Mystery of the Hindenburg Disaster: Properties of Matter

Learning Experience 1

Prologue

On May 6, 1937, at a Lakehurst, New Jersey, airfield, the passenger airship Hindenburg caught fire and crashed (see Figure 1.1). One third of the passengers and crew died. For years scientists and aviation specialists investigated the disaster to find its cause. They concluded that an explosion of hydrogen gas that was used to lift the airship started the fire. This conclusion was based on the highly flammable nature of hydrogen.

Figure 1.1: *The Hindenburg was used for air travel in the 1930s. Its crash killed 36 people.*

Recently, however, investigators have taken a fresh look at the crash of the *dirigible* (a balloon that has engines to control its horizontal movement). They now believe that the properties of other components of the Hindenburg might have caused the disaster. Their conclusions differ from those of the original investigation.

In this first learning experience, you will investigate the properties of some of the materials used in building the Hindenburg. Using what you learn about these properties and other data related to the event, you will propose your own solution to this mystery. This first learning experience will introduce you to many of the concepts that you will be exploring in this semester of chemistry.

Setting the Context

Investigations in science are a lot like detective work. Trying to understand a phenomenon requires gathering evidence; identifying which of the data are relevant and correct; and putting together observations, evidence, and the previous knowledge and knowledge gained by other investigators to reach a theory or conclusion. A valid theory about how or why something happens is one that can be tested and then used to make predictions.

Detectives also use understandings about scientific principles and methods to solve a mystery. One kind of investigator who uses both scientific principles and scientific methods is a fire investigator. A fire investigator's job is to determine the origin of the fire, where the fire started, and the cause of the fire. If it is determined that a fire was deliberately set, an arson investigation starts.

Brainstorming

Discuss the following with your partner and be prepared to share your ideas with the class.

Imagine you are a fire investigator sent to the scene of a devastating house fire that burned out of control. What kinds of information might you want to collect to determine:

- How the fire started?
- What materials burned?
- How quickly it burned?
- Why it burned uncontrollably?
- Whether it was deliberately set (arson)?

In the following investigation, you will use information-gathering skills similar to that of a fire investigator to construct a hypothesis about why an airship, the Hindenburg, burned and crashed in 1937.

Experimenting and Investigating

It is not surprising that hydrogen was the thing people thought of first when trying to figure out what happened to the Hindenburg. One of the chemical properties of hydrogen is that it is highly flammable. That is, in the presence of enough oxygen and an ignition source, hydrogen gas will burn. How is this known? Your teacher will demonstrate.

As you observe this demonstration take careful note of exactly what happens and write your observations in your notebook.

CHALLENGE: What caused the Hindenburg disaster?

In 1937, the Federal Bureau of Investigation (FBI) conducted a limited investigation into the destruction of the Hindenburg. It concluded that an explosion of hydrogen could have caused the fire. However, at the time, many people disagreed with that initial conclusion. What else might have caused the destruction of the Hindenburg? Could other materials or factors be to blame? You will be examining information about the mixtures that made up the components of the Hindenburg and their physical and chemical properties in order to develop an explanation for why it crashed.

In this investigation, you and your fellow students will act as members of a review board to look into the Hindenburg disaster. With your classmates discuss the kinds of information you think you might need in order to investigate this disaster.

Various groups that designed the Hindenburg or were involved in its flight and landing have provided your committee with information that they think your committee will need. You and your other committee members will review all available information and then develop an explanation about the cause of the disaster. As you collect your information keep in mind the kind of information that was important in analyzing the cause of a house fire.

Materials

You will have access to the following materials:

- The reading "The Hindenburg Disaster." This report describes the Hindenburg and the circumstances of its destruction.
- Two engineering reports relating to the components and design of the Hindenburg. Report 1 provides information about the structure and kinds of materials used in the airship. Report 2 examines some of the properties of those materials.
- A Weather Conditions Report that describes the weather that the Hindenburg flew through. It also provides the conditions at the time of its landing.
- Science Background that provides further scientific information that you might need to complete the challenge.
- A video and photographs of the disaster.
- Sister Ship Modifications, which describes modifications that were made to the Hindenburg's sister ship in 1937.

Procedure

Record all observations and answers in your notebook as you work.

1. Review all of the materials carefully.
   - With your group, brainstorm the kinds of details you should pay particular attention to as you read and why this information may be important.
   - While reading "The Hindenburg Disaster" and the other reports, write down any information that you think will help you develop your explanation for the disaster.
   - While viewing the video and photographs, observe:
     – the progress of the fire and the timing of it in relationship to the crash,
     – the characteristics of the flames,
     – whether an explosion actually occurred, and
     – anything else you think might be important.

   As you work, keep careful track of your observations, discussions, and the evidence you are using to support your conclusions.

2. Discuss your notes and observations with your group and come to an agreement about the crucial data.

3. Using your observations and data, develop an explanation about what caused the destruction of the Hindenburg. Note that there may be more than one correct answer. More than 60 years

after the disaster, scientists are still debating its cause. What is important is that you explain your reasoning.

4. Prepare a concise but complete (5- to 7-seven minute) group presentation. Your report should describe your explanation and describe the clues, observations, and information that support your explanation. Decide how you will present your conclusions to the class. Your report can take the form of posters, diagrams, a computer presentation, role-play, video, and so on.

READING: The Hindenburg Disaster

"They've dropped the ropes out of the nose of the ship, and it's been taken a hold of down on the field by a number of men. It's starting to rain again…The back motors of the ship are just holding it, just enough to keep it from…It's burst into flames...get this, Charlie, get this, Charlie... Get out of the way, please, oh, my, this is terrible, oh, my, get out of the way, please! It is burning, burst into flames and is falling on the mooring mast and all the folks we...this is one of the worst catastrophes in the world!… Oh, it's four or five hundred feet into the sky, it's a terrific crash ladies and gentlemen...oh, the humanity and all the passengers!" —Broadcaster Herb Morrison recording from Lakehurst, NJ, May 6, 1937, as he reported on the arrival of the Hindenburg.

