Grades K-5

Pencil Electrolysis

Introduction:

The process by which we separate the elements hydrogen and oxygen from water is called **electrolysis.** The word "lysis" means to dissolve or break apart, so the word "electrolysis" literally means to break something apart (in this case water) using electricity. It is difficult to break up water into it's elements lots of energy is needed to do that. Through a chemical means though, we can separate the compound of water into the elements that combine to make it. Electrolysis is very easy - all you have to do is arrange for electricity to pass through some water between to electrodes placed in the water. It's as simple as that!

CAUTION! HEALTH & SAFETY: The reaction neutralizes the solution, which can be disposed of by pouring it down the drain.

Materials:

- A battery or solar panel with a voltage greater than 1.5 volts - 9 volt batteries work well.
- Two pieces of electrical wire about a foot long. It's convenient, but not necessary, if the wires have alligator clips at each end.
- Two number 2 pencils
- tap water
- small piece of cardboard
- electrical or masking tape.
- 1 teaspoon Epsom Salt
- Petri dish
- A glass
- 1 tablespoon red cabbage juice

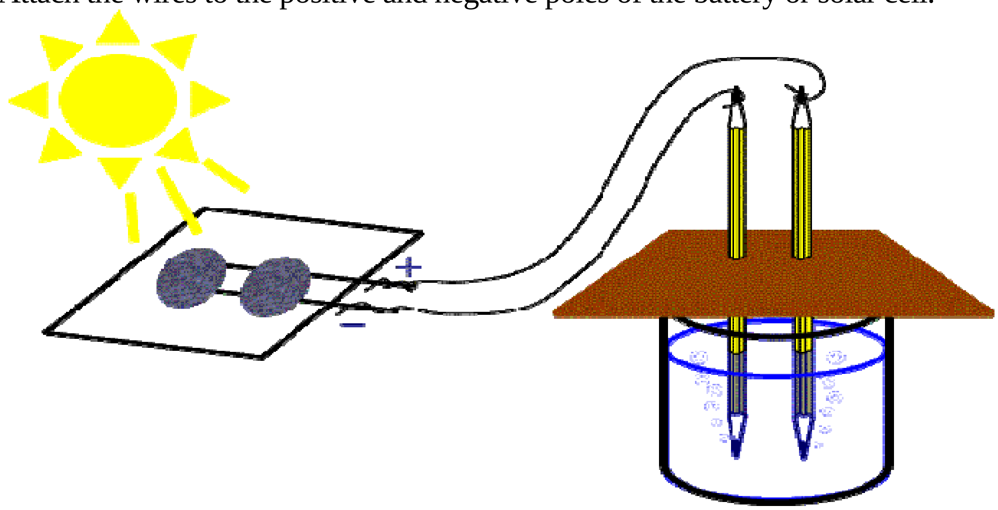
Procedure:

1. Remove the erasers and their metal sleeves from both pencils, and sharpen *both* ends of both pencils.
2. Fill the glass with warm water and add 1 teaspoon of Epsom salt and 1 tablespoon of red cabbage juice.
3. Stir the mixture thoroughly.
4. Pour some of the water mixture into the petri dish until it is ¾ of the way full.
5. Attach wires to the electrodes on the solar cell or battery, and the other ends to the tips of the pencils, as shown in the diagram below. It is important to make good contact with the graphite (lead) in the pencils. Secure the wires with tape.
6. Punch small holes in the cardboard, and push the pencils through the holes, as shown in the diagram below.

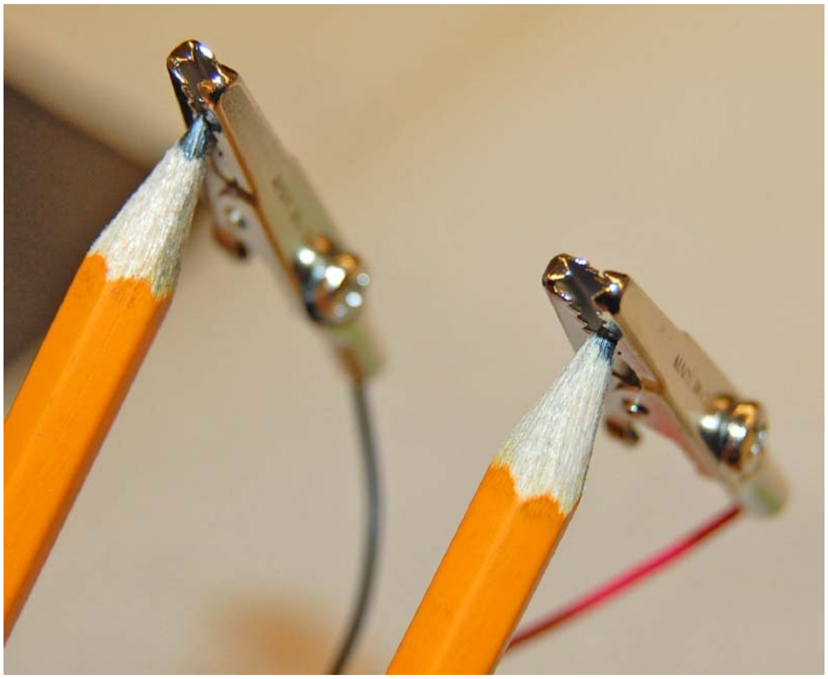
7. Place the exposed tips of the pencils in the water, such that the tips are fully submerged but are not touching the bottom, and adjust the cardboard to hold the pencils.
8. Wait for a minute or so: Small bubbles should soon form on the tips of the pencils. Hydrogen bubbles will form on one tip (associated with the negative battery terminal - the cathode) and oxygen from the other.

