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Atoms, Molecules, and Compounds are Everywhere

Introduction

When you take a breath, you inhale many trillions of oxygen molecules, nitrogen molecules, and hydrogen molecules. When you turn on a faucet, a similarly enormous number of water molecules flow out of it. When you eat a chicken nugget you eat the many atoms that make up sodium chloride (salt). Let's examine what atoms, molecules and compounds look like on a microscopic level and explore how their structures influence their properties. For example, why is the air we breathe air (a gas), and not liquid?

Concepts

• Experimental Design	• Structure and Properties of Matter
• Variables - control, dependent, independent	• Atoms and Molecules
• Physical Properties	• Chemical Bonds

Background

All Matter is Made of Atoms

Atoms are called the building blocks of matter because they combine in near infinite ways to give us all the tangible stuff on Earth. For example, two hydrogen atoms (H) combine with a single O atom (O) to form a water molecule, H_2O. Hydrogen atoms can also combine, or bond, with nitrogen atoms (N) to form ammonia molecules, NH_3. A molecule is a combination of two or more nonmetal atoms bound together. The periodic table lists all the various kinds of atoms that can combine to form compounds, another term for a combination of two or more nonmetal or metal atoms. See Figure 1.

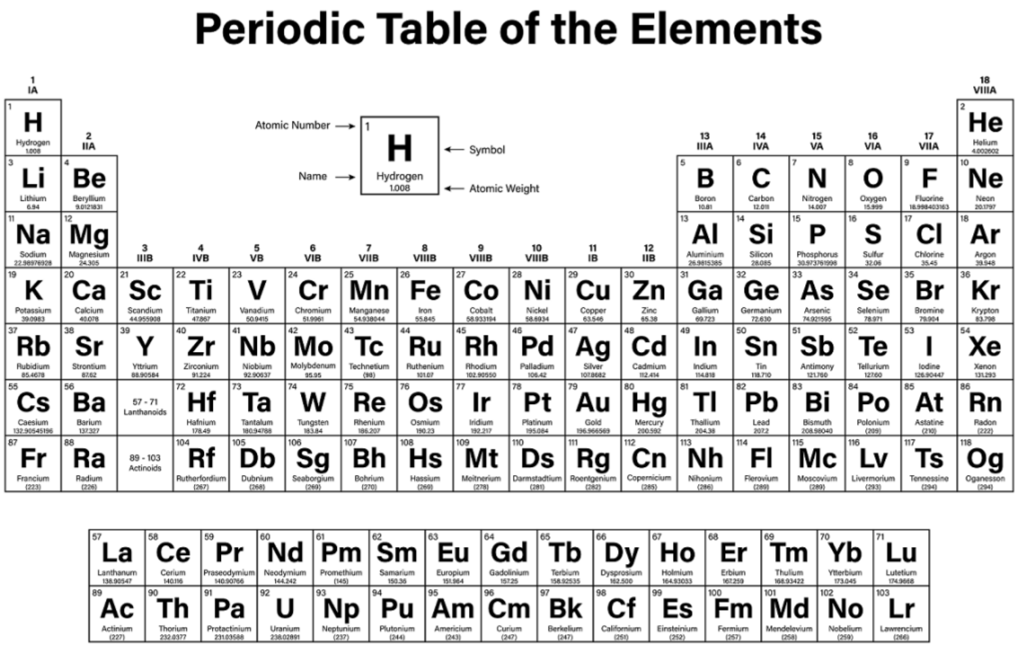


Figure 1. The Periodic Table of the Elements

Compounds can be composed of as few as two atoms or as many as thousands of atoms. And when the types and numbers of atoms in chemical compounds change, so do compounds' structures and properties. For example, water has the chemical formula H_2O and is drinkable and indeed, necessary for survival. In contrast, hydrogen peroxide has the formula H_2O_2, with just one more H atom than water, and is not safe to drink.

In this lab you will build models of molecules, the basic building unit of molecular compounds. You will also build a nonmolecular compound. Nonmolecular compounds are simply called ionic compounds. Ionic compounds are not built from molecules, but from atoms arranged next to each other in repeating patterns in all directions. An example of an ionic compound is sodium chloride, NaCl. Another way to understand the difference between "molecule" and "compound" is to use the terms. For example, water is a chemical compound formed from water molecules, which form from H and O atoms. Sodium chloride is a chemical compound formed from Na atoms and Cl atoms. Don't worry if this does not make complete sense right now, that is why you are going to build physical models! Before you build physical models, you need to know a little bit about bonding, or how and why atoms combine to form compounds.

Bonding – Why Atoms Combine

Atoms bond with other atoms to become more stable. Molecules are formed when atoms of nonmetals share electrons, forming a covalent bond. In general, only the outer energy level electrons or valence electrons are available for bonding. The number of valence electrons influences the number of bonds that an atom will form. The periodic table offers a convenient shortcut for determining the number of valence electrons in an atom. The columns in the periodic table represent groups or families of elements. Most periodic tables have the group numbers written above each column. These are written as Group 1 to 18 (see Figure 1). The number of valence electrons for any element, other than transition metals, is equal to the numeral in the ones place of the group number. Thus, potassium in Group 1 has one valence electron, carbon in Group 14 has four valence electrons, and chlorine in Group 17 has seven valence electrons.

The noble gases, Group 18, have eight valence electrons and are very stable. They do not readily combine with other elements because their outer energy levels are full. Other nonmetals may share electrons to achieve a valence electron "count" like that of the noble gases, thus becoming stable. This is known as the "rule of eight" or the "octet rule." Consider the chlorine atom with seven valence electrons. Each chlorine atom needs only one more electron to form a stable molecule—two chlorine atoms come together and share one bonding pair of electrons (Figure 2).

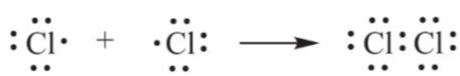


Figure 2. Two chlorine atoms share electrons to form a chlorine molecule.

Even though the total number of valence electrons in a chlorine molecule is 14, since each atom shares an electron with the other atom, the octet rule is satisfied for each chlorine atom. The chemical formula for a chlorine molecule is Cl_2, where Cl is the symbol of the element, and the subscript indicates the number of atoms of that element in the molecule. One shared pair of electrons is a single bond and can be represented by a single line between the element symbols. Figure 3 shows the structural formula of Cl_2. The structural formula may also depict the arrangement of the atoms in a molecule. In Figure 4, the structural formula for ammonia, NH_3, shows how the hydrogen atoms are bonded to the nitrogen atom. Some atoms share two or even three pairs of electrons with another atom. Double and triple bonds are represented by two and three lines, respectively.

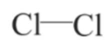


Figure 3. Structural formula of the chlorine molecule.

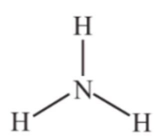


Figure 4. Structural formula of Ammonia.

Experiment Overview

This activity's purpose is to discover the basic structures of molecular and ionic compounds by building compounds with atoms of six different elements. The models will be used to write chemical formulas and draw structural formulas of the compounds. Then, you will use what you learn to design an experiment to observe that chemical compounds' structures are responsible for their properties. More specifically, you will determine which of two compounds is held together in the liquid state by weaker forces.

Pre-Lab Questions

1. What information does the chemical formula of a molecule provide? What additional information does the structural formula provide?

2. Of the 92 naturally occurring elements, only four make up more than 95% of living things. These four elements are listed in the chart below. Use a periodic table and the octet rule to complete the chart by filling in the element symbols, number of valence electrons, and number of bonds needed to gain stability. Note: hydrogen is an exception to the octet rule. Hydrogen has only two electrons around its nucleus when it bonds to other atoms, not eight.

Element	Symbol	Valence Electrons	Bonds Needed
Hydrogen			
Carbon			
Nitrogen			
Oxygen			

Materials

• Molecular Model Sets	• Hydrocarbons, Part C
• Teacher Demonstration, Part A	• Sodium Chloride, Part D
• Single, double, and triple Bonds, Part B	• Isopropyl (rubbing) alcohol, 1-2 mL
• Timer or stopwatch	• Water, 1-2 mL

Safety Precautions

While the activity is considered nonhazardous, protective eyewear is recommended. Use care when handling the floral wire connectors; the ends may have sharp points. Wash hands thoroughly with soap and water before leaving the laboratory

Procedure

General Procedure for Building Molecules

1. Atoms are represented by colored spheres with holes. The number of holes varies with each atom, depending on the number of bonds needed: carbon, (black), hydrogen (white), nitrogen (blue), oxygen (red).

2. Two different links are available to represent a pair of shared electrons. The shorter link is for single bonds and the longer flexible link is for molecules with double or triple bonds. Use one link per pair of shared electrons. If a molecule has one double bond, then two flexible links are needed to represent two shared pairs of electrons.

3. After building each molecule and drawing its structure, take apart the molecule and return the pieces to their respective bag for the next group to use.

Part A. Teacher Demonstration

1. Observe the models of ammonia, water, and carbon dioxide. How do the bonds in a water molecule fulfill the octet rule for hydrogen and oxygen?

2. Consider the water molecule. This is a single unit of water, the smallest unit of water that retains its properties. If you were to fill a small cup with water molecules how many, very roughly speaking, do you think would fit in the cup? Does this mean the water molecule is very small or very large?

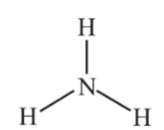
3. Consider again the single water molecule and the theoretical cup of water. The water molecule contains two single bonds, both between an H atom and the O atom. In the cup of water, the molecules are held together by bonds called intermolecular forces. As these forces get stronger it takes more energy (higher temperatures) to boil liquids, to break the forces that hold molecules together and turn them from liquid to gas. Water has a high boiling point (100 °C) relative to

other liquids. Does this mean the forces that hold the molecules in a cup of water together are weak or strong?

4. How are the bonds in the carbon dioxide molecule different than the bonds in the water or ammonia molecules? Explain why carbon and oxygen bond this way.

5. Complete Data Table A by filling in the chemical formula and structural formula for water and carbon dioxide.

Data Table A.

Name	**Chemical Formula**	**Structural Formula**
Ammonia	NH_3	
Water		
Carbon Dioxide		

Part B. Single, Double, Triple Bonds

1. Build models of hydrogen, nitrogen, and oxygen molecules as found in air according to the chemical formulas in Data Table B. Complete Data Table B by filling in the type of bond formed and the structural formula for each molecule.

Data Table B.

Name	**Chemical Formula**	**Type of Bond**	**Structural Formula**
Hydrogen	H_2		
Nitrogen	N_2		
Oxygen	O_2		

2. How many total electrons are shared by the two nitrogen atoms?

Part C. Hydrocarbons

1. Hydrocarbons are compounds containing only carbon and hydrogen. The simplest hydrocarbon is methane, CH_4, the largest component of natural gas. Ethane has two carbon atoms linked together with a single bond; the rest of the bonded atoms are hydrogen. Build a molecule of ethane and determine its chemical formula. Record the chemical and structural formulas for ethane in Data Table C.

2. A substituted hydrocarbon has one or more of its hydrogen atoms replaced by an atom or group of atoms of other elements. Isopropanol, or isopropyl alcohol, is a compound in which a –OH (hydroxyl) group is bound to a three-carbon chain at the central carbon atom. The central carbon atom thus forms single bonds with two CH_3 groups, an H atom, and the –OH group. Build a model of isopropanol. Fill in the information for isopropanol in Data Table C.

3. Some hydrocarbons have double or triple carbon bonds. Ethylene (also called ethene) has two carbon atoms double-bonded together. Build a molecule of ethylene, adding the correct number of single hydrogen bonds. Complete Data Table C for ethylene.

Data Table C.

Name	Use	Chemical Formula	Structural Formula
Ethane	2nd largest component of natural gas		
Isopropanol	Rubbing alcohol, antiseptic		
Ethylene	Ripens fruit		

Part D. Sodium Chloride

The atoms of most solid elements, molecules and ionic compounds are fixed in a regular pattern that repeats throughout the entire solid. Solid ionic compounds contain ions (atoms that have lost or gained electrons) arranged in an orderly and repeatable pattern called a crystal lattice. The smallest repeatable arrangement of the lattice is called the unit cell. You are going to build the unit cell for sodium chloride! When you shake salt onto your food, each tiny grain is composed of many of these unit cells, connected by chemical bonds in all directions. Let's build a sodium chloride unit cell to better understand this idea.

