and sell the product or use the process, even though both inventors might have equal claim to its invention. Be aware that no crime exists in such a situation unless one inventor intentionally tries to take credit for someone else's work. In that case, a problem similar to the one described in the scenario below exists.

Scene of the Crime

Apex Pharmaceuticals is working on a drug to reduce the effects of the flu. Three different research groups in the company are working on the same problem. A number of drugs have been tested, and one drug was successful. All the groups reported turning in the sample that proved to be successful. Your forensics consulting company has been called in to determine which research group created the drug that will now be patented and sold.

When the three research groups were first organized, the supervising lab manager gave each group a different blue dye to use in making their compound. Your forensic team's assignment is to analyze the blue dyes and determine which dye was actually used to make the successful drug. You will complete all your analysis and write a summary report to the president of Apex Pharmaceuticals identifying the research group that created the drug.

Using Paper Chromatography to Separate a Mixture

Problem

How can paper chromatography be used to separate components of certain mixtures?

Objectives

- **Relate** polarity to chromatography.
- **Determine** how paper chromatography can separate components of a mixture.
- **Compare and contrast** the results of using paper chromatography.

Materials

concentrated solutions of A, B, C, and unknown
250-mL beaker
capillary tubes
filter paper
scissors
metric ruler

Safety Precautions



- Always wear safety goggles and a lab apron.
- Use caution when cutting.

Pre-Lab

1. What is meant by bond polarity?
2. How can a molecule contain polar bonds yet be a nonpolar molecule?
3. What is meant by “like dissolves like”?
4. If a substance is not water soluble, what might you use as a solvent? Explain why you would choose this solvent.
5. Read the entire laboratory activity. Form a hypothesis about whether the solutions used are mixtures or not. Record your hypothesis on page 15.

Tools of the Trade

One way to determine whether certain materials are pure substances or mixtures is by the use of paper chromatography. In this technique, the material is dissolved in a known solvent. A drop of the solution is placed on a piece of filter paper (**Figure A**). The filter paper is then dipped like a wick into a solvent (**Figure B**). The solvent moves up the filter paper by capillary action, which is based on the attraction of the solvent for the filter paper. When the solvent reaches the drop on the paper, each component of the material in the drop dissolves and begins to move along the filter paper.

The dissolved substances move along the filter paper at different rates because the attraction of the solvent for each component contained in the drop differs. If the solvent is polar, as water is, then the more polar components will be dissolved first and move up the filter paper at a faster rate (**Figure C**). The less polar and nonpolar components will be less attracted to the solvent and move up the filter paper at a slower rate. If the solvent is nonpolar, then the less polar and nonpolar components will be dissolved first and move up the filter paper at a faster rate. Because they move at different rates, each component will appear as a separate spot of color on the filter paper.

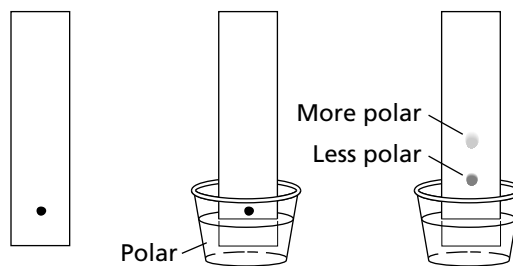


Figure A

Figure B

Figure C

In this experiment, water will be used as the solvent. Water (**Figure D**) is a polar molecule. Because of the large difference in the electronegativities of hydrogen and oxygen, the H–O bonds in water are polar. The molecule itself is polar because the two pairs of unshared electrons on the oxygen atom make the molecule asymmetrical. Therefore, the charges are unbalanced.

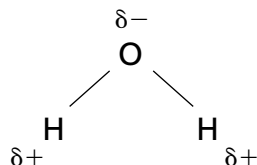


Figure D

Procedure

1. Referring to **Figure E**, use scissors to cut a 1-cm strip from the outer edge of a piece of filter paper to its center. Do not cut along the center solid line.

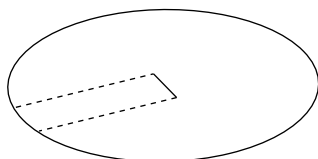


Figure E

2. Fold the strip along the solid, uncut line so that the strip is perpendicular to the surface of the filter paper, as shown in **Figure F**.

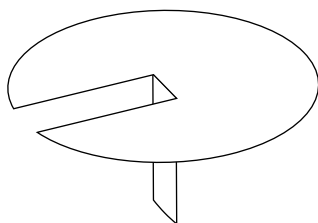


Figure F

3. Using a separate capillary tube for each substance, evenly space around the center of the prepared piece of filter paper a small spot of solutions A, B, C, and unknown as shown in **Figure G**. Be sure each dot is an equal distance from the strip.