Diagrams

Attach the wires to the positive and negative poles of the battery or solar cell.



Make good contact with the graphite in the pencils.



Where's the chemistry?

The chemical equation for electrolysis is:

$$\textbf{energy (electricity)} + 2\,H_2O \rightarrow O_2 + 2\,H_2\,.$$

At the cathode (the negative electrode), there is a negative charge created by the battery. This means that there is an electrical pressure to push electrons into the water at this end. At the anode (the positive electrode), there is a positive charge, so that electrode would like to absorb electrons. But the water isn't a very good conductor. Instead, in order for there to be a flow of charge all the way around the circuit, water molecules near the cathode are split up into a positively charged hydrogen ion, which is symbolized as H^+ in the diagram above (this is just the hydrogen atom without its electron, i.e. the nucleus of the hydrogen atom, which is just a single proton), and a negatively charged "hydroxide" ion, symbolized OH^-:

$$H_2O \rightarrow H^+ + OH^-\,.$$

You might have expected that H_2O would break up into an H and an OH (the same atoms but with neutral charges) instead, but this doesn't happen because the oxygen atom more strongly attracts the electron from the H - it *steals* it (we say the oxygen atom is more "electronegative" than hydrogen). This theft allows the resulting hydroxide ion to have a completely filled outer shell, making it more stable.

But the H^+, which is just a naked proton, is now free to pick up an electron (symbolized e^-) from the cathode, which is trying hard to donate electrons, and become a regular, neutral hydrogen atom:

$$H^+ + e^- \rightarrow H$$

This hydrogen atom meets another hydrogen atom and forms a hydrogen gas molecule:

$$H + H \rightarrow H_2,$$

and this molecule bubbles to the surface, and eureka! We have hydrogen gas!

Meanwhile, the positive anode has caused the negatively charged hydroxide ion (OH^-) to travel across the container to the anode. When it gets to the anode, the anode removes the extra electron that the hydroxide stole from the hydrogen atom earlier, and the hydroxide ion then recombines with three other hydroxide molecules to form 1 molecule of oxygen and 2 molecules of water:

$$4\,OH^- \rightarrow O_2 + 2\,H_2O + 4e^-$$

The oxygen molecule is very stable, and bubbles to the surface.

In this way, a closed circuit is created, involving negatively charged particles - electrons in the wire, hydroxide ions in the water. The energy delivered by the battery is stored by the production of hydrogen.

Enrichment Ideas

Is Hydrogen Dangerous?

Some people are worried that hydrogen might be too dangerous. It is true that hydrogen is a very explosive fuel, but so is natural gas and gasoline. For example, movies commonly depict automobiles burning up after crashing, and explosions involving natural gas are reported in the press from time to time. Two famous disasters involving hydrogen are the explosion of a zeppelin (an airship) called the Hindenburg (in 1937), and the explosion of the Space Shuttle Challenger (in 1986). You may want to study these disasters as a class project. The Hindenburg explosion, although often cited as an example of the danger of hydrogen, is thought by many to have been caused by flammable paint that caught fire from an electrical spark, and so might have caught fire even if the zeppelin had been filled with helium (an inert, nonflammable gas). Moreover, most of the people that died may have done so from coming into contact with burning diesel fuel (which powered the Hindenburg's airplane-type prop-engines) or from jumping of the Zeppelin before it landed.

Obstacles to a hydrogen-economy

There are two obstacles to a hydrogen-economy.