1. Use both the 2-inch and 1-inch connectors and the 2-inch and 1-inch spheres to construct the three layers shown in Figure 5. The 2-inch spheres represent chloride ions, and the 1-inch spheres represent sodium ions.

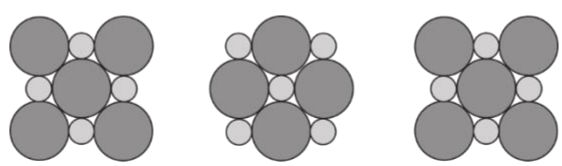


Figure 5.

2. Attach the ring with four large spheres between the other two rings so that the large spheres in the middle layer are “sandwiched” between the small spheres of the other two rings above and below (Figure 6).

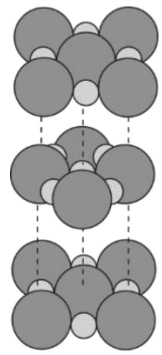


Figure 6.

3. You have just built the unit cell for sodium chloride. This is the smallest unit that has the properties of sodium chloride. It is far too small to see or taste. If you were to attach other unit cells to your unit cell on all sides, and then attach unit cells to each new attached cell you would have to use zillions of unit cells to create a visible, taste-able sodium chloride particle. If you would like, attempt to attach multiple unit cells from different lab groups together!

4. Sodium chloride is a solid that melts at a high temperature, 801 °C (1474 °F). Compare this to the melting point of water, which is a much lower 0 °C (32 °F). In other words, sodium chloride must be heated to a much higher temperature to break the bonds between its constituent particles so that they can spread out and assume a liquid state. Which of these compounds, sodium chloride or water, has the stronger forces (bonds) holding their constituent particles together? Explain.

Part E. Experimental Challenge: The Structure-Property Relationship

You have learned that the strength of the bonds that hold the particles together in a solid compound are directly related to the compound's melting temperature. As the bonds get stronger, the melting temperature gets higher. Bond strength impacts other properties, one of which is vapor pressure, or to simplify, how easily a liquid evaporates. The stronger the bonds between particles the longer it takes a liquid compound to evaporate, which means "turn into a gas." Your challenge is to design a procedure to determine if water of isopropyl alcohol has stronger bonds between particles. You will need just a small amount of both compounds.

To complete this Experimental Challenge, follow these steps:

1. Form a working group with other students and discuss the following questions.

    a. What variables should be controlled (kept constant) during the procedure?

    b. The independent variable in an experiment is the one changed by the experimenter, while the dependent variable responds to or depends on the changes in the independent variable. Name the independent and dependent variables in this experiment.

2. List the steps you will take to gather the data to help make your decision. Carry out the procedure and record your observations. Does water or isopropyl alcohol have stronger bonds between particles? Explain.

Post Lab Questions

1. Consider the fact that O_2 exists in its natural state as a gas, with the oxygen molecules far apart from each other and constantly moving in random directions. Do you think the oxygen molecules in a sample of air are bound tightly or weakly together? Explain.

2. Consider O_2 and N_2, the two main components of the air we breathe. Based on the models you built do you think it takes more energy to separate the O atoms in the O_2 molecule, or the N atoms in the N_2 molecule? Explain.

3. When ethane burns it combines with oxygen molecules in a chemical reaction to form carbon dioxide molecules and water molecules. What does this tell you about what happens to the bonds between atoms when molecules react to form new molecules?

Blood Types and Inheritance Patterns

Introduction

Blood type is determined by which proteins are present on the surface of the red blood cell. There are three possible proteins called antigens that can be present: A, B, and Rh factor. If antigen A is present on the red blood cells, it is Type A blood. If antigen B is present on the red blood cells, it is Type B blood. If both antigens A and B are present on the red blood cell, it is Type AB blood. If neither antigen A nor B are present, it is Type O blood. The presence of the Rh factor determines if the blood type is + or -. For example, Type A+ blood would have both A antigens and the Rh factor present, while Type A- blood would only have A antigens and no Rh factor.

Just like other traits, blood type is inherited. This means that you get one allele from mom and one from dad. This can be used to determine paternity of the offspring if the blood types of the parents and child are known.

Concepts

- Blood Types
- Complete Dominance
- Codominance
- Punnett Squares

Background

A person's blood type is determined by which proteins are present on the surface of their red blood cells. There are 8 possible blood types: O+, O-, A+, A-, B+, B-, AB+, and AB-. There are three possible proteins that can be on the surface of the red blood cell: A, B and Rh factor. These proteins are called antigens. People with Type A blood have the A antigen present on their red blood cells. People with Type B blood have the B antigen present on their red blood cells. People with Type AB blood have both the A and B antigen present on their red blood cells. People with Type O blood have neither the A nor the B antigen present on their red blood cells. A positive blood type (O+, A+, B+, AB+) means that the Rh factor is present on the blood cells, while a negative blood type (O-, A-, B-, AB-) means the Rh factor is absent.

Just like all traits, blood type is inherited from parents. Because there are many possible blood types, the inheritance pattern is a little complicated. The A and B antigen show complete dominance to O, but are codominant together. Complete dominance means that when both alleles are present, the dominant allele will be expressed, while the recessive allele will not be expressed. This means that if one A antigen allele is inherited from mom and one O allele is inherited from dad, the child's blood type will be Type A. The same is true if one B allele and one O allele are inherited, the offspring will have Type B blood.

Antigens A and B are codominant. This means that when both alleles are present, they will both be expressed. Because A and B are codominant, if one A allele is inherited from one parent and one B allele is inherited from the other parent, the offspring would express both alleles, meaning they would have Type AB blood: both A and B antigens will be present on the surface of their red blood cells.

Punnett squares can be used to predict the possible blood types of offspring if the genotypes of both parents are known. If a person has Type AB blood, their genotype will be AB; they have one A allele and one B allele. If a person has Type O blood, they must have the genotype OO; they have two O alleles. If a person has Type A blood, they may have the genotype AA (two A alleles) or AO (one A allele and one O allele). This is because A is completely dominant to O and therefore the person will still have Type A blood. The same is true for a person with Type B blood. They may have the genotype either BB or BO. For both Type A and Type B blood, we must know the correct genotype before the Punnett square is set up.

To use a Punnett square, the genotype of one parent is listed across the top of the grid and the genotype of the other parent is listed down the side. The four squares are then filled in by writing the alleles from the parents that are above the square and to the left of the square. The results show the possible genotypes of the offspring of the parents.

Blood type is one tool that can be used to determine the paternity of a child. If we know the blood type of the mother and the child, we can use a Punnett square to help determine whether the other person in question could be the father. For example. If the mother has Type O blood and the child has Type B blood, the father could have either Type B or Type AB blood. However, the father could NOT have Type O or Type A blood as those blood types combined with the mother's blood type could NOT result in a child having Type B blood.

Experiment Overview

In this experiment, you will start by creating models of the eight possible blood types. You will then complete several Punnett squares involving parents with different blood types. In the analysis section, you will then use what you know about blood types and their inheritance patterns to determine the paternity of a child.

Materials

- Styrofoam Balls, 1.5", 8
- Push Pins

Pre-Lab Questions

1. What is found on the surface of a red blood cell that determines a person's blood type?
2. What antigens are found on the surface of a red blood cell who has type AB+ blood?
3. What antigens are found on the surface of a red blood cell who has type A- blood?
4. What antigens are found on the surface of a red blood cell who has type B+ blood?
5. What antigens are found on the surface of a red blood cell who has type O- blood?

Safety Precautions

Be careful when using pushpins as they are sharp.

Procedure

Part A – Introductory Activity

1. Choose three colors of push pins to represent the A antigen, B antigen, and Rh factor.
2. Add the appropriate push pins to the Styrofoam ball to represent each blood type using table 1.

Table 1

Blood type	A Antigen	B Antigen	Rh Factor Antigen
O+	X	X	Yes
O-	X	X	X
A+	Yes	X	Yes
A-	Yes	X	X
B+	X	Yes	Yes
B-	X	Yes	X
AB+	Yes	Yes	Yes
AB-	Yes	Yes	X

3. Describe what you notice about the blood types.

4. List the possible genotypes for the following blood types:

Blood Type	Genotype(s)
Type A	
Type B	
Type AB	
Type O	

Part B -Experimental Challenge

5. Create a Punnett square that shows the possible offsprings of a person with Type A blood (genotype: AO) and a person with Type O blood.

   a. What is the chance that their offspring will have Type A blood?

   b. What is the chance that their offspring will have Type O blood?

c. What is the chance that their offspring will have Type B blood?

6. Create a Punnett square that shows the possible offsprings of a person with Type O blood and a person with Type AB blood.

a. What is the chance that their offspring will have Type A blood?

b. What is the chance that their offspring will have Type O blood?

c. What is the chance that their offspring will have Type B blood?

d. What is the chance that their offspring will have Type AB blood?

7. Create a Punnett square that shows the possible offsprings of a person with Type A blood (genotype: AO) and a person with Type O blood.

a. What is the chance that their offspring will have Type A blood?

b. What is the chance that their offspring will have Type O blood?

c. What is the chance that their offspring will have Type B blood?

8. Create a Punnett square that shows the possible offsprings of a person with Type A blood (genotype: AO) and a person with Type B blood (genotype: BO).

a. What is the chance that their offspring will have Type A blood?

b. What is the chance that their offspring will have Type O blood?

c. What is the chance that their offspring will have Type B blood?

d. What is the chance that their offspring will have Type AB blood?

Post Lab Questions

1. A mother with Type O blood has a child with Type A blood.
   a. What is the genotype of the mother?

   b. What is the genotype of the child? How do you know?

   c. What are the possible genotypes of the father? How do you know?

2. Three possible fathers have their blood type taken. Man 1 has blood Type O. Man 2 has blood Type B. Man 3 has blood Type AB. Based on what you know, which man could be the child's father? How do you know?

Build Your Own Spinning Pyramid

Introduction

What makes a merry-go-round spin? What about a ceiling fan or a boat propeller? All these objects require a source of energy to cause them to spin. You may have correctly answered that electrical energy or electricity is what makes a merry-go-round, a ceiling fan, or a boat propeller rotate; however, there are other energy sources that can be used to make objects spin, such as wind and steam.

Figure 1. Windmills are powered by the kinetic energy of winds.

In this investigation, you will build a spinning pyramid that spins due to the movement of hot air. The challenge of this investigation is to optimize the design of the spinning pyramid to make it spin faster and continuously!

Concepts

- Air Convection
- Energy Conversion
- Heat Transfer
- Kinetic Energy
- Motion
- Rotational Motion

Background

Wind is the natural movement of air relative to Earth's surface. Wind is something that can be easily experienced because we can feel it on our skin, blowing away our hair, and making water waves form in oceans or lakes. But why does air move at all causing winds?

Air is composed of various gases, mainly nitrogen and oxygen; when the air temperature increases due to the heat coming from the sun, its gas molecules move at higher speeds and the air expands. Heat makes the air less dense or lighter than cooler air, and thus hot air tends to rise to higher altitudes in the atmosphere. As hot air moves higher in the atmosphere, its temperature starts to decrease—it cools down—and becomes heavier, so it begins to move downward. This process in which hot air moves upward while cold air moves downward is known as *convection*, and it is responsible for the formation of winds.

Winds can push and move objects around. The energy of winds can be transformed into more useful forms of energy; for example, a windmill is a structure that transforms wind's energy into rotational kinetic energy. This rotational kinetic energy can then be used to mill (grind) grain.

In this investigation, you will build a spinning pyramid that uses air convection as the source of kinetic energy. You will propose and test modifications to the initial design to make the spinning pyramid rotate in a continuous and steady manner.