Dubbed "the luxury liners of the skies," dirigibles seemed to be the wave of the future in travel during the years 1900–1937. Dirigibles, or Zeppelins as they were also known, promised a faster and safer way to cross the Atlantic. Ocean liners took many days, and airplanes of that time could only travel short distances. Airplanes required constant refueling and were able to carry only small masses of cargo. Built in 1936 in Germany, the Hindenburg was meant to be the first of a fleet of dirigibles. With passengers paying up to $720 per flight (multiply by 10 to get today's equivalent price), this flying luxury hotel provided the finest comforts. Passengers could each take up to 280 pounds of luggage. Five gourmet cooks provided meals served on specially made blue and gold porcelain china. Sleeping cabins were small but lavishly designed with all the modern amenities. A piano and a 200-foot-long promenade deck ensured that passengers could relax and enjoy themselves. Cruising at an average speed of 78 mph, the airship flew at only 800 feet above the surface of the earth. As a result, the Hindenburg provided its passengers with spectacular views of cities, mountains, oceans, and plains through its Plexiglas windows. At 135 feet in diameter and over 800 feet in length, the Hindenburg remains the largest aircraft ever to have flown. If it were not for the Hindenburg's fiery ruin, the skies today might be filled with these behemoth-sized airships.

Prior to its ill-fated final journey, the Hindenburg had completed 10 successful round trips between the United States and Europe. The last voyage of the Hindenburg began in Frankfurt, Germany, on May 3, 1937. With a crew of 61, the craft was only half-booked with 36 passengers. After an uneventful trip, it arrived at Lakehurst, New Jersey, on May 6. Its landing was delayed for several hours by severe thunderstorms. Early in the evening, the airship was given clearance to land despite continued rain and distant lightning flashes. The Hindenburg headed toward the mooring mast where its nose would be secured with ropes. This permitted the craft to move so that its nose would always be pointed into the wind. As it moved toward the mast at a height of about 275 feet, the engines were reversed. The ropes were then dropped to the ground crew, who would tow the craft into position.

Suddenly, a small, mushroom-shaped orange flame appeared at the tail (aft) of the aircraft. Within seconds, the entire aft section was engulfed in an orange-red fireball that burned downward. Smoke billowed hundreds of feet into the air. The ship remained airborne for about 30 seconds. Then its nose pointed up, spreading flames toward the front of the ship. This caused the tail section to crash to the earth (see Figure 1.2).

Figure 1.2: *The Hindenburg burns.*

Passengers and crew leaped to the ground from the flaming mass. Some survived the fall, but many did not. Within 37 seconds from the moment the flames were first observed, the skeletal remains of the craft lay burning. Of the ship's crew, 22 died along with 13 passengers and one member of the ground crew.

Engineering Report 1: Structure of the Hindenburg

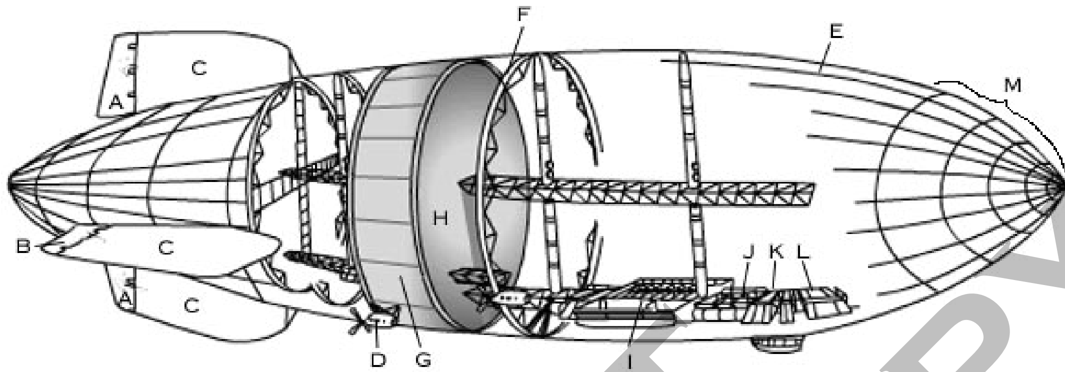

Figure 1.3: *Parts and materials of the Hindenburg.*

A. Rudder: controlled lateral (left and right) movement
B. Elevator: controlled vertical (up and down) movement
C. Fins: 105 feet long, 49 feet in breadth
D. Diesel engines: four (16 cylinder)
E. Main frame: solid mixture of aluminum and copper with traces of magnesium, manganese, iron, and silicon (duralumin)
F. Main frame O rings: provided craft with rigid structure to withstand pressure from lifting gas and weight of craft; rigidity came from diamond-shaped trusses arranged end to end and connected by steel wire
G. Gas cells: 16 gas cells contained 200,000 cubic meters (7 million cubic feet) of hydrogen gas; made of lightweight cotton fabric brushed with several layers of gelatin mixture to make them gas tight
H. Hydrogen: lighter-than-air gas provided lift; garlic aroma added to aid in detecting gas leaks
I. Passenger deck: six Plexiglas windows on each side for viewing; upper deck held 25 two-person cabins, a dining room, reading and writing room, and lounge; lower deck consisted of kitchen, crew quarters, small bar, and smoking room
J. Fuel tanks: carried diesel fuel for engines
K. Navigation and control rooms
L. Mail room
M. Fabric skin or shroud: cotton, coated with a mixture of iron oxide, cellulose butyrate acetate, and aluminum powder; the coating paint made the fabric taut and reflected the sun’s rays to prevent the hydrogen gas from heating up and expanding; the fabric skin was sewn together in separate sections or panels and was attached to the metal frame with ramie fibers