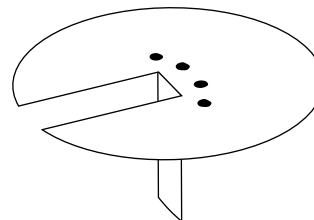


Figure G

4. Place the filter paper over the top of a 250-mL beaker that contains enough water to cover the bottom of the cut strip of filter paper to a length of 1 cm.
5. The water will move up the strip and across the filter paper by capillary action. This process is rather slow. Allow the water to move to approximately 1 cm from the outer edge of the filter paper.
6. Observe the filter paper. Sketch the results in Data and Observations.

Hypothesis

Cleanup and Disposal

1. Dispose of the filter paper and solutions as directed by your teacher.
2. Wash all equipment and return it to its proper place.

Data and Observations

Sketch and label your chromatography separation below.

Analyze and Conclude

1. Drawing a Conclusion Which solution matches the unknown solution? How did you arrive at this conclusion?

2. Acquiring and Analyzing Information State whether the solute in each solution is a mixture or a pure substance. Explain your reasoning.

3. Error Analysis What might be sources of error in this experiment?

Gathering the Evidence

Write about how the results of this lab apply to the identification of the blue dyes used by the research groups. Save the results of this lab until all labs relating to the crime are completed.

Conductivity

Problem

How can conductivity be used to identify an unknown substance?

Objectives

- **Determine** the conductivity of solutions.
- **Compare** conductivities to identify an unknown solution.

Materials

solutions of substances A, B, C, and unknown	50-mL graduated cylinder
CBL unit	large test tubes (5)
TI graphing calculator	distilled water
link cable	wash bottle
conductivity probe	marker or grease pencil
adapter cable	test-tube rack

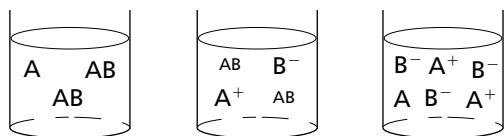
Safety Precautions



- Always wear safety goggles and a lab apron.
- Treat unknown materials with caution.

Pre-Lab

1. Label each of the diagrams below as a strong electrolyte, a weak electrolyte, or a nonelectrolyte.



2. As more ions are added to a solution, what happens to the conductivity of the solution?
3. Read the entire laboratory activity. Form a hypothesis about how electrical conductivity relates to the strength of electrolytes when comparing solutions of the same concentration. Record your hypothesis on page 18.

Tools of the Trade

Substances are classified as electrolytes or nonelectrolytes according to whether they yield molecules or ions when they dissolve in water. Molecules are neutral groups of atoms held together by covalent bonds. Ions are atoms or groups of bonded atoms that have a positive or negative charge. When an ionic compound dissolves, the positive and negative ions separate from each other and are surrounded by water molecules. Because they are charged, these

solute ions can carry an electric current through the solution. A substance that conducts an electric current when dissolved in water is called an electrolyte. All soluble ionic compounds are electrolytes.

When a strong electrolyte is dissolved in water, almost all of the solute exists as separate solute ions. When a weak electrolyte dissolves in water, only a small fraction of the solute exists as ions. Most of the solute remains as molecules. Such solutions conduct electricity but not as well as solutions of strong electrolytes. Acetic acid (HC₂H₃O₂) is an example of a weak electrolyte.

Other substances do not separate into ions at all when they dissolve in water but remain as molecules. A solution that contains only solute molecules does not conduct an electric current because it does not contain charged particles. These substances are called nonelectrolytes. For example, sucrose (table sugar) is a nonelectrolyte. It dissolves in water but does not form ions.

Procedure

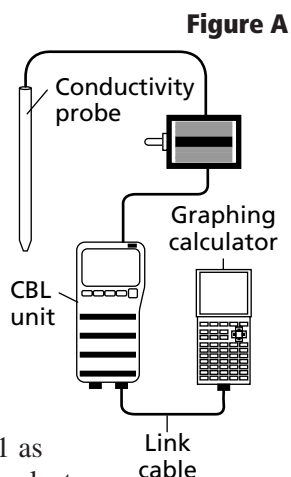
Part A: Preparing the CBL System

1. Plug the conductivity probe into the adapter cable in channel 1 of the CBL unit, as shown in **Figure A**.
2. Connect the CBL unit to the graphing calculator with a link cable.

- Turn on the CBL unit and the graphing calculator. Choose ChemBio from the list of programs. Press ENTER on the calculator twice.

- Choose SET UP PROBES from the MAIN MENU. Enter 1 as the number of probes. On the SELECT PROBES menu, choose CONDUCTIVITY. Enter 1 as the channel number. Then select USE STORED from the CALIBRATION menu and select H 1-2000 MICS from the CONDUCTIVITY menu. Make sure the switch on the box is set to the same value.

- From the MAIN MENU, select COLLECT DATA. On the DATA COLLECTION menu, select TRIGGER PROMPT. Allow the unit to warm up and then press ENTER.



- Rinse the probe with distilled water. Then place it in the test tube of solution A. Record the conductivity reading in **Data Table 1**.
- Rinse the conductivity probe with distilled water, and repeat step 4 for the other solutions and the distilled water.