Experiment Overview

In this investigation, you will build and optimize a spinning pyramid that uses air convection as the source of kinetic energy.

Materials

- Aluminum pie pan, 2
- Candle lighter, or matches
- Double-sided tape
- Dowel rod
- Modeling clay
- Pen, or fine tip marker
- Pushpin
- Ruler
- Scissors
- Spinning pyramid template
- Tea candles, 6

Pre-Lab Questions

1. When the air gets heated up it becomes less dense, or lighter. In which direction will hot air move with respect to the ground?

2. Cold air is denser—or heavier—than hotter air. In which direction does colder air move with respect to the ground?

Safety Precautions

Please follow all laboratory safety guidelines. Wear safety glasses. Tie back long hair. Do not eat or drink anything in the lab. Do not play with fire or flame sources and keep flames away from you and your classmates. Wash hands thoroughly with soap and water before leaving the laboratory.

Procedure

Part A. Introductory Activity

Follow these steps to build your own spinning pyramid:

1. Cut the spinning pyramid template along the solid lines. Do not cut along the dotted lines; these are folding lines only.
2. Carefully cut the circular bottom of one of the aluminum pie pans. Keep the aluminum foil flat and free of wrinkles while you do this. Be careful not to cut yourself with the scissors or the aluminum foil edges.
3. Use double sided tape to attach the spinning pyramid template to the aluminum foil circle. Then, cut along the edges of the aluminum foil to make it into a circle that is the same size as the spinning pyramid template.
4. Cut through the template and the aluminum foil circle along the solid lines only.

5. Carefully fold the aluminum foil along the dotted lines. Do this on a flat, hard surface like a lab bench or desktop. You may use a small ruler to help you fold along these dotted lines.
6. Hold the aluminum foil circle horizontally and ensure that the folded part of each blade forms an angle of approximately 30–45° with respect to an imaginary vertical line.
7. Gently remove the paper template and double-sided tape from the aluminum fan. Once the paper template and tape have been removed, make sure the aluminum fan keeps the initial shape and folds made in previous steps.
8. Pierce the center of the aluminum fan using the pushpin. Wiggle the pushpin to widen the hole so that it is slightly wider than the needle of the pushpin.
9. Carefully insert the pushpin needle into one end of the 15 cm-long Dowel rod such that the rod is perpendicular to the aluminum fan. Do not press the pushpin all the way into the Dowel rod; the aluminum fan should be able to spin freely without wobbling up and down too much.
10. Set the second aluminum pie pan on a flat surface (lab bench or desktop) and mark the center of the circular bottom using a pen or marker.
11. Knead some modeling clay and stick it to the center of the aluminum pie pan. Shape the modeling clay into a cone-shaped pile.
12. Then, stick the bottom end of the Dowel rod into the modeling clay and knead the clay around it until it sits straight up and steadily on the pan.
13. Place two candles inside the aluminum pan surrounding the base of the spinning pyramid but not directly in contact with the modeling clay. Use a pen or marker to mark the positions of the candles.
14. Carefully light the candles using a lighter or matches. Observe carefully what happens during the first five minutes after lighting the candles and write any observations in **Table 1**.

Table 1. Spinning Pyramid Observations

Observations

Part B. Experimental Challenge

Congratulations! You have built your own spinning pyramid.

Now your challenge is to get the spinning pyramid to spin.

15. If your spinning pyramid is not rotating, think about possible reasons why this may be happening. Record one or two possible reasons for this and how you could test if these are real causes for the pyramid's lack of movement.

16. Test the reasons you described in step 15 and record your results.

Post Lab Questions

1. Is there any relationship between the number of candles used and the rotation of the spinning pyramid? Explain your answer based on your own observations and results.

2. Draw a sketch of the spinning pyramid and use arrows to indicate the direction in which the hot air moves and the direction in which the blades move.

3. What makes the spinning pyramid rotate? To write your explanation, consider what happens when the air's temperature increases. Also, think about how air causes objects to move, or recall how a windmill works.

4. What forms of energy are involved in the rotational movement of the spinning pyramid?

5. What energy transformations are involved in the rotational movement of the spinning pyramid? Describe as many energy transformations as you can identify.

P.O. Box 219 • Batavia, IL 60510
(800) 452-1261 • Fax (866) 452-1436
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Colorful Salting Out

Chemical Demonstration Kit

Introduction

Two immiscible colorless liquids are in a bottle. A green marker is added to the bottle and the contents shaken, dying the solutions inside. With the marker again removed the solutions are now observed to be yellow and blue. Give the bottle a shake and the solution turns back to green. The layers then slowly return to yellow and blue.

Concepts

- Chromatography
- Non-polar vs. polar
- Solutions
- Immiscibility

Materials

Isopropyl alcohol, reagent, 500 mL*

Sodium chloride, 100 g*

Water, distilled or deionized

Balance, 0.1 g precision

Bottle with cap, plastic, 1 L*

Forceps, large

Funnel

Graduated cylinder, 500 mL, 2

Green marker*

*Materials included in kit.

Safety Precautions

Isopropyl alcohol is a flammable liquid and a fire hazard. It is slightly toxic by ingestion and inhalation. Wear chemical splash goggles, chemical-resistant gloves and a chemical-resistant apron. Wash hands thoroughly with soap and water before leaving the laboratory. Follow all laboratory safety guidelines. Please review current Safety Data Sheets for additional safety, handling and disposal information.

Preparation

1 Add 90 g of sodium chloride to the bottle.
2. Add 400 mL of distilled or deionized water to the bottle.
3. Cap the bottle and shake until the sodium chloride is mostly dissolved.
4. Add 400 mL of isopropyl alcohol to the bottle.
5. Cap the bottle tightly and shake to thoroughly mix the solution. Caution: Pressure may build up while shaking. Slightly loosen the cap to relieve the pressure then tighten the cap again.

Procedure

1. Present the bottle to the students and allow them to write down initial observations, completing questions 1–4 on the Colorful Salting Out worksheet.
2. Uncap the bottle and add the marker.
3. Recap the bottle and shake vigorously.
4. Uncap the bottle and remove the marker before recapping it (you might find it useful to have forceps on hand to remove the marker).
5. Have the students write down their observations.
6. Shake the bottle vigorously to completely mix the two liquids and place it on the table.
7. Once again have students record their observations.

Disposal

The bottle may be reused for many years, although only the first group of students will get to see you adding the marker.

Tips

- This kit contains enough materials to create one demonstration bottle.
- The cap may be glued onto the bottle to prevent opening, spillage or tampering.

Discussion

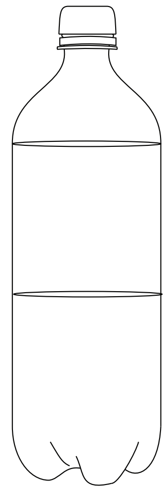
Water and isopropyl alcohol are miscible liquids that form strong hydrogen bonds. When sodium chloride is added to the solution, the ionic solid dissociates. The ions attract the water molecules and disrupt the hydrogen bonds between the water and isopropyl alcohol molecules. As two liquid layers separate, the isopropyl alcohol/water solution will appear on top of the more dense aqueous sodium chloride solution. The phenomenon is known as salting-out and is widely used to separate and purify organic compounds from aqueous mixtures. It is also used to precipitate proteins from aqueous cell extracts.

The pigments in the marker have different chemical structures and polarities. The polar blue pigment interacts positively with the polar sodium chloride solution and is primarily found in this region. Whereas, the non-polar yellow pigment is primarily found in the less polar isopropyl alcohol/water layer.

When the bottle is shaken, a nearly homogenous mixture of isopropyl alcohol and sodium chloride solution is formed, this type of homogeneous mixture is known as an emulsion. The emulsion recombines the two pigments and the original green color of the marker is observed. After the bottle is set down the emulsion starts to separate back into the two separate layers with the yellow layer on top and the blue layer on the bottom.

Answers to Discussion Questions *(Answers will vary.)*

1. Draw a diagram of the bottle and its contents as presented by your instructor.



2. Isopropyl alcohol and saturated sodium chloride solution have different densities. One has a density of 0.785 g/mL and the other 1.2 g/mL. How can you infer from your diagram which is denser?

   The more dense material will be on the bottom of the bottles. Materials with greater density sink to the bottom.

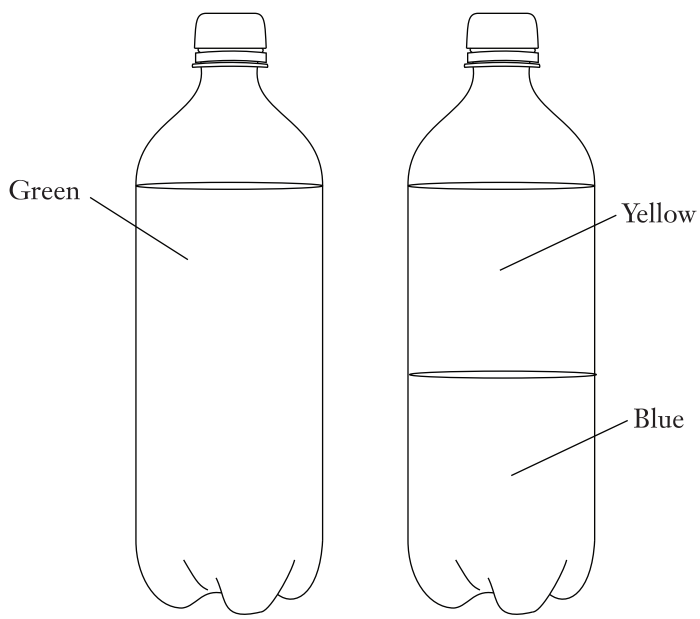
3. Predict what will happen after the marker is added to the bottle.

   When the marker is added to the bottle the color of the layers will change. The top layer will turn yellow, and the lower layer will turn blue.

4. Predict what will happen if the bottle is shaken and set back down.

   When the bottle is shaken the two colored layers will form and green emulsion. On standing they will separate back into the two different colored layers.

5. Draw diagrams of the bottle immediately after it was shaken and long after the bottle was shaken.

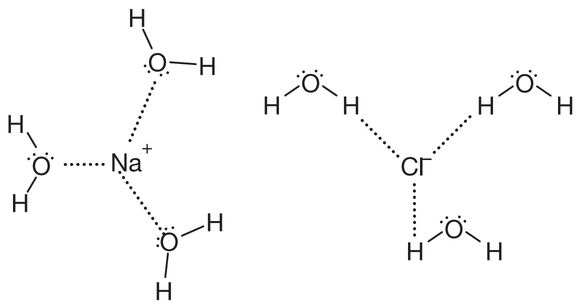


6. Write a possible explanation for what happened when the bottle was shaken and set back down.

   When the bottle was shaken, the isopropyl alcohol and sodium chloride solution mixed completely, making a temporary homogenous solution of uniform polarity. This combined the two colored pigments to give a green solution. On standing, the two layers separate and the pigments are again found in the layers that the result in the strongest intermolecular forces.

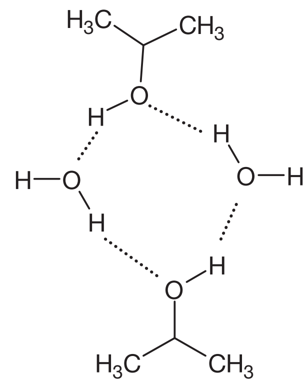
7 (*Optional*) Draw separate molecular diagrams of how sodium chloride and isopropyl alcohol would interact in water. Identify the types of intermolecular attractions within each diagram.

Sodium chloride in water



Ion–dipole interactions

Isopropyl alcohol in water



Hydrogen bonding interactions

8. (Optional) Based on previous answers, which colored pigment do you think is the most polar.

   The lower layer, containing the sodium chloride solution, is the more polar of the two. Since this layer is blue, and the upper layer yellow, it is reasonable to conclude that the blue pigment is more polar than the yellow.

Acknowledgment

Special thanks and acknowledgement to Kathryn Robles, Troy High School, MI for her assistance in the development of this demonstration.