Engineering Report 2: Properties of the Hindenburg's Materials

Table 1.1: *Properties and Functions of Materials in the Hindenburg*

Material	Flammability	Conductivity[1]	Characteristics	Location[2]/ Function
Hydrogen gas	Highly flammable	Not applicable	Colorless, odorless, lighter than air; burns with a pale blue flame that moves in an upward direction; can explode when mixed with sufficient oxygen	Found in gas cells (H); provides lift
Iron oxide	Not flammable	Poor	Color may be black, or red; medium hard	Part of coating mixture (M); helps reduce wear and tear on the skin or fabric of the airship
Cellulose butyrate acetate	Highly flammable	Poor	Burns orange-red	Part of coating mixture (M); adds rigidity to skin and helps in aerodynamics
Aluminum powder	Flammable	Poor but can hold a charge	Resists corrosion[3]; durable; burns bright white	Part of coating mixture (M); reflects sunlight
Duralumin[4]	Not flammable	Good	Rigid with some flexibility; light in weight	Main frame (E); provides framework and rigidity to structure
Ramie fibers	Flammable	Poor	Cotton fabric	(M); connects skin to metal frame
Manila ropes	Flammable	Good when wet	Plant fiber	Connects craft to mooring mast during landing; discharges static electricity from the airship to ground

[1] Ability to conduct an electric charge
[2] Letter corresponds to location in Figure 1.3
[3] *Corrosion* is the wear on a substance caused by a chemical reaction
[4] An alloy made of copper, aluminum, magnesium, manganese, iron, and silicon

Weather Conditions Report

A summary of relevant weather conditions:

- Prior to landing, the Hindenburg had flown through a lightning storm.
- At the landing site there were periods of rain from passing thunderstorms and lightning in the distance.

Science Background

- Hydrogen gas, like all gases, expands when heated in a flexible container.
- A mixture of powdered aluminum painted on a surface will reflect the sun's rays.
- During a storm, large amounts of static electricity can build up in the atmosphere. This can occur when particles in the air rub against each other and create a charge. (If you have shuffled your feet on a carpet on a dry day and touched a door, you may recall getting a small shock. This "shock" is actually a small spark passed from you (charged object) to the wall (uncharged object).) A surface containing metallic particles can also become statically charged in a storm.
- When a charge is created in the sky, an opposite charge is created in the ground. Sky-to-earth and earth-to-sky lightning occurs when the charge finds the path of least resistance back to the ground in order to return to a neutral state.
- Static electricity on the surface of an object can be discharged by connecting the object to the ground with material that conducts electricity.
- Static electricity can also be discharged by moving from one section of the object that is charged to a section that is not charged in the form of a spark.

Sister Ship Modifications

The LZ 130, the Hindenburg's sister ship, was in the process of being built when the Hindenburg burned. Records show that after the disaster, engineers made the following significant modifications:

- Calcium sulfamate and powdered bronze (an alloy or mixture made of tin and copper) were substituted for aluminum and iron oxide in the coating paint.
- The ropes connecting the skin to the frame of the airship were treated with graphite.

Table 1.2 contains information about the materials used in LZ 130.

Table 1.2: *Properties of Materials Used in LZ 130*

Material	Flammability	Conductivity	Characteristics	Function
Calcium sulfamate	Not flammable	Not conductive	Flame retardant	Used to fireproof textiles
Powdered bronze	Not flammable	Highly conductive	More dense than aluminum	Reflects sunlight
Graphite	Not flammable	Highly conductive	Soft; made of carbon	Discharges static electricity

Processing for Meaning

Questions for Discussion

You and your team will present your explanation of the cause of the disaster and the evidence that supports it. As part of your discussion be prepared to address the following kinds of questions:

1. Which parts of the Hindenburg do you think were made up of mixtures?
2. Which of the properties listed in Table 1.1 are physical properties? Which are chemical properties?
3. How do you think the individual properties of the substances mixed in the coating affect its properties once they are mixed? Would the properties of these substances remain the same or change? Explain.
4. Why might it have been important to understand the conductivity of some of the materials?
5. Why might it have been important to understand the flammability of some of the materials used to construct a dirigible?
6. Why do you think it is important to know the properties of substances that are used in mixtures? T
7. When you hear something advertised as "new and improved," what do you think that might mean?

Thinking About What You Did

One way of expressing your understanding of a concept or topic is to create a concept map. A concept map is a way of organizing information and demonstrating connections among ideas or topics. An idea or word relating to a concept is placed in a circle and a line is drawn to connect it to another concept. One or two words (usually verbs) are written on the line to indicate how these words are connected. There is no one correct concept map; connections can be made in many different ways. But there are good maps and not-so-good maps, and there are correct and incorrect connections.

Construct a concept map using key ideas and words about the Hindenburg. Include the following words: dirigible, friction, charge, hydrogen, mixtures, fabric, static electricity, ropes, coating mixture, flammable, not flammable, physical properties, chemical properties, crash. You may add any other words you wish.

Extending Ideas

- Hydrogen was first recognized as a unique gas in 1766 by Henry Cavendish. Research his work and describe the experiments that enabled him to make this discovery.

- What role should politics play in science? Because of political disagreements between the United States and Germany, the designers of the Hindenburg were forced to use hydrogen even though they were aware of the dangers. Sometimes the goals of politicians determine what research can or cannot be done. Find an example of this in recent times and discuss the issue and the ethical implications.