Hypothesis

Cleanup and Disposal

- Dispose of the solutions as directed by your teacher.
- Wash and return all equipment.

Data and Observations

Data Table 1	
Conductivity Data	
Test tube	Conductivity
A	
B	
C	
U	
D	

Part B: Collecting Data

- Label five test tubes A, B, C, U, and D, respectively. Place the test tubes in the test-tube rack.
- Measure 20 mL of solution A and pour it into the test tube labeled A. Rinse the graduated cylinder with distilled water and repeat this step for solutions B and C, the unknown solution (U), and distilled water (D).

Analyze and Conclude

- Collecting and Interpreting Data** Sequence solutions A, B, and C and distilled water from weakest to strongest electrolyte. How did you determine your sequence?

- Drawing a Conclusion** Which solution contained the same solute as the unknown solution? Explain.

Gathering the Evidence

Write about how the results of this lab apply to the identification of the blue dyes used by the research groups. Save the results of this lab until all labs relating to the crime are completed.

pH

Problem

How can pH be used to identify an unknown solution?

Objectives

- **Measure** the pH of solutions.
- **Compare** the pH values of several solutions to identify an unknown solution.

Materials

solutions of substances A, B, C, and unknown	50-mL graduated cylinder
CBL unit	large test tubes (5)
pH probe	distilled water
TI graphing calculator	wash bottles
link cable	test-tube rack
AC adapter	marker or grease pencil

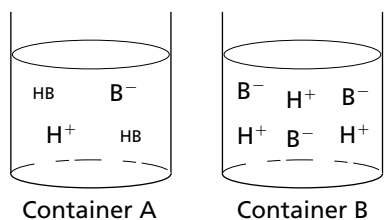
Safety Precautions



- Always wear safety goggles and a lab apron.
- Do not allow solutions to come in contact with skin.
- Immediately report any spills to your teacher.

Pre-Lab

1. What is the pH of a solution with a $[\text{H}_3\text{O}^+]$ of $1.0 \times 10^{-10}M$? Is the solution acidic or basic?
2. What is the pH of a solution with a $[\text{H}_3\text{O}^+]$ of $5.0 \times 10^{-6}M$? Is the solution acidic or basic?
3. Calculate the $[\text{H}_3\text{O}^+]$ for a solution with a pH of 3.70. Is the solution acidic or basic?
4. Which container below contains the more acidic solution? Which container contains the solution with the greater pH? Explain.



5. Read the entire laboratory activity. Form a hypothesis about the relationship between pH and the strength of an acid or a base when comparing solutions of equal molar concentration. Record your hypothesis on page 20.

Tools of the Trade

When hydrogen ions (H^+) are present in a water solution, they combine with water molecules to form hydronium ions (H_3O^+). Hydronium ions and hydroxide ions (OH^-) are always present in a water solution. The product of the concentrations of these two ions in a water solution is equal to 1.0×10^{-14} . For example, if the hydronium ion concentration ($[\text{H}_3\text{O}^+]$) is $1.0 \times 10^{-5}M$, the hydroxide ion concentration ($[\text{OH}^-]$) equals $1.0 \times 10^{-9}M$.

In a neutral solution, the concentrations of the hydronium ion and the hydroxide ion are equal. Thus, in a neutral solution, $[\text{H}_3\text{O}^+] = [\text{OH}^-] = 1 \times 10^{-7}M$. But many solutions are not neutral. An acidic solution contains more H_3O^+ ions than OH^- ions, and $[\text{H}_3\text{O}^+]$ is greater than $1 \times 10^{-7}M$. A basic solution contains more OH^- ions than H_3O^+ ions, and $[\text{OH}^-]$ is greater than $1 \times 10^{-7}M$.

The pH scale is a convenient way of expressing the hydronium ion concentration. The pH of a solution is the negative logarithm of the hydronium ion concentration. Mathematically, $\text{pH} = -\log [\text{H}_3\text{O}^+]$. For example, a solution with a hydronium ion concentration of 1.0×10^{-3} has a pH of 3. Neutral solutions have a pH of 7. For acidic solutions, the pH is less than 7, and for basic solutions, pH is greater than 7.

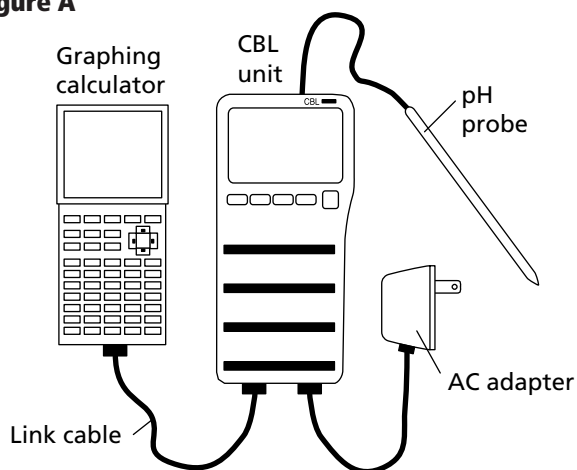
pH is measured by means of indicator paper or electronically by either a CBL pH probe or a pH meter. In this activity, you will measure the pH of the same solutions you used in Lab B2 and use your data to identify the unknown.