- **It takes a lot of volume (or energy) to store hydrogen** - usually five times or so the volume, at reasonable pressures, needed to store an equivalent amount of energy with gasoline. One company that has made headway on solving this problem, however, is Dynetek (www.dyneteck.com).
- **There is no hydrogen infrastructure:** Making the transition to a hydrogen economy might mean having to scrap the fossil fuel infrastructure that we have already developed. One company that has made progress on refueling equipment is Stuart Energy (www.stuartenergy.com).

Both of these problems might be surmounted by using **synthetic fuels**. For example, it is possible, using a catalyst, to combine water, carbon dioxide (extracted from the air), and renewable electricity to make fuels such as methanol, a carbon-based fuel. When this fuel is burned, water and carbon dioxide are produced. But because the carbon dioxide used initially to make the fuel was extracted from the air, the cycle is closed with respect to both water and carbon dioxide, and so won't contribute excess carbon dioxide to the atmosphere. Fuel cells can already use such fuels (either by extracting the hydrogen from the fuel prior to the fuel cell, or even directly in certain types of fuel cells).

Grades K-12

ENERGY

Producing Oxygen Gas

Introduction:

In this chemistry experiment children can witness and feel a chemical reaction in their hands. It is the creation of oxygen gas from simple household materials.

CAUTION! HEALTH & SAFETY: The reaction neutralizes the solution, which can be disposed of by pouring it down the drain.

Materials:

1 plastic teaspoon
Dry yeast
5mL pipettes
Hydrogen peroxide
Small Ziploc bag
Food coloring

Procedure:

1. Using a plastic spoon, add one teaspoon dry yeast in to the Ziploc bag.
2. Add a mixture of various food coloring to make a strange color.
3. Add 5 mL of hydrogen peroxide into the Ziploc bag and seal quickly.
4. Observe the mixture and note any changes in texture and temperature.

Where's the chemistry?

Hydrogen peroxide (H_2O_2) is a reactive molecule that readily decomposes into water (H_2O) and oxygen gas:

$2H_2O_2 \text{ --> } 2H_2O + O_2(g)$

In this demonstration, yeast catalyzes the decomposition so that it proceeds much more rapidly than normal, producing foam. Food coloring can color the film of the bubbles so that you get colored foam. In addition to being a nice example of a decomposition reaction and a catalyzed reaction, the reaction is exothermic, so heat is produced and can be felt by the students when holding the bag.

ENVIRONMENT

Grades K - 3

Magic Nuudles

Introduction:

These are biodegradable building blocks made from cornstarch.

Materials:

Magic Nuudles
paper towel or sponge
water

Procedure:

1. Wet the sponge or a paper towel with water.
2. Give it a good squeeze to make it slightly damp.
3. "Bump" a Nuudle on the sponge or paper towel – DO NOT SOAK THE NUUDLE.
4. Press moistened Nuudles against dry Nuudles to create a masterpiece. (If you are having problems, it's usually due to using too much water.)
5. To dispose, put old Nuudles in the sink and run water – they melt like ice.
6. To clean surfaces, wipe with a damp cloth. For clothes, launder as usual.

Where's the Chemistry?

Both polystyrene and cornstarch are made of polymers, which are long-chain molecules that have a basic repeating unit. Some polymers are polar (such as cornstarch), others are nonpolar (such as polystyrene); the repeating units of both are shown on the Student Activity. The polar parts of cornstarch are the hydroxy (–OH) groups that hang off the main chain. These hydroxyl groups interact with water molecules to form hydrogen bonds, and as a result, cornstarch is soluble in water. Polystyrene has no hydroxy groups and is nonpolar, so it does not dissolve in water. The crosslinking structure of polystyrene can be broken down in some organic solvents such as acetone. However, such solvents are usually toxic and harmful to the environment.

Grades K - 12

Colorful Lather Printing

Introduction:

Paper marbling has been popular for centuries. In a Japanese version called *sumi nagashi* (meaning "ink-floating"), hydrophobic, carbon-based inks are dropped onto water and blown across the surface to produce swirls like those seen in polished marble. Rice paper lifts the ink off the surface of the water. In this activity, you will investigate the art and science of the creation of colorful marbled paper patterns using shaving cream and food color.

CAUTION! HEALTH & SAFETY: Be Safe! Shaving cream can become irritating if left on skin for too long. Wash your hands when you are done. Please be sure not to be too generous when dispensing the shaving cream.