- Hydrogen is estimated to make up more than 90 percent of all the atoms or three quarters of the mass of the universe. But in its elemental form (H_2 gas) as a gas, there is very little of it in our atmosphere. However, it is one of the most common elements found in molecules on Earth. List other elements that hydrogen can combine with and identify the substances that are formed.

- Should the designers of the Hindenburg have been aware of the dangers based on their understanding of chemistry? If so, how might they have determined whether the dangers were real?

- Hydrogen has other uses in addition to lifting dirigibles. Research the role of hydrogen in fuel cells.

Unit 1

Organization of Matter

Unit 1: Organization of Matter

Overview

The word "chemistry" can bring lots of different images to mind, including test tubes, scientists in lab coats, the periodic table of elements. But chemistry is so much more than just those examples; it is part of what you do and see everyday. For instance, some of today's popular television series whisk you right into the middle of a crime scene, where you can watch investigators use chemistry to solve a mystery. In this unit, you will learn a bit more about how chemistry can be used to solve unknowns and how chemicals are organized through the use of the Periodic Table. You'll complete the following learning experiences:

Learning Experience 2: Have you ever thought about how chemists identify unknowns? In this lesson, you will read about a person who may be exposed to anthrax. You will then role-play chemists who are testing a white powder, like that in the story, to see if it could be anthrax or a hoax. You will find out that matter is made up of different substances and that each substance is unique and can be identified by its properties. You will then carry out some laboratory tests of different properties to distinguish different substances that look alike.

Learning Experience 3: What are all substances made of? In this lesson, you'll learn about elements that combine to form the enormous variety of substances in our world. You'll start by seeing if water can be decomposed, or broken down, into elements. You'll learn that an element is both one kind of atom and a special kind of substance that contains only one kind of atom. You will then read about the creation of the periodic table of elements. You will re-create this work by making your own table of elements by looking for patterns of similar properties among the elements.

It's time to get moving with Unit 1. Have fun!

Learning Experience 2

Anthrax Hoax at the Newspaper: Identifying an Unknown White Powder

Prologue

What if you were told that you were exposed to a deadly substance or material? Such situations have occurred involving the deadly bacteria anthrax. Several people died from infection by anthrax after receiving it in the mail. Thousands more thought they had been exposed to the bacteria and had to wait until scientists determined that they had been the victim of a hoax, or trick.

Even if an anthrax scare turned out to be a hoax, it was still a serious crime. Investigators had to determine what material had been used for the hoax, and then attempt to find the people responsible for perpetrating the hoax. In this learning experience, you will take on the role of chemists who are testing several samples that were used in anthrax threats but which tested negative for the presence of the deadly bacteria. Authorities would like to determine the identity of the samples and suspect that they are common household products. You will be testing the samples to see if the authorities are correct. As you complete this challenge, you will answer the following questions: How can you identify substances? In what ways are substances different from each other?

Setting the Context

Let’s start by thinking about what you already know about anthrax and about substances in general. Consider the following questions.

Brainstorming

1. Have you heard of anthrax hoaxes? What do you know about them?
2. What do you think the word “substance” means to chemists?
3. Using your definition of substance in question 2, what common household products are substances?
4. Are all substances different from each other? If so, in what ways are they different?

The following story is a fictional account of a possible anthrax scare. Throughout the learning experience, you will be role-playing the chemists who will be testing the material received by the editor’s assistant.

STORY: Horror, then Hoax, at the Digest

The offices of *New York Digest*, a daily newspaper in New York City, are bustling with activity today. Reporters are scrambling to meet their deadlines, and editors are pouring over the stories before they go to layout. Amidst the chaos is Dylan, the assistant to the *Digest's* editor-in-chief, Madeleine Jones. One of Dylan's responsibilities as Madeleine's assistant is to open the dozens of letters that are sent to her every day. It can be a tedious task, but Dylan gets a kick out of reading some of the whacky letters she gets from fanatics who are upset about how a news piece was covered in the *Digest*.

Like every other day, Dylan sits down with his coffee and starts to sort through the tall stack of letters. Halfway through the pile, he discovers a discolored envelope that catches his attention. The address is written in big block letters and there's no return address. Thinking he's probably in for reading an interesting letter, he tears it open with gusto. Whoosh! White powder goes everywhere—on his hands, face, and desk. Dylan screams and jumps back, drawing the attention of his nearby coworkers. Then it dawns on him—this is exactly what happened in the months following the September 11th terror attacks in 2001. Letters containing the deadly bacteria anthrax (*Bacillus anthracis*) were sent to news organizations and senators, and several people died from the bacteria.

Madeleine runs out of her office to see what the commotion is about. Dylan's in a state of shock and paralyzed with fear. Madeleine rushes back to her office and calls 911. After getting instructions from the 911 dispatcher, she hurries back to the gathered crowd and announces that everyone must evacuate the building.

As the employees of *New York Digest* scramble to get outside, a terrified Dylan remains motionless. Madeleine tries to reassure him, telling him to put the letter on his desk and go wash his hands and face thoroughly with soap and water. She tells him calmly that the dispatcher explained that most likely the letter is a hoax because anthrax is extremely difficult to obtain. Dylan dashes to the nearest men's room before leaving the building.

Within a matter of minutes, the area is sealed off. Experts are then brought in to take samples from the workplace and get them to a laboratory for testing. Dylan waits anxiously for two days but he is heartened by the support he is getting from his coworkers. When the tests are completed, Dylan finds out to his great relief that the threat was, indeed, a hoax. He learns that further efforts will be made to see if the white powder he received was the same as that found in two other anthrax hoax letters that were sent to other news agencies at about the same time. The investigators hope to be able to identify the perpetrator of the hoax.

Thinking About What You Read

Write your responses to the following questions in your notebook. Be prepared to discuss your answers.

1. What are the characteristics of the material Dylan received in the mail?

2. Why was it likely that the scare was a hoax?

3. Since the anthrax letter turned out to be a hoax, what common household products might have been used? List all that you can think of.