Procedure

Part A: Preparing the CBL System

1. Connect the CBL unit to the pH probe. Make sure the pH probe is in channel 1. Then, using a link cable, connect the CBL to the graphing calculator, as illustrated in **Figure A**.

Figure A



2. Turn on the CBL unit and the graphing calculator. Press the PRGM button on the calculator and choose ChemBio from the list of programs. Press ENTER on the calculator twice.
3. Choose SET UP PROBES from the MAIN MENU. Enter 1 as the number of probes. On the SELECT PROBES menu, choose pH. Enter 1 as the channel number. Select USE STORED from the CALIBRATION MENU.

Part B: Collecting Data

1. Label five test tubes A, B, C, U, and D, respectively. Place the test tubes in the test-tube rack.
2. Measure 20 mL of solution A and pour it into the test tube labeled A. Rinse the graduated cylinder with distilled water and repeat this step for solutions B and C, the unknown solution (U), and distilled water (D).

3. From the MAIN MENU on the calculator, select COLLECT DATA. On the DATA COLLECTION MENU, select TRIGGER PROMPT. Follow the directions on the calculator to collect data.
4. Rinse the probe with distilled water. Then place the pH probe in the test tube of solution A. When the pH meter is stable, press TRIGGER on the CBL unit.
5. The calculator will read VALUE? Enter 0. This will give the pH value. Record the pH reading in **Data Table 1**.
6. Repeat steps 4 and 5 for the other solutions and distilled water. From the DATA COLLECTION MENU, select MORE DATA and record the new pH readings.

Hypothesis

Cleanup and Disposal

1. Dispose of the solutions as directed by your teacher.
2. Wash all equipment and return it to its proper place.

Data and Observations

Data Table 1	
pH Data	
Test tube	pH
A	
B	
C	
U	
D	

Analyze and Conclude

1. Collecting and Interpreting Data Based on your results, sequence solutions A, B, and C and distilled water from least to most acidic. Explain how you determined your sequence.

2. Drawing a Conclusion Which solution contained the same solute as the unknown solution? Explain.

3. Measuring and Using Numbers Calculate the $[H_3O^+]$ for solutions A, B, and C.

Gathering the Evidence

Write about how the results of this lab apply to the identification of the blue dyes used by the research groups. Save the results of this lab until all labs relating to the crime are completed.

Effects of Acids and Bases on the Color of a Dye

Problem

How can the effects of acids and bases on the color of a dye be used to identify it?

Objectives

- **Determine** the effects of adding acids and bases to known solutions containing dyes.
- **Compare and contrast** the effects of adding acids and bases to several solutions containing dyes to identify an unknown solution.

Materials

solutions of substances A, B, C, and unknown
 1M NaOH
 1M HCl
 large test tubes (8)

test-tube rack
 marker or grease pencil
 pipettes or droppers (2)

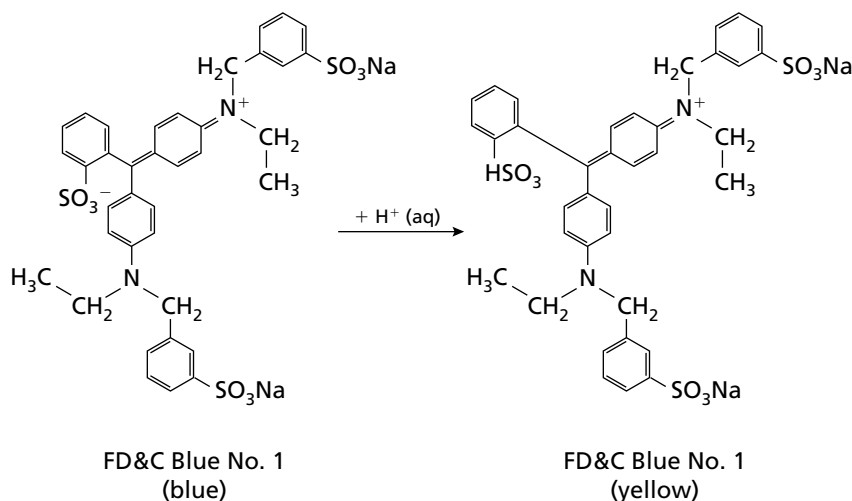
Safety Precautions



- Always wear safety goggles and a lab apron.
- Do not allow solutions to come in contact with skin.
- Immediately report any spills to your teacher.