The *Salting Out—Density Bottle Demonstration Kit* is available from Flinn Scientific, Inc.

Catalog No.	Description
AP9831	Colorful Salting Out—Chemical Demonstration kit
OB2138	Flinn Scientific Electronic Balance, 300 x 0.1-g

Consult your *Flinn Scientific Catalog/Reference Manual* for current prices.

Name: ______________________________

Colorful Salting Out

Discussion Questions

1. Draw a diagram of the bottle and its contents as presented by your instructor.

2. Isopropyl alcohol and saturated sodium chloride solution have different densities. One has a density of 0.785 g/mL and the other 1.2 g/mL. How can you infer from your diagram which is denser?

3. Predict what will happen after the marker is added to the bottle.

4. Predict what will happen if the bottle is shaken and set back down.

5. Draw diagrams of the bottle immediately after it was shaken and long after the bottle was shaken.

6. Write a possible explanation for what happened when the bottle was shaken and set back down.

7. (Optional) Draw separate molecular diagrams of how sodium chloride and isopropyl alcohol would interact in water. Identify the types of intermolecular attractions within each diagram.

8. (Optional) Based on your previous answers, which colored pigment do you think is the most polar.

Crazy about Chromatography

Introduction

Black is the lack of color–or is it? In this lab, you will separate three black ink mixtures from water-soluble, felt-tip pens or markers. Then, in the challenge activity you will produce a radial paper chromatography image.

Concepts

- Chromatography
- Separation of a mixture
- Physical properties

Background

Many common materials are made up of mixtures of compounds. Separating mixtures to determine the identity of one or more compounds has many practical applications in the fields of medicine, law enforcement, and manufacturing. It is often difficult to separate mixtures if the compounds are chemically similar. *Chromatography* is a technique used to identify and analyze components of a mixture.

Paper chromatography is a type of chromatography called adsorption chromatography. The paper acts as an *adsorbent,* a solid which can attract and stick with the components in a mixture (think of the word adhere). The solvent carries the materials to be separated through the adsorbent. In this lab, the solvent will be water.

The mixture to be separated is “spotted” onto the surface of the paper and water is then allowed to seep through the paper. As the components of the mixture dissolve in the water, they will travel up the paper at different rates depending on their physical properties. If one of the components in the mixture is more strongly attracted onto the paper than another, it will spend less time in solution and will move up the paper more slowly than the water. Components that are not strongly attracted onto the paper will spend more time in solution and will move up the paper at a faster rate. This separates the components and gives rise to different bands, depending on their physical attraction for the paper versus the solvent (water). If the components of the mixture are colored, the bands are easy to see.

Radial chromatography is a technique using a paper circle with a hole in the center. Ink is spotted onto the circle. A paper "wick" is inserted into the hole and then placed in a cup of water, making sure the paper circle does not come in direct contact with the water (Figure 1). The water seeps up the wick, then outward through the paper. The different pigments making up the ink mixtures will separate in a circular (radial) pattern. The resulting pattern is called a *chromatogram*.

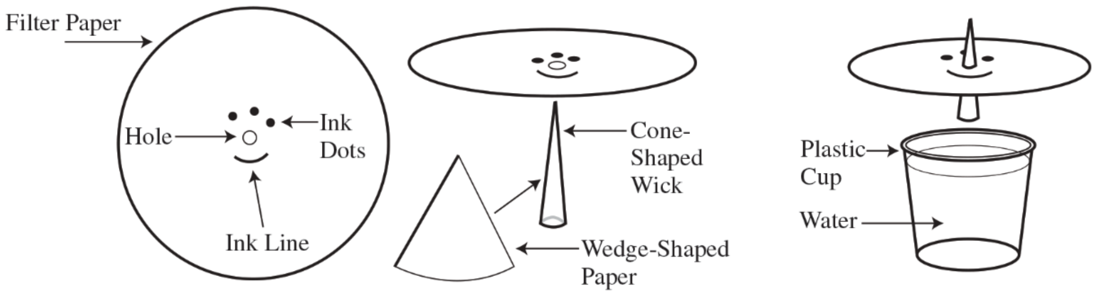


Figure 1. Radial Paper Chromatography

Experiment Overview

The purpose of this lab is to study the separation of mixtures by physical properties. In the introductory activity, students will investigate the ink of three black markers or pens. Then, in the challenge activity, students will produce a radial paper chromatography image based on their results from the introductory activity.

Materials

- Colored pencils (optional)
- Cups, plastic 30-mL, 2
- Cups, plastic 16 oz, 3
- Filter paper, 12.5 cm diameter, 4
- Graduated cylinder, 50-mL
- Markers and pens, black, water-soluble, various types, 3
- Paper clip (optional)
- Paper towels
- Pencil
- Ruler, metric
- Scissors
- Stapler
- Tape (optional)
- Water
- Wooden splints, 3

Pre-Lab Questions

1. Define the following three terms: chromatography, solvent, and adsorbent.

2. Draw a picture of the radial chromatography final set up and label all the parts.

3. What will be the adsorbent in this activity? What will be the solvent?

Safety Precautions

Although the materials in this activity are considered nonhazardous, please observe all normal laboratory safety guidelines. Wash hands thoroughly with soap and water before leaving the laboratory.

Procedure

Part A. Introductory Activity

1. Cut three strips of filter paper from one piece of filter paper, as shown below with the dotted lines in Figure 2.

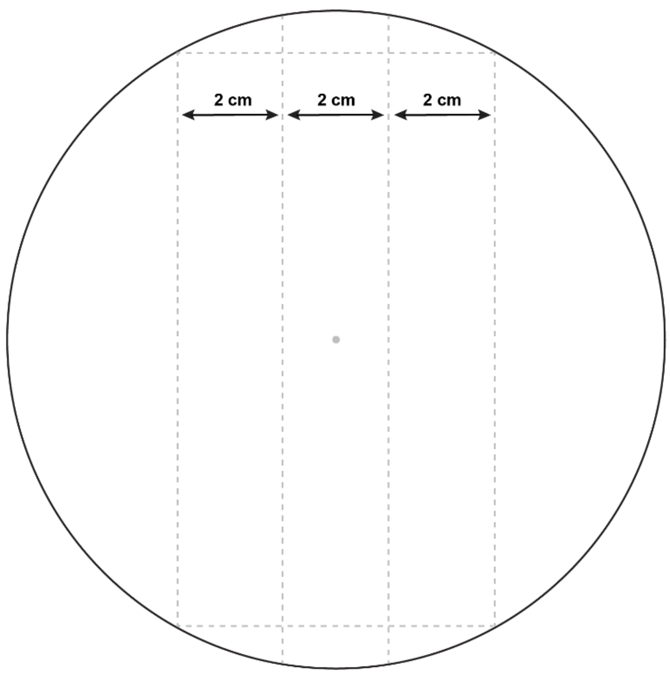


Figure 2. Cutting the Filter Paper Strips

2. Using a pencil, lightly draw a line across the width of each strip, 2 cm from one end (see Figure 3a).

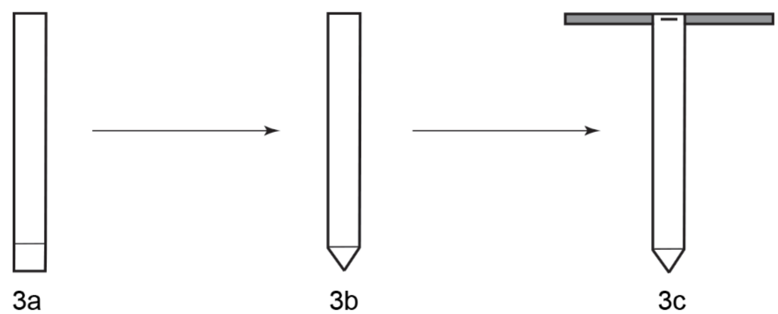


Figure 3.

3. Cut off the bottom corners of each strip to create a point, as shown in Figure 3b. Staple or tape the strip to a wooden splint as shown in Figure 3c. Repeat for all three strips.
4. Add 25 mL of water to each 16 oz. plastic cup.
5. Using a pen or marker, place a small dot on the center of the drawn line on one chromatography strip.
6. Using a pencil, label what pen or marker you used at the top of the strip or on the wooden splint.

7. Slowly lower one filter strip into the plastic cup. See Figure 4. The sample spot should remain above the solvent (the water). If it is not, your sample will dilute into the water. If the water is not high enough, remove the filter strip and add more water in 5 mL increments until the water touches the bottom point of the filter strip.

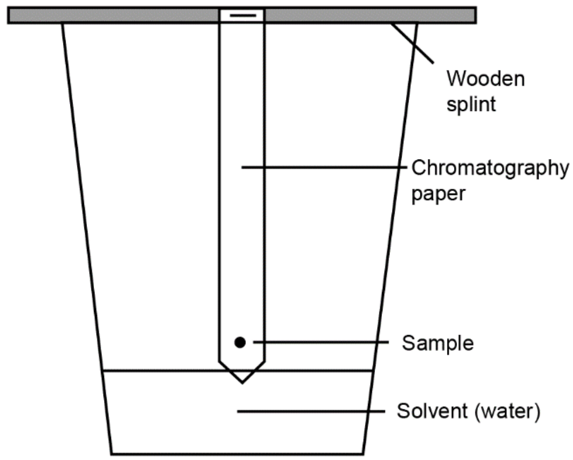


Figure 4.

8. Repeat steps 5-7 for two more different pens or markers (one pen/marker dot per strip).
9. Allow the filter strips to run until the water line reaches approximately 1 cm from the top of the paper (about 15-25 minutes).
10. Take pictures or sketch your results with colored pencils.
11. Share with at least two other groups to get the results of all eight markers.

Data Table 1.

Pen/Marker	Color(s) Observed	Photo or Sketch (with colored pencils)

Part B. Challenge Activity

12. Different designs and patterns can be made with radial chromatography. For example, see Figure 5 for two versions made with a variety of markers and pens.

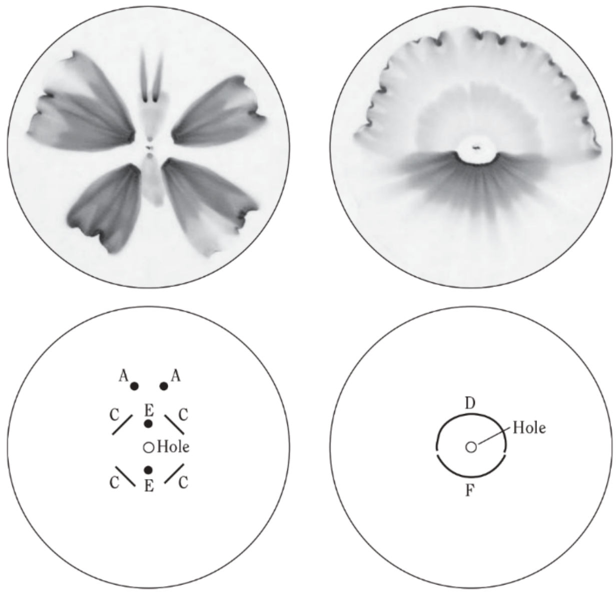


Figure 5.

13. The different letters, in Figure 5, correspond to different markers. Ink formulations are constantly changing, use what you discovered in Part A to decide what markers and pens to use to make your own artwork.

14. Your teacher also has some additional example artwork to reference for more ideas.

15. Discuss with your group and decide on two designs.

16. To make your radial chromatography designs follow the following steps:

a. Obtain a piece of filter paper.

b. Using a sharp pencil, paperclip, or pushpin, poke a small hole in the center of the filter paper.

c. Fill a 30-mL plastic cup to within about 1 cm from the top with tap water.

d. Starting at least 5 mm from the center hole, place a small but concentrated spot of ink from a water soluble marker or pen onto the paper. The “spot” may be a dot, a wedge, a short line, an arc, etc. See Figure 5 for an example.

e. Obtain a wedge piece of paper from your teacher and roll up the filter paper wedge into a tight cone. Insert the cone-shaped “wick” into the hole in the center of the filter paper. See Figure 1 for reference.

f. Set the prepared filter paper circle on top of the water-filled cup. When the water has advanced to within 1-2 cm of the outer edge of the filter paper (about 10-15 minutes), carefully lift the chromatography image and set it on a paper towel to dry.