ACTIVITY: Recognizing Substances and Mixtures

At the beginning of this learning experience, you talked about your definition of a substance. In this activity, you will learn about the chemical definitions of substances and mixtures, examine the ingredients lists of white powders that are in your home, and attempt to identify substances and mixtures using the ingredients lists.

In the field of chemistry, a *substance* is matter that has a uniform composition and that has unique physical and chemical properties. For example, salt and water are both substances. No matter where in the salt shaker you took a pinch, each pinch is the same. And if you took a pinch of salt from a different salt shaker, that pinch too would be the same. The same is true for water: water is the same no matter which part of the water you sample, or which bottle you sample it from. Usually, something referred to as "pure" is a substance.

Although salt and water are both substances, most products we use do not consist of only one substance, but contain two or more substances. This form of matter is called a "mixture." A *mixture* contains two or more different substances that can be combined in varying amounts.

However, each substance still retains its properties in a mixture. If you mixed salt and water together, you would get a mixture that has some of the properties of salt and some of the properties of water. The amount of each substance in the mixture determines the properties of the overall mixture. For example, a drop of salt water from one mixture might taste quite a bit saltier than a drop of salt water from a different mixture, because the first mixture had a higher ratio of salt to water.

There are several kinds of mixtures. A mixture can be *homogeneous*; that is, it appears to be the same throughout with no visibly different parts whether you examined it by sight or with a light microscope. The most common kind of homogeneous mixture is called a *solution.* Salt water is a solution and is, therefore, an example of a homogeneous mixture. Other examples of solutions are sodas and sports drinks.

Another kind of mixture is a *heterogeneous* mixture. In this kind of mixture, the different substances that make it up can be distinguished by sight or with a light microscope. Chicken soup, fruit juice with pulp, and milk are examples of heterogeneous mixtures.

Complete the following assignment to help you identify mixtures and substances. Write your answers in your notebook or on Think Sheet 2.1, as directed by your teacher.

1. In the previous section, you identified possible household products that are white powders that could be used in an anthrax scare. At home, try to find as many of the products the class listed as you can. Look for an ingredients list on the container and record the ingredients for each product.

2. Identify which products you examined in question 1 that you think are mixtures and which products you think are substances. (You need to use the ingredients list to help you do this because homogenous mixtures appear uniform throughout and can be mistaken for substances.)

3. Examine the list of ingredients on labels for other household products such as cleaning products, grooming products, or foods. (You do not need to record the list of ingredients.) Make a list of the products you examined and identify which products appear to be substances, which homogenous mixtures, and which heterogeneous mixtures.
4. Based on your survey of products, are most household products substances or mixtures?
5. You looked at several kinds of white powders in your home, any of which could have been used for an anthrax hoax. What kinds of tests might you do to see if two substances that look alike are the same or not? List all the tests you can think of.

Experimenting and Investigating

CHALLENGE: What is the unknown white powder?
Although there have been a few documented cases of letters containing anthrax, there have been more than a thousand "hoax" letters. In each case, people received a white powder. In this challenge, you will role-play chemists performing quick comparison tests to help assess whether substances that have been identified as hoaxes are common household products or not. Your goal is to make initial findings that can guide further testing in a more specialized lab that might help identify the perpetrator. One of the samples is the one opened by Dylan at *New York Digest*. Because this is a role-play, you will not really be working with any dangerous materials.

Pre-lab Discussion

Discuss the following topics with your classmates to help you prepare for the investigation.

1. Review your answer to question 5 at the end of the previous section. What are possible tests that could help you determine if the white powder Dylan received was a common household product?
2. Review the materials list and the entire procedure for the investigation on pages 18–23. What are the goals of the investigation? Can you summarize the main steps? What precautions will you need to take?
3. What are the six household products you are testing as controls? What do you already know about each? What are their characteristics?
4. Some of the household products are substances and some are mixtures. How do you think this will affect your tests of properties?
5. Chemists identify unknown substances and mixtures by testing their properties and comparing them to properties of known substances and mixtures. Chemists divide properties into two types: physical and chemical. Discuss the following definitions:
   - *Physical properties* are the properties of a substance that can be observed and measured without the substance changing into other substances.
   - *Chemical properties*, on the other hand, relate to a substance's participation in a chemical reaction. If a substance reacts, it changes into other substances.

6. Table 2.1 describes some chemical and physical properties. Review these properties and discuss them.

Table 2.1: *Description of Commonly Measured Physical and Chemical Properties of Substances*

Test	Visible Results	Information gained
Physical property: Appearance		State of matter and color of a substance.
Physical property: Solubility in water	Particles of a substance are no longer visible by sight or a light microscope when mixed with water	A positive result shows that the substance has characteristics that allow it to dissolve in water.
Physical property: Melting point	Substance changes its state from solid to liquid	The temperature at which a substance changes state from a solid to a liquid.
Physical property: Boiling point	Material changes its state from liquid to gas	The temperature at which a substance changes state from a liquid to a gas.
Physical property: Density		The mass of a one cubic centimeter (or one liter) of a substance.
Physical property: Electrical conductivity		The amount of current that flows when voltage is applied.
Physical property: Heat conductivity		The amount of thermal energy that flows when there is a difference in temperature.
Chemical property: Reactivity with acid	Evidence of a new substance, such as color change, bubbles of a gas, or precipitation of a solid	A positive result shows that the substance reacts with acid.
Chemical property: Reactivity with water	Evidence of a new substance, such as color change, bubbles of a gas, or precipitation of a solid	A positive result shows that the substance reacts with water.
Chemical property: Reactivity with pH indicator	Indicator changes color	A positive result shows that the indicator has reacted with the substance, indicating that the substance is an acid or base.
Chemical property: Flammability	Substance can burn in air	A positive result shows that the substance reacts with oxygen in air in a combustion reaction.