Pre-Lab

1. Indigo is the dye used to give blue jeans their color. Describe a condition in which indigo is not a stable color.
2. Read the section in your text regarding acid/base indicators. What is the range in pH units for most indicators?
3. The diagram below shows a molecule of blue dye and one of yellow dye. Explain the difference in the two molecules.
4. Read the entire laboratory activity. Form a hypothesis about how adding an acid to a dye affects its color. Record your hypothesis on page 23.



Tools of the Trade

Dyes are used to color materials. Some dyes made from natural ingredients have been used for thousands of years. Indigo was used in Asia as early as 3500 B.C. Many other dyes were derived from plants and animals, and some are still in use today.

Not all dyes are made from plants or animals. Some dyes are made from minerals, and some are synthetic compounds. As science continues to improve the synthesis of dyes, more and more of them are synthetic and fewer are made from natural materials. Dyes commonly color fabrics and other textiles, but dyes have many other uses, such as coloring hair or tracing blood flow in certain medical procedures.

In order for a dye to have practical uses, it must be stable under a variety of conditions, such as exposure to sunlight or high temperatures. Dyes also must be stable when acids and bases are added to them. In this investigation, you will determine if the addition of an acid or a base affects the color stability of the dyes provided to the research teams.

Procedure

1. Add solutions A, B, C, and Unknown (U) to the appropriately labeled test tubes so that each test tube is one-third full. Place the test tubes in the test-tube holder.
2. Add 10 drops of 1M HCl (an acid) to each test tube. Record in **Data Table 1** any color change that is observed.
3. Repeat steps 1 and 2 using 1M NaOH (a base).

Hypothesis

Cleanup and Disposal

1. Dispose of solutions as directed by your teacher.
2. Wash all equipment and return it to its proper place.

Data and Observations

Data Table 1		
Solution	Color change with HCl	Color change with NaOH
A	blue →	blue →
B	blue →	blue →
C	blue →	blue →
U	blue →	blue →

Analyze and Conclude

1. **Thinking Critically** Can a general statement be made about what happens when an acid is added to a dye? A base? Explain your answers.

- 2. Drawing a Conclusion** Which solution contains the same dye as the unknown solution? Explain.

Gathering the Evidence

Write about how the results of this lab apply to the identification of the blue dyes used by the research groups.

The Final Analysis

Compare your results from Labs B1–B4 to the table your teacher will provide for you. Are you able to identify the unknown solution by the analysis of the evidence? Use your data and any other evidence you have to come to a group consensus about the identity of the successful research team. Write a summary report to the president of Apex Pharmaceuticals identifying the research group that created the drug.



The Case of the Fallen Walkway

Pedestrian Bridge Collapsed at Motor Speedway headlines an actual newspaper article in which 100 people were reported injured when a five-year-old steel-reinforced concrete walkway collapsed after a NASCAR race. Structural engineers and a team of forensic investigators were called to the scene to investigate the cause of the accident. They found that the grout, a paste used to fill the holes made where the metal supports are bolted, was contaminated with calcium chloride. You do not often think about forensics investigators being involved in this type of case. However, this is not an unusual situation. The investigative team must know both chemistry and architecture. The first task is to decide the cause of the collapse, then to trace the source of the problem. After all the evidence is collected, it is up to the courts to decide whether it was an accident, neglect on the builder's part, or sabotage.

The following investigation involves a similar situation. The failure of a structure will be examined to determine what caused its collapse. You will perform chemical tests related to the fall of a walkway and draw conclusions from the results. This evidence will then be used to conclude whether a crime was committed. If it was, evidence will point toward the person or persons responsible.

Scene of the Crime

A suspended walkway connecting two buildings at East Myrtle Mall collapsed. The steel wire rope broke away from the steel steps leading to the bridge. Sabotage is suspected. A construction worker is currently under investigation. A metal file was found in his toolbox, as well as other evidence not yet released by the police.

Bridge specifications as reported by Smithe Construction Company, the company that constructed the bridge, are as follows:

- The bridge frame and support are iron painted with enamel.
- The walkway is made of 1-in. steel wire rope with a floor made of 2 × 6 in. oak planks.

- The connections from wire to frame are made of galvanized iron nuts, washers, and bolts.
- Cathodic protection was provided by a magnesium bar connected to the steel wire and buried in the ground near the base of the frame.

The construction worker has hired your team to prove that he is innocent.

Prior to conducting the analysis, you will conduct experiments with known materials to give you practice and to help you better understand the expected results. When you are ready for the challenge, ask your teacher for the forensic samples. You will be given materials collected from the scene for analysis.

Oxidation and Reduction

Problem

What is oxidized and what is reduced when two metals and solutions of their ions are in contact with each other?

Objectives

- **Measure** the voltage produced by a chemical process.
- **Determine** the anode and cathode in a redox process.
- **Determine** the oxidation and reduction agents in a process.

Materials

1M copper(II) nitrate ($\text{Cu}(\text{NO}_3)_2$)	zinc metal
1M zinc nitrate ($\text{Zn}(\text{NO}_3)_2$)	voltmeter
1M potassium nitrate (KNO_3)	sandpaper
copper metal	filter paper
	plastic surface
	dropper

Safety Precautions



- Always wear safety goggles and a lab apron.
- Copper(II) nitrate is irritating to human tissue.