17. Take a photo or sketch your artwork below. Use colored pencils, if desired.

18. If time allows, try making another radial chromatograph! Your group has enough supplies to make a total of three designs for this challenge activity.

Post Lab Questions

1. List the brand of each pen tested in this activity and record the colors observed. For each pen, list the colors (pigments) from least mobile to most mobile. The least mobile pigments will be the ones closest to the dots or lines made – these pigments have the greatest attraction to the paper. The most mobile will be closest to the outside or top edge of the papers.

2. Why does an ink separate into different pigment bands?

3. Do any of the pens or markers appear to contain common pigments? How can you tell if similar-colored pigments from different pens are actually the same compound? Do any similar-colored pigments appear to be different compounds?

4. Why were only water-soluble markers or pens used in this activity?

5. When the inks separate, is this a chemical change or a physical change?

Discover Newton's Second Law

Introduction

Newton's second law of motion states that an object or system's acceleration is equal to the net force applied to the object or system divided by the object or system's mass.

$$\vec{a} = \frac{\Sigma\vec{F}}{m} \qquad \textit{Equation 1}$$

Thus, if the same force were applied to two objects of different mass, the less massive object would experience a greater acceleration. In this lab you will discover this relationship first-hand!

Concepts

• Experimental Design	• Force and Acceleration
• Variables - control, dependent, independent	• Direct and Inverse Relationships
• F = ma	• Graphing Data

Background

Force and Acceleration

Multiple forces acting in complex systems may be added together to find the resulting acceleration. Acceleration along a given axis can only be the result of all the forces in that axis. Forces in the y direction will not affect acceleration in the x-direction, and vice versa. For example, consider a game of tug-of-war between two teams pulling on a rope with great force. The system will often experience very little acceleration because the two forces are acting in opposition along the same axis.

Free body diagrams are often used to describe the forces that act on objects. For example, the Atwood's machine in Figure 1 consists of two masses connected with a string suspended on a two-pulley system. The machine was developed in the late 18th century to indirectly measure acceleration due to gravity. If the masses are equal, the net force acting on both masses in the y direction is 0 N and the system is static. However, if one of the masses is heavier than the other, the lighter mass will accelerate up and the heavier mass down owing to a net nonzero force in the y direction. In this lab, a modified Atwood's machine, shown in Figure 2, will be used to quantitatively explore the mathematical relationships associated with Newton's second law. The acceleration of a hanging weight system will be determined by recording the time it takes the weight to travel a measured distance.

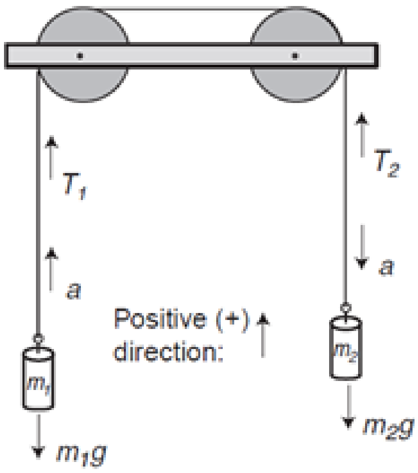


Figure 1.

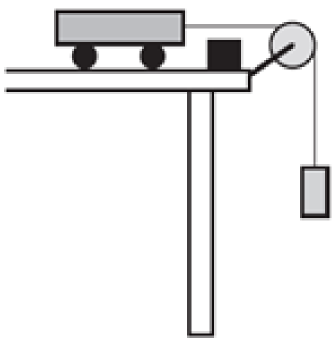


Figure 2.

The acceleration can be calculated by assuming free-fall conditions and assigning an initial velocity of 0 m/s to the system. As a result, the traditional equation (Equation 2), which describes the distance an object in free fall travels, reduces to Equation 3. You will use Equation 3 for the calculations needed in this lab.

Equation 2

$d = \frac{1}{2}at^2 + v_i t$

where
d is the distance the object moves (in m)
a is the acceleration of the object (in m/s^2)
t is the time (in seconds)
v_i is the initial velocity of the object

Equation 3

$a = 2d/t^2$

Experiment Overview

This activity's purpose is to gather data to discover what Newton first did, that the mass and acceleration of an object are related by the equation F = ma.

Pre-Lab Questions

1. If a cart travels 0.6 m in 2.4 s, what is its acceleration?

2. According to the equation a = bc, what type of algebraic relationship (direct or inverse) exists between the quantities a and c? Draw a simple graph to describe the relationship between a and c. Assume b is a constant.

Materials

• Balance, 0.1 g precision	• Plastic bag
• Hall's carriage	• String, 130 cm
• Meter stick	• Table pulley
• Timer	• Washers

Safety Precautions

While the activity is considered nonhazardous, protective eyewear is recommended because projectiles may be inadvertently launched during the activity. Please follow all normal laboratory safety guidelines.

Procedure

Introductory Activity

1. Measure and mark distances of 0.1 m and 1.1 m from the edge of a tabletop with a meter stick or ruler and masking tape. The cart will traverse this distance. The distance may be varied to accommodate the height of available tables. Low tables will require shorter distances.

2. Secure a table pulley to the table's edge.

3. Attach a plastic bag to one end of a string, approximately 130-cm long, using a looping knot. See Figure 3. Attach the other end of the string to the cart.

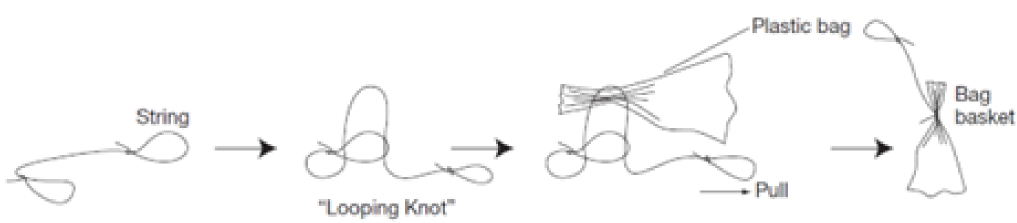


Figure 3.

4. Weigh one washer and place it inside of the plastic bag.

5. Add four washers to the cart and weigh.

6. Place the cart at the 1.1 m tape mark, farthest from the table pulley. Hold the cart in place and lay the string over the top of the pulley.

7. Release the cart and use a timer to time its travel between the tape marks.

8. Perform steps 6–7 ten times and display the collected mass and time data in Data Table 1.

9. Use Equation 3 to calculate the acceleration for each trial; and the average acceleration. Display the values in Data Table 1.

Data Table 1

Trial	**Time (s)**	**Acceleration (m/s^2)**
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
Average		

Experimental Challenge: Relationship Between Mass and Acceleration

By completing the introductory activity, you have learned how to use the materials provided to calculate the acceleration of a system. Your challenge is to use what you have learned to develop a simple procedure for determining the relationship between the mass and acceleration of the system.

To complete this Experimental Challenge, follow these steps:

1. Form a working group with other students and discuss the following questions.

   a. Using Newton's second law, F = ma, what variable should be held constant to determine the relationship between mass and acceleration?

b. How could the variable identified in the previous question be held constant?

c. What variable could be changed to study the relationship between acceleration and mass?

d. How can that variable be altered?

2. Write a step-by-step procedure to determine the relationship between the mass and acceleration of the cart-mass system. Identify the independent and dependent variables, and any variables that should remain constant.

Post Lab Questions

1. Construct a graph of mass versus acceleration using the data you collected in the Experimental Challenge part of the experiment.

2. What type of relationship do the data indicate exists between mass and acceleration?

3. Consider the equation F = ma. Explain why the value of a must decrease as m increases if F is held constant.

Egg Float

A Density Demonstration

Introduction

This classic and simple demonstration should allow students to start to visualize the difficult concept of density. This demonstration will pique interest and stimulate further activities to explore density.

Concept

- Density

Materials

Graduated cylinders, 500-mL, 3

Fresh eggs, 3 (medium sized)

Saturated sodium chloride, NaCl, 600 mL

Funnel, long-stem

Rubber or latex tubing to fit over the end of the long-stem funnel

Balance (optional)

Safety Precautions

Although the materials in this demonstration are considered nonhazardous, follow all normal laboratory safety guidelines.

Preparation

1. Prepare a saturated salt solution by slowly adding about 300 g of sodium chloride to 1000 mL of tap water. Stir. If all the salt does not go into solution, decant the solution.
2. Pour about 400 mL of tap water into the first 500-mL graduated cylinder.
3. Pour about 400 mL of saturated sodium chloride solution into the second 500-mL graduated cylinder.
4. Pour about 200 mL of tap water into the third 500-mL graduated cylinder.
5. Attach rubber or latex tubing to the end of a long-stem funnel so the end of the tubing will reach the bottom of a 500-mL graduated cylinder. Place the funnel into the third cylinder with only 200 mL of water. Make sure the tubing reaches the bottom of the cylinder.
6. Slowly add 200 mL of saturated sodium chloride solution through the funnel into the third graduated cylinder. Since the salt water is more dense than the tap water, it will form a layer below the tap water. If the salt water is added slowly, very little mixing will occur.
7. If necessary, adjust the level of the liquid in all three cylinders to be the same.

Procedure

1. Carefully lower a fresh egg into each of the three 500-mL graduated cylinders. The egg will sink in the tap water, float in the salt water, and settle at the interface of the salt and tap water layers in the third cylinder.
2. Try to push the egg to the bottom of the salt/tap water cylinder with a meter stick. Does the egg remain on the bottom? Why does it float back up to the middle of the cylinder?
3. *(Optional)* Mass the three graduated cylinders to demonstrate that each system has a different mass, but all have identical volumes.

Disposal

Please consult your current *Flinn Scientific Catalog/Reference Manual* for general guidelines and specific procedures governing the disposal of laboratory waste. The salt water may be disposed of according to Flinn Suggested Disposal Method #26b. Thoroughly wash the eggs after use.

Publication No. 10507
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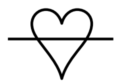
Tips

- Different eggs will have different densities depending on shell thickness and the size of the egg. Determine the density of the egg prior to the demonstration. This can be done by massing the egg and determining its volume by volume dis placement. Most eggs will have a density between 1.06 and 1.09 g/mL.
- The density of saturated sodium chloride is about 1.2 g/mL at 25 °C.
- If fresh eggs are not available, golf balls will also work. Golf balls have a density of about 1.15 g/mL.
- If students have difficulty remembering the density equation, try the following visual aid. Show them a drawing of a heart with a horizontal line through it. Tell them, “Density is mass over volume. If you can’t remember that, it will break my heart.” The line through the heart separates it into an M and a V. Yes, it is a “groaner,” but it works!

 $= \frac{m}{v}$

- Use good quality lab grade sodium chloride or kosher salt. Some lower quality sodium chloride (like rock salt) will give a cloudy solution.

Discussion

Density is a property of material representing the mass per unit volume. It is usually expressed in g/mL, or g/cm^3 or g/cc for solids and liquids, and g/L for gases. Specific gravity is the ratio of the density of a substance to the density of a reference material. For solids and liquids, the reference material is water which has a density of 1.0 g/mL or 1.0 g/cc. Specific gravity is a ratio of densities, and is therefore a dimensionless quantity—it has no units. Since the volume of many materials change with temperature, the literature values of density and specific gravity are usually reported at a given temperature.

Connecting to the National Standards

This laboratory activity relates to the following National Science Education Standards (1996):

Unifying Concepts and Processes: Grades K–12
Systems, order, and organization
Evidence, models, and explanation

Content Standards: Grades 5–8
Content Standard B: Physical Science, properties and changes of properties in matter, understanding of motions and forces

Content Standards: Grades 9–12
Content Standard B: Physical Science, structure and properties of matter, motions and forces

Acknowledgment

Special thanks to Kathleen Dombrink from McCluer North High School in Florissant, MO and Jeff Bracken from Westerville North High School in Westerville, OH for sharing this idea with us.