Note: Some substances do not have melting or boiling points because they decompose when heated.

Materials

- lab apron
- goggles
- 6 labeled, closed containers or test tubes containing powdered sugar, talcum powder, flour, baking soda, baking powder, and cream of tartar
- 6 spatulas
- clear plastic wellplate (the wellplate must have at least 12 wells; otherwise use 2 wellplates)
- piece of paper
- dropper bottle of distilled water
- dropper bottle of vinegar
- toothpicks
- small labels or marking pen
- conductivity tester
- wash bottle with distilled water
- 125-mL beaker
- dropper bottle of universal indicator
- 3 labeled, closed containers or test tubes containing sample 1, sample 2, and sample 3

The density of a powder is hard to measure. Measurements of some other properties, such as melting point and boiling point, can require specialized equipment. Therefore, you will not be testing every possible property at this time, as the goal of these tests is to get initial findings that can help determine further testing. Review the procedure below before you begin the tests, and list which tests of properties that you will perform in this lab.

Procedure, Part A

SAFETY NOTE
Wear protective equipment.
Do not lean close to the wellplate when testing reactivity.

Prepare to test the household products

1. Your teacher will pass out the equipment you need. Arrange the equipment neatly.
2. Arrange the household products in an order that makes sense (alphabetical for example). Always keep the products in the same order during tests to minimize confusion.
3. Determine a code for each of your household products so you can identify each with a letter or number.
4. Describe the appearance of each product. Note any differences that you see among them.
5. Label 6 spatulas with the codes of the household products, one spatula for each product.

   Note: As you proceed with the investigation, use only the corresponding labeled spatula for each product when you have to transfer the particular powder.

   Stop and Think: Why is it important to label the spatulas?

6. On the paper under your wellplate, label each well with the code of the household product to be tested in it. Indicate next to each well if the household product will be tested with vinegar or with water by adding a “V” or a “W” to its code.

   Note: You will use 12 wells of your wellplate. Each household product will be tested twice. One sample of the product will be tested with vinegar and then a second sample of the product will be tested with water.

7. Using the appropriate scoop, transfer approximately the same amount of each household product to their labeled wells. Carefully tap the scoop of each product into its well.

Test each product’s reactivity with vinegar

1. Add 10 drops of vinegar into each of the 6 wells that are labeled “V” using the vinegar dropper bottle.

2. Stir with a toothpick and observe each well for signs of bubbles as you add the vinegar. Record any that you see.

   Stop and Think: What would cause bubbles?

Test each product’s reactivity with water

1. Add 10 drops of water into each of the 6 wells that are labeled “W” using the water dropper bottle.

2. Stir with a toothpick and observe each well for signs of bubbles as you add the water. Record any that you see.

   Stop and Think: What would cause bubbles?

Test each non-water-reactive product’s solubility in water

1. With your group, determine which of the household products DID NOT react with water. You will test solubility on those products only.

   Stop and Think: Why shouldn’t you use products that react with water for this test?

2. Add 10 more drops of water into each of the wells that contain the products you are testing for solubility.
3. Stir with a toothpick and observe the solid closely to see if it dissolves in the water (forms a solution).

4. Repeat steps 2 and 3 several more times. Stop adding water if a product completely dissolves, or if a well becomes full. Keep track of how many drops of water are added to each well.

5. Record if any products completely or partially dissolved and how many drops of water you added to the wells of those products.

Test each dissolved product for conductivity (when mixed in water)

SAFETY NOTE
If a wire or battery is getting hot, disconnect the circuit immediately.

1. With your group, determine which of the household products completely or partially dissolved in water. You will test conductivity on those products only.

2. Insert the open end of the conductivity test circuit (see Figure 2.1) into each of wells that contains the products you are testing for conductivity. Between each test, use the wash bottle and an empty beaker to rinse the wires. Do not let the wires touch the bottom of the well.

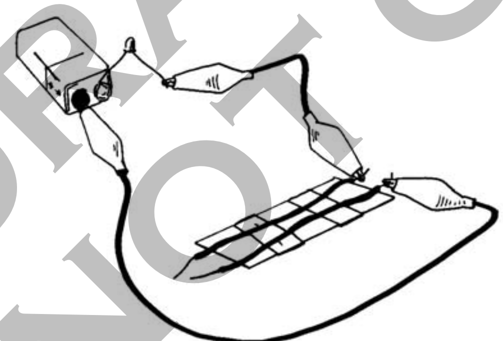

Figure 2.1: *Conductivity test circuit. The two wires taped to the cardboard are inserted in the test solution. If the solution is conductive, then the light-emitting diode (LED) will light.*

3. For each well, see if the bulb lights. Record any results.

Test each dissolved product to see if it is an acid or a base

1. Add 2 drops of universal pH indicator into each of wells that contain the products you just tested for conductivity.

2. See if the indicator changes color. If so, the product is an acid or base. Record any color change that you see.

   Stop and Think: What would cause a color change?

3. Clean the wellplates, spatulas, and work areas.

Procedure, Part B

SAFETY NOTE
Wear protective equipment.
Do not lean close to the wellplate when testing reactivity.

Prepare to test the unknown samples

1. Your teacher will pass out the equipment you need. Arrange the equipment neatly.
2. Arrange the household products in numerical order. Always keep the samples in the same order during tests to minimize confusion.
3. Describe the appearance of each sample. Note any differences that you see among them.
4. Label 3 spatulas with the numbers of the unknown samples, 1 spatula for each sample.

   Note: As you proceed with the investigation, use only the corresponding labeled spatula for each sample when you have to transfer the particular powder.