Pre-Lab

1. What is oxidation? What is reduction?
2. Define *oxidizing agent* and *reducing agent*.
3. Read the entire laboratory activity. Form a hypothesis about what is oxidized and what is reduced. Record your hypothesis on page 27.
4. If you place a piece of iron in water and rust (Fe_2O_3) is formed, what is oxidized and what is reduced?
5. Write equations for half-reactions for the reaction in question 4.

Tools of the Trade

You will use a voltmeter in this lab. It measures the voltage of the current in a circuit. On a voltmeter, the black terminal is connected to the negative electrode and is where electrons leave the electrochemical cell and enter the meter. If the voltage on the meter reads a positive value, the black electrode is the anode. At the anode, oxidation occurs and electrons are released to the external circuit. The red terminal is connected to the positive electrode, called the cathode, and it is where reduction occurs. One way to remember this information for an electrochemical cell is **reduce red cats**. This means that reduction occurs at the cathode, which is the red lead.

Procedure

1. Place a small rectangular piece of filter paper on a plastic surface.
2. Use the sandpaper to clean any oxides or other impurities from the surfaces of a piece of copper metal, a piece of zinc metal, and the terminals of the voltmeter.
3. Place the pieces of copper and zinc metal about 3 cm apart on the paper.
4. Place 2 drops of the $\text{Cu}(\text{NO}_3)_2$ solution on the paper just at the edge of the copper metal so that the solution soaks under the metal.
5. Place 2 drops of the $\text{Zn}(\text{NO}_3)_2$ solution on the paper so that it soaks under the zinc metal.
6. Place 2 drops of KNO_3 on the dry paper in between the wet circles so that it contacts both solutions.
7. Touch the red probe of a voltmeter to the copper and the black probe to the zinc metal. Record the voltage in **Data Table 1**.
8. Reverse the probes. Record the voltage in **Data Table 1**.

Hypothesis

Cleanup and Disposal

1. Wash and dry the metal strips for reuse.
2. Dispose of the filter paper as directed by your teacher.
3. Wash all equipment and return it to its proper place.

4. Wash your hands thoroughly with soap and water when finished.

Data and Observations

Data Table 1		
Voltages		
Red probe	Black probe	Voltage reading
Cu	Zn	
Zn	Cu	

Analyze and Conclude

The setup that gives a positive voltage should be used for your analysis.

1. **Thinking Critically** What was the purpose of the potassium nitrate solution?

2. **Collecting and Interpreting Data** Which metal was oxidized? Which ion was reduced?

3. **Applying Concepts** Write half-reactions for the system.

4. **Thinking Critically** Which metal is actually decreasing in mass?

5. **Predicting** The voltmeter records the flow of electrons. It does not supply any energy. The energy was actually produced by the potential energy difference between the two metal/metal ion cells. With this in mind, explain what will happen to the mass of an iron nail placed in water.

6. **Hypothesizing** What effect might such a reaction have on a structure, such as a bridge?

7. **Error Analysis** Provide an explanation as to why the voltmeter might not register a current.

Gathering the Evidence

Write about how the results of this lab apply to the construction of the fallen walkway. Save the results of this lab until all labs relating to the crime are completed.

Sources and Causes of Corrosion

Problem

What ions that promote redox reactions involving metals might be present in or around the walkway?

Objectives

- **Experiment** to find out what common contaminants could cause problems in a metal structure.
- **Analyze** the effect contaminating ions will have on the corrosion of iron.
- **Determine** how effective galvanizing is at protecting iron from corrosion.

Materials

25-well microplate	marker or grease
0.1M copper(II) chloride (CuCl ₂)	pencil
0.1M calcium chloride (CaCl ₂)	plastic cups (12)
0.1M sodium chloride (NaCl)	distilled water
1M potassium ferrocyanide (K ₄ [Fe(CN) ₆])	metal file
100-mL graduated cylinder	galvanized iron nails
	iron nails
	droppers

Safety Precautions



- Always wear safety goggles and a lab apron.
- CuCl₂ is highly toxic if ingested.
- Keep K₄[Fe(CN)₆] away from heat and concentrated acids.

Pre-Lab

1. Read the entire laboratory activity. Form a hypothesis about which ions (Cu²⁺, Ca²⁺, Na⁺) would be reduced by iron and which ions would be reduced by zinc. Record your hypothesis on page 30.
2. If you place a piece of zinc in a copper(II) nitrate solution and copper metal appears, what has been oxidized? What has been reduced?
3. Write equations for the half-reactions involved in the reaction in question 2.
4. The ion concentrations used in this lab are far higher than would be found in nature. Why is it necessary to use higher concentrations than would be found near the actual site of the bridge collapse?
5. Write a balanced chemical equation for the double-replacement reaction that occurs when the following solutions are mixed. A precipitate is formed in each.
 - a. Iron(III) chloride (FeCl₃) and potassium ferrocyanide (K₄[Fe(CN)₆]) (Hint: The precipitate formed is Fe₄[Fe(CN)₆]₃.)
 - b. Zinc chloride (ZnCl₂) and potassium ferrocyanide (K₄[Fe(CN)₆]) (Hint: The precipitate formed is Zn₃K₂[Fe(CN)₆]₂.)