Materials for *Egg Float* are available from Flinn Scientific, Inc.

Catalog No.	Description
S0064	Sodium Chloride, Laboratory Grade, 2 kg
GP2030	Graduated Cylinder, Borosilicate Glass, 500-mL
AP1265	Graduated Cylinder, Polymethylpentene, 500-mL
GP5010	Long Stem Funnel, Glass

Consult your *Flinn Scientific Catalog/Reference Manual* for current prices.

Electrical Conductors and Insulators

Introduction

Why is the inside of wires used for electrical circuits made of thin metal threads? And why are the thin metal threads in these wires coated with plastic?

You may be familiar with the concept of electricity and how certain materials and objects allow electricity, or an electric current, to pass through them. Metals are known for their ability to conduct or allow electricity to travel through them. This is why wires used in electrical appliances and circuits in general are made with some type of metal.

Electrical conductivity is a physical property of matter that describes the ability of a material to allow electricity to pass through them. Materials that conduct electricity are called *conductors*; most metals are good conductors and even carbon, a non-metal, conducts electricity.

On the other hand, materials that do not conduct electricity are called *insulators*. Plastics, sand, and wood are examples of insulators.

In the laboratory, an instrument known as a conductivity meter is used to determine the electric conductivity of various types of materials including solids, liquids and solutions. In this investigation, you will build your own conductivity meter to test the conductivity of household solids and liquids.

Concepts

- Conductivity
- Conductor
- Electricity
- Electron
- Insulator
- Physical Properties

Background

Electricity is a type of energy—just like heat, sound, chemical, and nuclear energy. Electricity can flow or move in the form of electric currents, or it can be static and confined to an object or place. Static electricity or simply "static" is what you may experience as an electric shock when touching a doorknob during a dry, cold winter day.

Electricity is related to the presence of charges (negative or positive) in matter. To get a better grasp of what this means, one must think about the properties of matter at the level of atoms.

Atoms make up every material and living organism you can think of, yet they are tiny and invisible to the naked eye. Each atom has a nucleus made up of nuclear particles called protons and neutrons. Each proton has a positive charge (+) while neutrons—like the name neutron implies—are neutral and have no charge. Surrounding the atom nucleus are the electrons, which are much smaller than protons and neutrons. Each electron carries a negative charge (–).

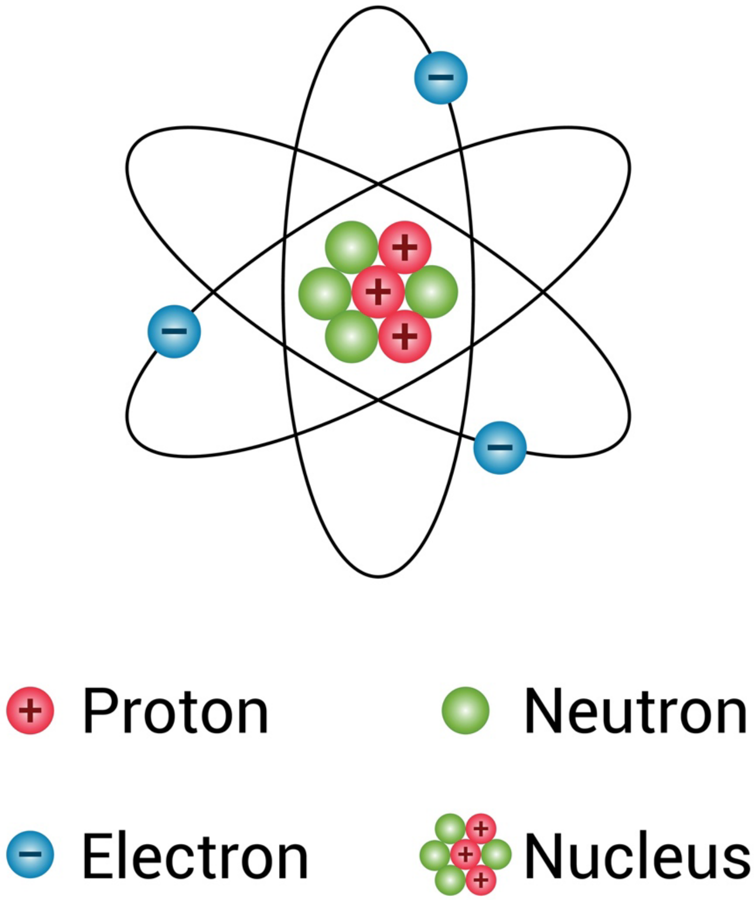


Figure 1. Model of an atom showing protons and neutrons in the nucleus (i.e., the core or center of the atom) and electrons surrounding the nucleus.

Atoms tend to have an equal number of protons and electrons, such that the number of positive (protons) and negative charges (electrons) are equal, and the atom stays neutral. However, some atoms may gain or lose electrons, and become negatively charged (gaining electrons) or positively charged (loosing electrons). When atoms become charged (positively or negatively), electrons tend to move or “jump” between atoms.

The continuous movement of electrons between atoms in a material is called an electric current. Metals like copper and gold are examples of materials in which electrons can easily move through forming electric currents. These types of materials are called *conductors*.

On the other hand, glass, wood, and pure water are examples of materials that do not conduct electricity. These materials are called *insulators* because electric currents can’t flow or pass through them.

In this investigation, you will build a conductivity tester to test various household substances and materials for their ability to conduct electricity.

Experiment Overview

In this investigation, you will build a small device that can be used to test the electrical conductivity of various household substances and materials.

Materials

- Button battery, 3.0 V
- Copper tape
- Fine tip marker, or pen
- LED light
- Paper clips, 3
- Paper cups, or small beakers, 2
- Ruler
- Scissors
- Small sample objects for testing, 5
- Table salt (sodium chloride)
- Tape
- Teaspoon, or scoop (optional)
- Water, distilled
- Wooden stick

Pre-Lab Questions

1. Lightning rods are used to protect buildings from structural damage that lightning may cause. A lightning strike or lightning bolt is a powerful discharge of electricity from the atmosphere to the ground. Lightning rods receive the electricity discharge from the atmosphere and direct it to the ground so that it doesn't pass through the building's structure.

Figure 2. Image of a lightning rod set on a roof.

If lightning rods are to protect buildings from lightning strikes, should lightning rods be made of materials that are conductors or insulators? Explain.

2. Why do electrical appliances such as straightening irons and hair dryers come with warning tags not to use them while in the shower or bathtub?

Safety Precautions

Please follow all laboratory safety guidelines. Wear safety glasses. Tie back long hair. Do not eat or drink anything in the lab. Use caution when handling scissors and other sharp objects such as metal wire and tape. Wash hands thoroughly with soap and water before leaving the laboratory.

Procedure

Part A. Introductory Activity

Follow these steps to build your conductivity tester:

1. To start, notice that the LED light has two prongs, one longer than the other. The longer prong is called the "anode" and it is represented or marked with a plus sign (+). The shorter prong is called the "cathode" and it is represented or marked with a negative sign (–).
2. Examine the battery and note that it has a positive and a negative side. The positive side is typically engraved with a plus sign (+), which leaves the opposite side as the negative one (–).
3. Place the battery between the LED prongs such that the positive (longer) prong on the LED is in contact with the positive side of the battery. The negative prong on the LED should contact the negative side of the battery. The LED should immediately light up. **Note:** If the LED doesn't light up, make sure the battery is correctly positioned between the LED prongs. If the light is not coming up still, invert the position of the battery between the LED prongs (see **Figure 3**).

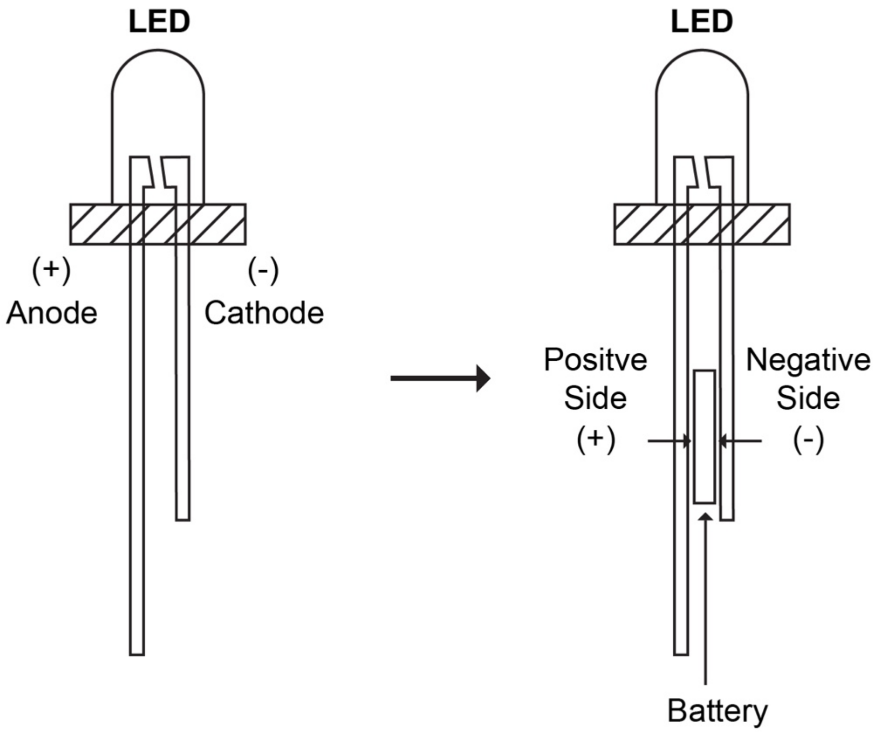


Figure 3. Testing the LED light with a battery.

4. Use scissors to cut two strips of copper tape. Each strip should have a length of approximately 14 cm.
5. Mount the LED on the end of the wooden stick so one prong extends downward on each side of the stick (see **Figure 4**). Use a marker to write a plus sign (+) on the side of the stick with the positive LED prong.

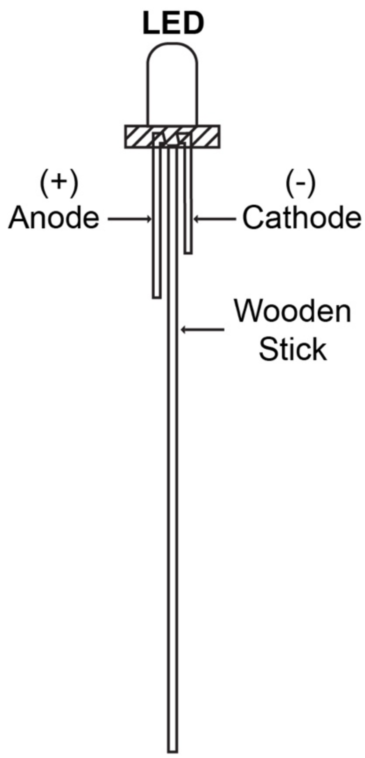


Figure 4. Mounting the LED on the wooden stick.

6. Gently peel the backing from one strip of copper tape and stick it to one side of the wooden stick, covering first the LED prong and then moving down the stick. Be sure to completely cover the prong of the LED so there is a permanent connection between the prong and the tape (see **Figure 5**).

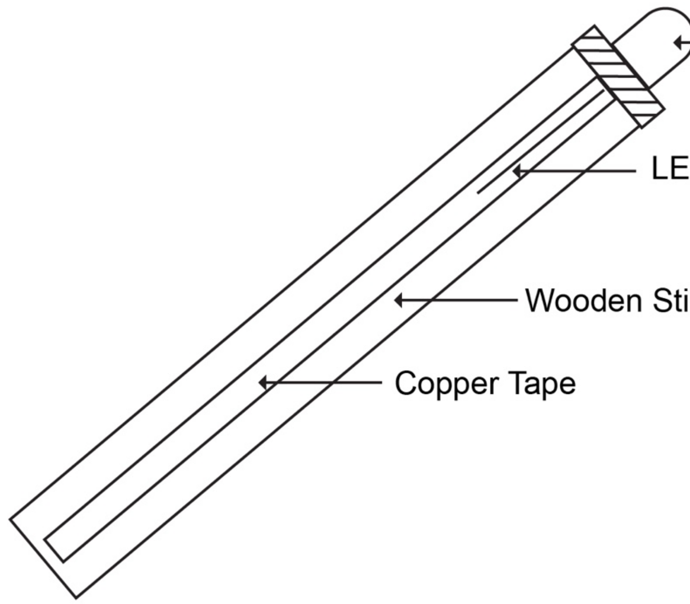


Figure 5. Using copper tape to attach the LED to the wooden stick.