   Stop and Think: Why is it important to label the spatulas?

5. On the paper under your wellplate, label each well with the number of the unknown sample to be tested in it. Indicate next to each well if the unknown sample will be tested with vinegar or with water by adding a "V" or a "W" to its number.

   Note: You will use 6 wells of your wellplate. Each unknown sample will be tested twice. One sample of the product will be tested with vinegar and then a second sample of the product will be tested with water.

6. Using the appropriate scoop, transfer approximately the same amount of each sample to its labeled well. Carefully tap the scoop of each sample into its well.

Test each sample's reactivity with vinegar

1. Add 10 drops of vinegar into each of the 3 wells that are labeled "V" using the vinegar dropper bottle.
2. Stir with a toothpick and observe each well for signs of bubbles as you add the vinegar. Record any that you see.

   Stop and Think: What would cause bubbles?

Test each sample's reactivity with water

1. Add 10 drops of water into each of the 3 wells that are labeled "W" using the water dropper bottle.
2. Stir with a toothpick and observe each well for signs of bubbles as you add the water. Record any that you see.

Stop and Think: What would cause bubbles?

Test each non-water-reactive sample's solubility in water

1. With your group, determine which of the unknown samples DID NOT react with water. You will test solubility on those samples only.

   Stop and Think: Why shouldn't you use samples that react with water for this test?

2. Add 10 more drops of water into each of the wells that contain the samples you are testing for solubility.
3. Stir with a toothpick and observe the solid closely to see if it dissolves in the water (forms a solution).
4. Repeat steps 2 and 3 several more times. Stop adding water if a sample completely dissolves or if a well becomes full. Keep track of how many drops of water are added to each well.
5. Record if any samples completely or partially dissolved and how many drops of water you added to the wells of those samples..

Test each dissolved unknown sample for conductivity

SAFETY NOTE
If a wire or battery is getting hot, disconnect the circuit immediately.

1. With your group, determine which of the unknown samples completely or partially dissolved in water. You will test conductivity on those samples only.
2. Insert the open end of the conductivity test circuit (see Figure 2.1 on page 20) into each of the wells that contain the samples you are testing for conductivity. Between each test, use the wash bottle and an empty beaker to rinse the wires. Do not let the wires touch the bottom of the well.
3. For each well, see if the bulb lights. Record any results.

Test each dissolved unknown sample to see if it is an acid or a base

1. Drop two drops of universal pH indicator into each of wells that contain the samples you just tested for conductivity.
2. See if the indicator changes color. If so, the sample is an acid or base. Record any color change that you see.

   Stop and Think: What would cause a color change?

3. Clean the wellplates, spatulas, and work areas.

Data Analysis

With your group, complete the following questions and record your answers in your notebook. Be prepared to share your answers with the rest of the class.

1. You examined the appearance of each material in this lab. Is appearance a physical or chemical property? Explain your reasoning.
2. Summarize the data on the properties of the household products in a table (use Think Sheet 2.2, if available).
3. Summarize the data on the properties of the unknown samples in a table (use Think Sheet 2.2, if available).
4. Examine both tables. Do any of the unknown samples appear to be a common household product that is white and powdery? Explain your reasoning.
5. Do any of the unknown samples appear to be something other than the household products that were tested? Explain your reasoning.

Processing for Meaning

Your lab has finished its work on the unknown samples. Your findings are preliminary but they are important because they will help guide the rest of the testing process and provide initial results for the people who received suspicious packages. In this section, you will continue role-playing lab workers testing suspicious substances; now you are at the reporting stage. You will present your results to the people exposed to the unknown powders and describe and defend your conclusions.

PRESENTATION: Can the Anthrax Hoaxes be Identified?

Prepare and give a presentation about the identification or lack of identification of ONE of your three unknown samples.

When you are presenting, please be sure to do the following:

- Describe and compare the test results of your controls (household products) and sample.
- Make sure your visual materials can be seen by the audience and look at the audience while you speak instead of reading from notes.

If you are in the audience, please be sure to do the following:

- When each group is presenting, make sure to take notes of their conclusions and of how strong their evidence is. Record notes in your notebook.

Questions for Discussion

After all the groups have presented, meet with your group and discuss the following questions. Record your answers in your notebook or on Think Sheet 2.3, as directed by your teacher, and be prepared to share them with the rest of the class.

1. What evidence did each group use to make its conclusions about the identities of the samples?
2. Did all the groups obtain the same results? If not, what might have caused differences in identification?
3. What other tests can be done to confirm of the identity of the samples?
4. What effect did the use of mixtures (in the common household products) have on measuring properties?
5. Each substance has a unique set of properties that allows it to be identified. Using what you know about the nature of matter, offer an explanation for why each substance is unique.

READING: What Differentiates Hoax from Horror?

Why are substances unique? Why does each have different properties? This is one of the most important questions in chemistry. In short, each substance is unique because it has specific kinds of atoms or *ions*—these are atoms that carry a positive or negative electrical charge—arranged in a specific way in space. While it is very difficult to see atoms and ions because of their small size, we know the following about them:

a. Matter is made up of atoms and ions.
b. There is empty space between atoms and ions.
c. There are different unique kinds of atom and ions, referred to as "elements."
d. Atoms and ions interact with each other.

What is the nature of the interactions between atoms and ions? With a few exceptions, atoms and ions can form chemical bonds with each other. A *chemical bond* is a strong attraction between atoms or between ions that holds them very tightly together.

Note: There are different ways that atoms can bond to each other and these ways will be explored in Learning Experience 9.

There are main types of atomic arrangements. Some kinds of atoms and ions can bond together to form a *network*, which is a structure that has chemical bonds throughout the entire substance. These networks are always solids at room temperature, and are sometimes called "network solids." Some kinds of atoms can bond together into small groups of atoms called *molecules*. A molecular substance contains a large number of molecules. There are no chemical bonds between molecules; there are, however, attractions between them that are called *intermolecular attractions*. See Figure 2.2 for an example of each kind of atomic arrangement.