Tools of the Trade

Iron is the most common metal used in construction. As you already know, iron reacts with oxygen in a moist environment to produce iron oxides, and the iron loses mass.

To help prevent this reaction, zinc, which is a more active metal, is used as a coating on the iron. This process is called **galvanizing**. In hardware stores, you will find a wide variety of galvanized products, including buckets and nails. Instead of iron being oxidized, the zinc is oxidized, and the iron lasts longer.

Both of these reactions are electrochemical, and electrons are transferred. Ions must be present in the water to allow free flow of the electrons. In this activity, you will test common ions found in or near structures that could allow such a redox reaction to occur.

Procedure

1. Label three plastic cups CuCl_2 . Repeat for each of CaCl_2 , NaCl , and *Water*.
2. Pour 50 mL of a 0.1M CuCl_2 solution into each of the three labeled plastic cups. Copper ions might be present at the site of the bridge because copper fittings might be used.
3. Pour 50 mL of a 0.1M NaCl solution into each of three labeled plastic cups. Sodium ions might be present at the site of the bridge because salt (NaCl) is often used to melt ice on bridges and other structures.
4. Pour 50 mL of a 0.1M CaCl_2 solution into each of three labeled plastic cups. Calcium ions might be present at the site of the bridge because calcium chloride is a common deicer, and calcium ions are always present if concrete is used.
5. Pour 50 mL of distilled water into each of three labeled cups as your control.
6. Using a file, make several deep scratch marks on four galvanized nails.
7. Divide the cups containing the liquids into three sets. Each set should contain one cup of each solution and one cup of water.
8. Place an iron nail in each cup in one set of solutions, a galvanized nail in the second set of cups, and the filed galvanized nail in the third set.
9. Observe the nails and solutions after 10 minutes. Sketch your observations in the Data and Observations section.
10. Place a 24-well microplate on a sheet of white paper. Label the top three rows of cells *Iron*, *Galvanized*, and *Filed galvanized*, respectively.

Label the first four columns CuCl_2 , CaCl_2 , NaCl , and *Water*. You will use this setup to test each solution for ions that have come from a nail.

11. Place 20 drops of each solution from the cups in the appropriate well of the microplate. To each well, add 5 drops of 1M potassium ferrocyanide ($\text{K}_4[\text{Fe}(\text{CN})_6]$) solution. A blue precipitate indicates the presence of the Fe^{3+} ion. A white precipitate indicates the presence of the Zn^{2+} ion. Record your results in **Data Table 1**. Use a plus sign (+) if some precipitate forms, two plus signs (++) if a lot of precipitate forms, and a minus sign (–) if no precipitate forms.
12. Make observations of the solutions in the cups once a week for three more weeks. You may need to add water as it evaporates. When you make the observations, test for the presence of iron and zinc ions. Record all results in the appropriate data tables.

Hypothesis

Cleanup and Disposal

1. Dispose of the solutions and nails as directed by your teacher.
2. Wash all equipment and return it to its proper place.

Data and Observations

Data Table 1				
Data Table of Ion Tests—After 10 min				
	CuCl ₂	CaCl ₂	NaCl	Water
Test for Fe ³⁺				
Iron				
Galvanized				
Filed Galvanized				
Test for Zn ²⁺				
Iron				
Galvanized				
Filed Galvanized				

Data Table 2				
Data Table of Ion Tests—After 1 week				
	CuCl ₂	CaCl ₂	NaCl	Water
Test for Fe ³⁺				
Iron				
Galvanized				
Filed Galvanized				
Test for Zn ²⁺				
Iron				
Galvanized				
Filed Galvanized				

Data Table 3				
Data Table of Ion Tests—After 2 weeks				
	CuCl ₂	CaCl ₂	NaCl	Water
Test for Fe ³⁺				
Iron				
Galvanized				
Filed Galvanized				
Test for Zn ²⁺				
Iron				
Galvanized				
Filed Galvanized				

Data Table 4				
Data Table of Ion Tests—After 3 weeks				
	CuCl ₂	CaCl ₂	NaCl	Water
Test for Fe ³⁺				
Iron				
Galvanized				
Filed Galvanized				
Test for Zn ²⁺				
Iron				
Galvanized				
Filed Galvanized				

1. Sketch each cup and record your observations.
After 10 minutes:

After week 1:

After week 2:

After week 3:

Analyze and Conclude

- 1. Observing and Inferring** Did any reactions occur when the nails were added to the solutions? If so, what observations indicated that a reaction took place?