7. Repeat step 7 with the other side of the wooden stick. Make sure to completely cover the LED prong with the copper tape strip on this side.
8. Place the battery with its negative pole on the side of the wooden stick that has the negative LED prong. The battery should be placed 1.0-1.5 cm from the bottom of the wooden stick. (see **Figure 6**).

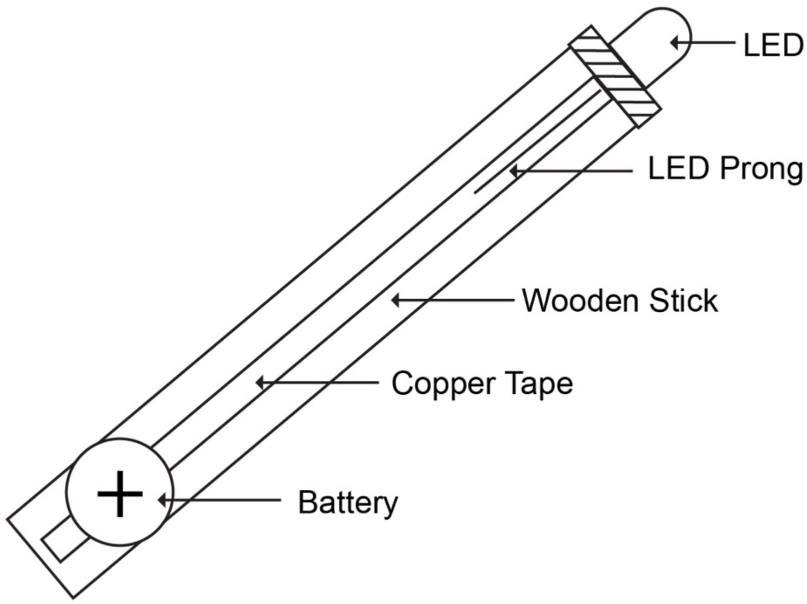


Figure 6. Adding the battery to the device.

9. Place a paper clip against the positive side of the battery, and another one on the opposite side of the wooden stick. About half the length of each paper clip should stick out from the bottom tip of the wooden stick.
10. Wrap a piece of tape around the paper clips and battery to hold them tight in place. At this point the device should look like the sketch show in **Figure 7**.

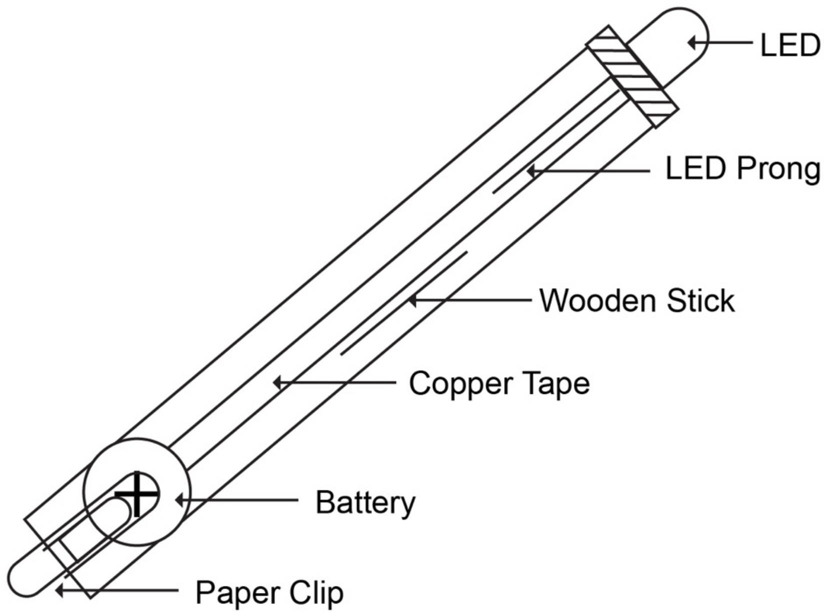


Figure 7. Diagram of the conductivity tester device.

11. To test your conductivity tester, touch the tips of the paper clips on the device with another paper clip. The LED should light up. The paper clip used to contact the two clips attached to the device closes the electric circuit loop of the device. When the loop is closed, electricity can flow from one side of the battery, through the LED and back into the opposite side of the battery.

Part B. Experimental Challenge

Congratulations! You have built your own conductivity tester device!

Now your challenge is to test the conductivity of different samples described in **Table 1**. Conductors will cause the LED on the conductivity tester to light up, while insulators will not cause the LED to emit light.

12. To test the electrical conductivity of each sample, touch the surface of the sample with the paper clip leads of the conductivity tester. Test all the dry samples first.

13. Now test the distilled water. Only the tips of the paper clips on the conductivity tester must be immersed into the liquid.

14. Dissolve one teaspoon of table salt (sodium chloride) in one cup of distilled water and test the conductivity of this solution.

Table 1. Electrical conductivity of various household substances and materials.

Sample	Conductor or Insulator?	Observations
Distilled Water		
Distilled Water + Table Salt		

Post Lab Questions

1. Reflect on the results and observations from the Introductory Activity. What happened when a third paper clip is used to contact both paper clips attached to the device? What is the role of this third paper clip?

2. Think about the objects and substances that you determined to be conductors or insulators in the Experimental Challenge.

   a. Why does the LED light up when both paper clips touch a conductor?

b. Why doesn't the LED light up when both paper clips touch an insulator?

Investigating Visible Light

Introduction

On Earth, our main source of light is the sun. Sunlight gives us the daytime and it is the source of energy that plants require to carry out photosynthesis. Incandescent light bulbs, candles, and fires are also common sources of light. And in the last century, humanity has gained access to other sources of light, including lasers and LEDs (light emitting diodes).

What do all these light sources have in common? What are the properties of the light produced by each one of these sources?

One thing you may quickly realize about the light that each of these sources emit is that it is light that is visible to most humans. Though you should never stare directly at the sun or laser beams, it is evident that these sources produce visible light, either white light or light of some color. Also, keep in mind that the sun produces ultraviolet light that the human eye cannot see.

How do scientists study light? And how can they determine the differences and similarities between light produced by different sources?

In this investigation, you will build a device to study the properties of visible light emitted by different sources!

Concepts

- Diffraction of Light
- Color Filter
- Light
- Light Spectrum
- Visible Light

Background

Visible light, or the light we can perceive with our eyes may come to us from the sun (sunlight), a fire, or some kind of lamp. The light from a laser pen or LED tends to be of a certain color like green or red, for example. Light from incandescent light bulbs or sunlight may appear white or simply be called *white light*. However, white light and visible light in general is typically composed of an array of colors.

If you have ever played with a prism or have looked at the shiny side of a DVD/CD in the light, you should have noticed that a multicolor, rainbow-like pattern appears as light passes through the prism, or as it reflects off the surface of the DVD/CD. In both cases, light is separated into its color components which shows up as a multicolor pattern that includes red, yellow, green, blue, and violet (see **Figure 1**).

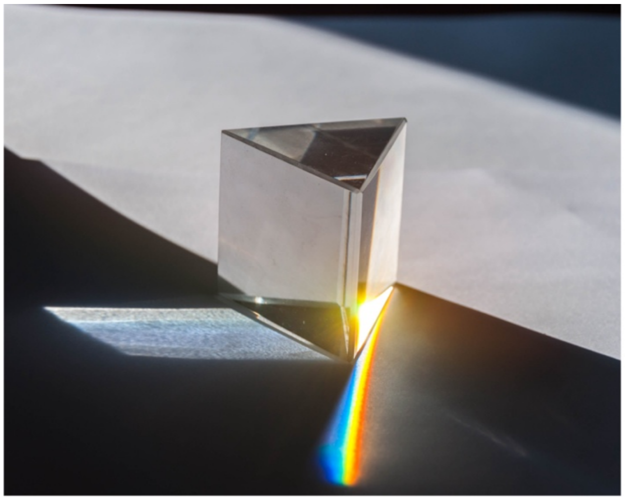


Figure 1. When sunlight passes through a prism, it bends and separates into its color constituents (left). The shiny surface of a DVD or compact disk (CD) also separates light into its components and reflects them back to your eyes.

Scientists have developed special instruments to analyze the properties of light from various sources. Generally, these instruments are known as spectroscopes or optical spectrometers. In this investigation, you are going to build a simple spectroscope to analyze the composition or *spectrum* of visible light produced by various light sources.

Your spectroscope will consist of a tube with a hole covered with a piece of a special material called a *diffraction grating* which can break up visible light into its color components. Once you build your spectroscope, you will be able to determine the similarities and differences of visible light emitted by different sources.

Experiment Overview

In this investigation, you will build a device to study the properties of visible light produced by various sources!

Materials

- C-Spectra, 1.5-cm square
- Cardboard tube (paper towel size)
- Cellophane tape
- Color filters
- Construction paper, black
- Electrical tape, black
- Hole puncher
- Light sources (candle, LED, etc.)
- Pencil
- Ruler
- Scissors

Pre-Lab Questions

1. When sunlight enters water droplets suspended in the air it gets separated into its color components. What colors of light can be seen when this happens?

2. The surface of CDs or DVDs like the one shown in **Figure 1** breaks up white light into its components causing the familiar rainbow pattern. What colors of light can be seen in this rainbow pattern?

3. If you could find a way to combine all the color components of light as it exits a water droplet (see pre-lab question 1) or the rainbow pattern (see pre-lab question 2) what would be the color of the resulting light? Explain.

Safety Precautions

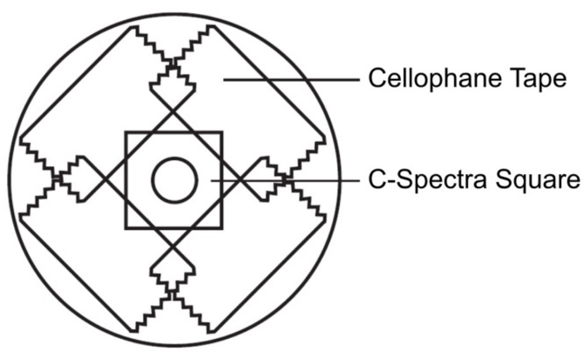
Please follow all laboratory safety guidelines. Tie back long hair. Do not eat or drink anything in the lab. Wash hands thoroughly with soap and water before leaving the laboratory.

Procedure

Part A. Introductory Activity

Follow these steps to start your investigation:

1. Using the end of the cardboard tube as a guide, trace two circles having the same diameter as the tube onto black construction paper.
2. Carefully cut out each circle, making sure the diameter is no smaller than the tube. Each circle must completely cover the open end of the tube.
3. Using the hole punch, make a hole in the center of one of the circles.
4. Cut a 1.5-cm square piece from the sheet of Flinn C-Spectra® (C-Spectra). **Note:** Wear gloves or hold the grating by the edges. Fingerprints and scratches will affect the results of the experiment.
5. Take the circle with the punched round hole and, holding the square of C-Spectra by the edges, cover the hole with the C-Spectra. Secure it to the paper circle with small pieces of cellophane tape. Do not place any tape over the part of the C-Spectra that will be visible through the hole (see **Figure 2**).