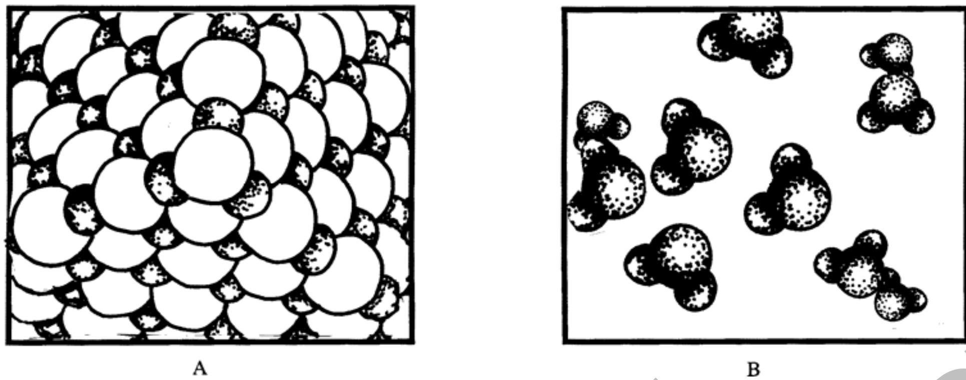

Figure 2.2: *There are two main types of atomic arrangements in substances that have chemical bonds: a network (A) and molecules (B).*

Thinking About What You Read

Write your responses to the following questions in your notebook. Be prepared to discuss your answers.

1. Explain why each substance has different properties.
2. What is a network? What is a molecule?
3. Two different substances with different properties are made up of the same kinds of atoms. Explain what else must be different about these two substances.

SUMMARY READING: From a Crime Scene to Chemistry

In this learning experience, you saw that the identification of different materials and substances is important in looking at a crime scene—in this case, knowing what substance was used to perpetrate an anthrax hoax. You used the properties of substances or of mixtures of substances to help you try to identify unknown white powders. This identification was possible because each substance is unique. So while many substances can be alike in appearance, they will differ in their other properties, such as reactivity, solubility, conductivity, and so on. Each substance has its own set of properties. Therefore, different substances and different mixtures of substances can be identified by testing their properties.

You also learned that there are two kinds of properties: physical and chemical. Physical properties are the properties of a substance that can be observed and measured without the substance changing into other substances. Appearance, density, melting point, boiling point, electrical conductivity, heat conductivity, and solubility are some physical properties. Chemical properties, on the other hand, relate to a substance's participation in a chemical reaction. If a substance reacts, it changes into other substances. Flammability, reactivity with acid, reactivity with water, and reactivity with a pH indicator are some chemical properties.

Finally, you learned that the explanation for why each substance is unique lies at the atomic level. Each substance has a unique composition and arrangement of atoms or ions that gives it its unique properties.

What are the different kinds of atoms (also called “elements”)? How did people figure out what they were? What do we know about them? These are the questions that you will address in Learning Experience 3.

Extending Ideas

- Using granulated sugar cubes with a marker dot on each side, explore factors that affect the dissolving rate of sugar. If you use a heat source, follow safety guidelines given to you by your teacher.
- The density of water is 1.00 g/mL and the density of sugar (sucrose) is 1.59 g/mL. Predict how the density of a water-sugar mix will change as more sugar is added. Check your prediction in the lab and graph your results.
- Both sand and glass have the same kinds and ratio of atoms (glass is made by melting sand and allowing it to cool). Research how the structures of these two substances differ and represent your findings with drawings.

Career

Chemical Engineer

In 1973, Gary Klein was a college student in chemical engineering and an accomplished bicycle racer. At a number of races, Klein noticed that many bicycles weighed much less than his. With the help of a professor and a few students, Klein set out to make a better bicycle frame. This effort was so successful that Gary Klein created his own company, Klein Cycles, to make new kinds of bicycle frames. Since its inception, Klein Cycles has created a number of new materials for bicycles and is still an innovator in bicycle manufacturing. Many of Klein Cycles’ materials are made by mixing different kinds of substances together. The goal of this process is to create a mixture that has desirable properties contributed by each of its components.

How does an engineer actually create new materials? In his first project, which he began while still a student, Klein and his colleagues collected and analyzed the tubes of a number of bicycle frames. They determined where strength and rigidity were most critical and where weight reduction might be beneficial or harmful to safety and comfort. They all agreed that the best choice of available material to make the bicycle lighter was aluminum because its low density is one-third that of steel. However, they recognized that pure aluminum is very soft. But Klein knew that adding other substances to the aluminum would make it harder. He heated the aluminum to 1,000° F and added magnesium, silicates, and chromium. By the late 1980s, this alloy (an *alloy* is a solid mixture containing primarily metal) was perfected and was used in his new bicycle frame. Klein had reduced the weight from 4.5 pounds to 3 pounds.

In 1990, Gary Klein began a new project. He experimented with a lithium-aluminum alloy that used zirconium to replace chromium as one of the alloying agents. For hardening, magnesium and silicon were again used. Copper was added to increase fatigue strength. *Fatigue* in metals refers to the weakening of a metal that may happen as a result of continued bending and unbending, similar to what happens when you bend a coat hanger many times. In addition, a small amount of manganese was added to the alloy to improve the ability to shape the material at a low temperature. When Klein tried out this new mixture, the weight of the frames decreased to a little over 2 pounds. These frames were also one-third stronger and could endure five times the number of bending stress cycles before failure.

Klein cycles has continued to experiment with creating new materials as new substances become available or cheaper in price.