- 2. Thinking Critically** Write a balanced chemical equation for any reaction described in question 1.

- 3. Collecting and Interpreting Data** Which cup produced a positive test for Fe^{3+} first? Why do you think this occurred first?

- 4. Thinking Critically** Why do you think you tested for both zinc and iron ions?

- 5. Error Analysis** Explain why the filed galvanized nail might not have produced any iron ions after the 3-week period.

Gathering the Evidence

Write about how the results of this lab apply to the construction of the fallen walkway. Save the results of this lab until all labs relating to the crime are completed.

Identifying Sacrificial Metals

Problem

Which metals will react with corroding agents to prolong the life of an iron structure?

Objectives

- **Compare and contrast** the effects of water on zinc and iron.
- **Determine** which metals will protect iron from corrosion.

Materials

agar	galvanized nails
1M potassium ferrocyanide ($K_4[Fe(CN)_6]$)	100-mL graduated cylinder
phenolphthalein solution	400-mL beaker
iron nails	petri dishes
magnesium ribbon	stirring hot plate
copper wire	magnetic stirrer
	Celsius thermometer
	distilled water

Safety Precautions



- Always wear safety goggles and a lab apron.
- Use caution when handling hot materials.

Pre-Lab

1. Read the entire laboratory activity. Study the activity series on page 35. Form a hypothesis about which metals might protect iron from corrosion. Record your hypothesis in the next column.
2. Why are some metals that are more active than iron not practical for use in construction?
3. From your knowledge of other uses of the word *sacrificial*, what do you think a sacrificial metal might do?
4. Phenolphthalein solution turns pink in what type of solution?
2. Heat the water to about 80°C. Gradually add the agar, while stirring.
3. When the agar is completely dissolved, add 10 mL potassium ferrocyanide solution and 5 drops of phenolphthalein solution. Stir well to mix. Then pour the agar into three petri dishes.
4. In each dish, place an iron nail. In addition, in the first dish, place an iron nail wrapped in magnesium ribbon; in the second, an iron nail wrapped with copper wire; in the third, a galvanized nail.
5. Observe the petri dishes for the next 3 days. Record any observations in **Data Table 1**.

Tools of the Trade

When iron is used in construction, a sacrificial metal is often included to prolong the life of the structure. In the previous lab, we discussed the role of galvanizing iron with zinc. Zinc acted as a sacrificial metal, reacting with corroding agents more readily than iron reacts with them. In addition to coating iron with another metal, another strategy is to place a bar composed of a more active metal in the ground near the structure and connect it by a wire to the metal structure.

Procedure

1. Measure and pour 200 mL of distilled water into a beaker. Place the beaker on a stirring hot plate, and place a magnetic stir bar in the beaker.

Hypothesis

Cleanup and Disposal

1. Dispose of the agar and metals as directed by your teacher.
2. Wash all equipment and return it to its proper place.

Data and Observations

Data Table 1			
Day	Dish	Observations	Conclusions
1	1		
	2		
	3		
2	1		
	2		
	3		
3	1		
	2		
	3		
4	1		
	2		
	3		

LAB C3 CHEMISTRY FORENSICS LABORATORY MANUAL

Analyze and Conclude

- 1. Drawing a Conclusion** As you learned in Lab C2, when iron or zinc is oxidized and moves into solution, a reaction with the $K_4[Fe(CN)_6]$ produces a color change. A blue color indicates the presence of Fe^{3+} ions, and a white color indicates the presence of Zn^{2+} ions. From this information and from what you know about the behavior of phenolphthalein, what conclusions can you draw from your observations? Record these conclusions in **Data Table 1**.
- 2. Thinking Critically** Active metals, such as magnesium, produce a hydroxide and hydrogen when they react with water. Write a balanced chemical equation for the reaction of magnesium with water. What effect would such a reaction have on phenolphthalein?

- 3. Acquiring and Analyzing Information** Look closely at the activity series of metals. What other metals could act as sacrificial metals and be used to protect iron?

- 4. Error Analysis** Why might results be erroneous if tap water was used instead of distilled water?

Activity Series of Metals

↑	Li Rb K Ba Sr Ca Na Mg Al Mn Zn Cr Fe	} react with water and acids to displace hydrogen
	[WATER]	
	Cd Co Ni Sn Pb	} react with acids to displace hydrogen
	[H ₂]	
	Sb Bi Cu Hg Ag Pt Au	} react with oxygen to form oxides

- Any metal higher in the activity series will displace another metal in a single-replacement reaction.
- Metals above water may react with water.

Gathering the Evidence

Write about how the results of this lab apply to the construction of the fallen walkway.

The Final Analysis

Obtain an evidence box from your teacher. Use the skills learned in Labs C1–C3 to investigate the evidence and determine whether the construction worker was guilty of sabotage or not. Prepare a report of your findings and the evidence supporting these findings for a court presentation.

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