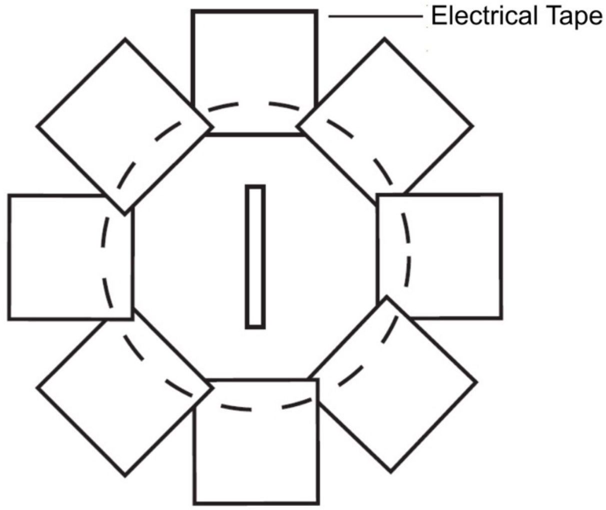


6. Use the electrical tape to secure the circle with the C-Spectra facing inward to one end of the cardboard tube. Use enough tape so that light enters the tube only through the hole, not around the edges.
7. Fold the other black circle in half and cut a 1-cm slit in the middle of the half-circle, starting at the fold.

8. Make an identical slit 1 mm from the first one, then cut the resulting small strip from the circle (see **Figure 3**).

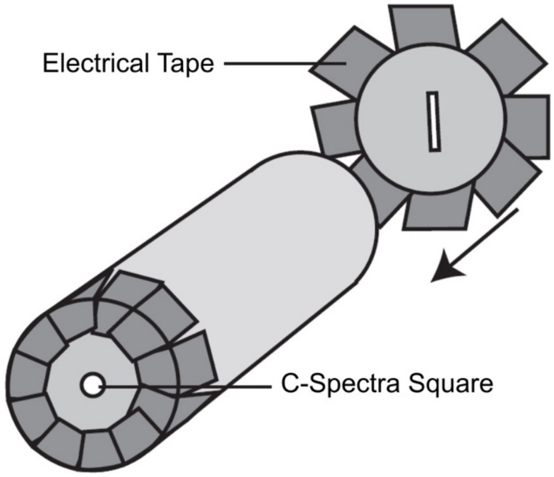
9. Unfold the circle. There should be a slit approximately 2 cm × 1 mm in the middle of the circle. The edges should be clean, not frayed.

10. Press pieces of electrical tape firmly around the edges of the circle with the slit, but do not fasten to the tube yet. Use enough tape to completely cover the edge of the circle (see **Figure 4**).



11. Hold the circle with the slit over the open end of the tube and look at a ceiling lamp or a lit candle through the hole in the other end containing the C-Spectra. Rotate just the tube until a clear spectrum of the light is visible on both sides of the slit and the spectrum is as wide as possible. Tape the circle with the slit to the end of the tube in this position

(see **Figure 5**).



12. Record your observations in **Table 1**.

Table 1. Observations for Various Light Sources

Light Source	Observations
Room Lamp	
Indirect Sunlight	
Candlelight	

Part B. Experimental Challenge

Congratulations! You have built your own spectroscope. A spectroscope is a device that separates light into its components. In other words, a spectroscope allows you to observe the *spectrum* of light, in this case the spectrum of visible light!

Now your challenge is to use your spectroscope along with color filters to see how they block certain colors of visible light from reaching the eyes!

13. Grab a color filter and place it in front of the hole covered with the C-Spectra. Look at the same light sources from the Introductory Activity and observe the colors that make up each light. What do you see with and without the filter? Record your observations in **Table 2**.

Table 2. Observations for Various Light Sources Using Color Filters

Light Source	Observations Using Color Filters
Room Lamp	
Indirect Sunlight	
Candlelight	

Post Lab Questions

1. Think about your observations from the Introductory Activity. When you looked at light through the spectroscope, what did you see? What does this mean for the light that passes through the C-Spectra? Explain.

2. All the light sources used in the Introductory Activity and Experimental Challenge are considered "white light" sources. Based on your observations, is the light from all these sources the same? Explain.

3. How do color filters affect the light from the different sources you analyzed using the spectroscope? Construct an explanation based on your own observations and results.

Is It Chemistry?

Introduction

An episode of a popular show portraits a scientist working in a Space Research lab. In one scene, the scientist is grinding chunks of rock using a mortar and a pestle. The pieces of rock are the suspected remains of an asteroid that landed on Earth a few days back.

In another scene, the scientist transfers the finely ground rock sample into a flask made of glass, and then pours a clear liquid that mixes with the powdered rock. Almost immediately gas bubbles form, and the mixture turns bright orange. The scientist is elated at these results because the rock samples may be authentic and extremely interesting after all!

It is decided that the chemical reaction between the rock powder and the clear liquid deserves more investigative work. But how can the scientist be sure that a chemical reaction really occurred? And first, what is a chemical reaction?

Figure 1. This photo shows a demonstration of the popular Elephant's Toothpaste chemical reaction. Notice the various colors, and the foam rising and spilling out of the flask containing the mixture of chemicals. How do chemists know that this is a chemical reaction?

In this investigation, you will learn about the signs that characterize a chemical reaction!

Concepts

- Chemical Change
- Physical Change
- Chemical Reaction
- Structure and Properties of Matter

Background

A chemical reaction changes the way in which atoms are bound to each other in a substance.

For example, imagine that two substances are mixed and a chemical reaction between them occurs. One substance is represented with the formula **AA** and the other is represented with the formula **BC**. When **AA** and **BC** react chemically, two new substances (or products) form: **AB** and **AC**.

Note that these two products (**AB** and **AC**) are not the same as the initial substances (**AA** and **BC**). This could be represented as follows:

$$\mathbf{AA + BC \rightarrow AB + AC}$$

In this example, the plus sign (+) indicates that **AA** and **BC** are combined or mixed, and the arrow represents that a chemical reaction occurs and produces **AB** and **AC**.

Chemical reactions happen all the time inside and outside living organisms, and pretty much everywhere in the universe. Chemists have identified thousands of chemical reactions and thanks to that we now know the most common signs that characterize chemical change. These signs include:

a. Gas formation (release of gas bubbles)

b. Color change

c. Odor production

d. Release of light/heat

e. Production of popping sounds

These signs are used to determine the likelihood that chemical change is involved. To determine with certainty if a chemical reaction is happening or has happened, chemists use specialized equipment and tests.

Substances can also experience *physical changes* and, contrary to *chemical* changes, physical changes don't alter the chemical composition of substances.

For example, when a block of dry ice—that is solidified carbon dioxide, or the gas you exhale during breathing—is left out at room temperature, it evaporates over time. The gas emanating from the dry ice is still carbon dioxide—nothing has changed in the chemical composition of the carbon dioxide, only its physical state changed from solid to gas.

In this investigation, you will learn to recognize some of the signs that accompany chemical reactions, and the difference between chemical and physical changes!

Experiment Overview

In this investigation, you will learn to recognize some of the signs that characterize chemical reactions, and the difference between chemical and physical transformations.

Materials

- Calcium chloride solution
- Hydrogen peroxide, 3%
- Sodium carbonate solution
- Sodium chloride
- Steel wool
- Vinegar
- Water, distilled
- Ice cube
- Marker, fine tip
- Paper towels
- Pipets, 4
- Scissors
- Scoop or spatula
- Small beaker, or watch glass
- Stirring rod, glass
- Test tubes, 6
- Test tube rack
- Thermometer (optional)

Pre-Lab Questions

1. Physical changes affect the form of a substance or material but not its chemical composition. Between the following two events (**a** and **b**), which one is a physical change and why?

   a. Evaporation of water from the ocean due to heat coming from the sun.

   b. Burning candle wax which releases gas, water vapor, heat, and light.

2. Chemical changes affect the chemical composition of a substance or material, that is the type and number of atoms present, or how they are bound to each other. Between the following two events (**a** and **b**), which one is most likely to be a chemical change and why?

   a. A sheet of iron metal is treated with acid to produce iron oxide.

   b. A piece of copper metal is cut into smaller pieces.

Safety Precautions

Please follow all laboratory safety guidelines. Wear safety goggles, gloves, and a lab coat or apron. Tie back long hair. Do not eat or drink anything in the lab. Handle sharp objects with caution. Wash hands thoroughly with soap and water before leaving the laboratory.

Hydrogen peroxide (3%) solution is an oxidizing agent that can cause skin and eye irritation. Vinegar and sodium carbonate solutions can also be irritating to skin and eyes. You must wear safety goggles and gloves while handling these solutions.

Procedure

Part A. Introductory Activity

Follow these steps to explore the difference between chemical changes and physical changes.

1. Place an ice cube inside a small beaker, or on a watch glass. Record any observations in **Table 1** after 5 min and 15 min.
2. Place three test tubes in the test tube rack and label them 1–3.
3. Use a pipet to transfer sodium carbonate solution to test tubes 1–3, filling each tube to about one third of its volume. **Note:** Do not use this pipet with any other solution besides sodium carbonate.
4. Check **Table 1** to find out which substance is to be added to each of the tubes prepared in step 2.
5. Add the required substance to test tube 1. Gently stir the test tube and record any observations in **Table 1**.
6. Repeat step 4 with the remaining three test tubes. Record all your observations in **Table 1**.**Table 1. Introductory Activity Results and Observations**

Sample	Substance to Add	Observations
Ice Cube	**None**	
Test Tube 1: Sodium Carbonate	**20 Drops of Distilled Water**	
Test Tube 2: Sodium Carbonate	**20 Drops of Vinegar**	
Test Tube 3: Sodium Carbonate	**20 Drops of Calcium Chloride Solution**	

Stop and reflect on the following information!

- The melting of the ice cube represents a physical change, or a change of state (solid to liquid) but the water that makes the ice cube is still water after it melts—there is no chemical change.

- Adding water to test tube 1 containing sodium carbonate solution is also a physical change in that water is mixing with the solution in the tube, and no chemical transformation is taking place. Ultimately, the test tube still contains water mixed with sodium carbonate.
- Test tubes 2 and 3 contain mixtures in which chemical reactions do take place. In test tube 2, sodium carbonate and vinegar react to form gas bubbles (carbon dioxide), sodium acetate (dissolved), and water. In test tube 3, sodium carbonate reacts with calcium chloride to form a solid (calcium carbonate) which deposits over time at the bottom of the tube, plus sodium chloride (dissolved).

Part B. Experimental Challenge

Congratulations! You can now recognize some of the typical signs that characterize a chemical reaction.

Now your challenge is to spot all the signs that may indicate chemical reaction or only physical change in the following experimental setup.

To determine if a chemical reaction has occurred, look carefully for any of the following signs:

a. Gas formation (release of gas bubbles)

b. Color change

c. Odor production

d. Release of light/heat

e. Production of popping sounds

Physical changes like solubilization (solid in liquid, or gas in liquid) or change of state (solid to liquid, liquid to gas, or the reverse of these changes) are typically not accompanied by any of the signs described above.

7. Place three clean test tubes in the test tube rack and label them 1–3.
8. Cut three steel wool pieces approximately 1 cm × 1 cm in size.
9. Use a pipet to fill about one third of test tubes 1 and 3 with 3% hydrogen peroxide.
10. Pour about half a teaspoon of sodium chloride (NaCl) into test tubes 2 and 3. Gently stir test tube 3.
11. Record any initial observations for test tubes 1–3 under “Initial Observations” in **Table 2**.
12. Add one piece of steel wool into each one of the three test tubes. Gently mix the contents of each test tube using a stirring rod (clean this rod between use in different tubes).

13. Record any observations in **Table 2** under “Final Observations”.

Table 2. Experimental Challenge

Test Tube	Initial Observations	Final Observations
1		
2		
3		

Post Lab Questions

1. Explain why the changes observed with the ice cube are only physical and not chemical.

2. Based on the results and observations from the Introductory Activity, what are some of the signs that a chemical reaction has taken place in any of the test tubes?

3. Were there any physical changes observed during any of the experiments performed in the Experimental Challenge section?

4. Based on the results and observations from the Experimental Challenge, which were the signs that chemical change(s) took place in any of the test tubes?