Materials:

- aerosol shaving cream (standard white type)
- lineless index cards
- spatula or popsicle stick
- toothpicks
- food coloring
- dropper
- water
- small transparent cup
- paper towels

1. Read the label on a can of aerosol shaving cream. Record the list of ingredients.
2. Place a drop of food coloring on an index card. Observe and record how the drop spreads.
3. Fill a small, transparent cup half-full with room-temperature water. Without stirring, add a drop of food coloring to the water. Observe and record how the drop spreads.
4. Spray a pile of shaving cream the size of your fist onto a paper towel. Use a scraper such as a spatula or tongue depressor to shape the pile so that the top surface is flat and slightly larger than the paper that you will marble.
5. Apply only 4 - 6 drops of food coloring to the shaving cream surface, one drop at a time. Observe and record how the drops spread.
6. Drag a toothpick through the shaving cream and food coloring to create colored patterns. Press a 3 - 5 in. index card firmly on the shaving cream surface.
7. Lift the index card off of the shaving cream. Scrape off any excess shaving cream close to the paper with a spatula or side of a tongue. Observe the front of the index card. What happened?

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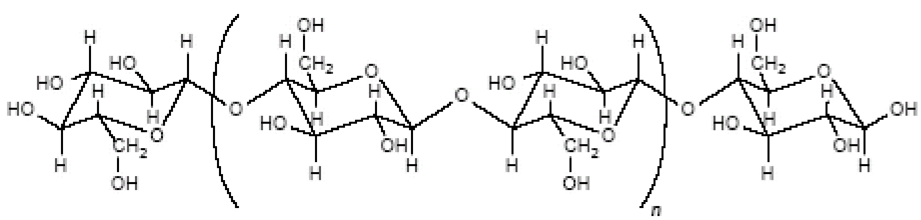
8. Repeat steps 5 - 6 to marble additional papers with the remaining tinted shaving cream, or move on to step 8.
9. Using a spatula or tongue depressor, mix the leftover pile of colored shaving cream until it is one uniform color. If most of the color has already been removed by paper, add 1 - 5 more drops of food coloring before mixing completely.
10. Using an eye dropper, apply a drop of water to the tinted shaving cream. Observe and record what happens.

More Things to Try

Try the same marbling technique using foam pump soap or gel shaving cream as the base, or different artists' paints on standard white shaving cream. What factors influence your results?

Where's the chemistry?

Shaving cream contains a mixture of a liquid (soap dissolved in water), additional solid soap, and a propellant gas, which classifies it as a lather. A fatty acid like stearic acid and the base triethanolamine are often used to make the soap in shaving cream. When a water drop is added to the surface of shaving cream tinted with food color, the color instantaneously disappears in the lather at the point of contact. Soaps and other surfactants are wetting agents. When a wetting agent dissolves in water, the surface tension of water is lowered. In this Activity, wetting occurs as the soap in the shaving cream dissolves in the drop of water that falls onto the tinted shaving cream. The surface tension of the added water drop is lowered, and the drop of water spreads. Shaving cream contains soap, which consists of long ionic species that have a hydrophilic ("water-loving") head and a hydrophobic ("water-hating") tail. Paper contains cellulose, which is a polymer of glucose (see below), as well as other chemical substances. The different substances used in the printing have different states of polarity: water (polar), paper (partially polar), and shaving cream (which contains both polar and non-polar components) which effect how the substances interact together.



cellulose

Information from the Web (accessed Jan 2007)
Paper decorating. *http://www.cbbag.ca/BookArtsWeb/PaperDecorating.html*
Shaving cream—background, raw materials, the manufacturing.
http://www.madehow.com/Volume-1/Shaving-Cream.htm l
Consumer product chemistry careers.
http://www.chemistry.org/portal/a/c/s/1/acsdisplay.html?DOC=vc2\3wk\wk3_cpd.htm l

Sweet Measurements!

Many of the foods that we eat today are filled with sugars, such as fructose, sucrose, or glucose. Sugars taste very sweet, but we eat far too much of them. Sugar added to candies and sodas provides calories without many essential nutrients. In this activity, you will get a chance to see just how much sugar is in a soda. You may be surprised.

YOU WILL NEED

- Empty soda pop bottle or can with a "Nutrition Facts" label (8 or 12 oz., not diet soda)
- Kitchen or postal scale calibrated with grams
- Box of sugar cubes
- Tongs
- Calculator (optional)

You may substitute packets of sugar for sugar cubes. The measurement will be slightly off, but the lesson will be the same.

DO NOT EAT ANY OF THE MATERIALS IN THIS ACTIVITY.

1. Guess how many sugar cubes would be equal to the sugar in a bottle of soda. Write your guess in the space provided in the "What Did You Observe?" section.
2. Read the "Nutrition Facts" label on the soda bottle to see the number of servings in the bottle. Write the number in the "What Did You Observe?" section.
3. Read the "Nutrition Facts" label on the soda bottle to see how many grams (g) of sugars are in 1 serving of soda. Write the number in the "What Did You Observe?" section.
4. Multiply the number of grams of sugars in one serving by the number of servings to find the number of grams of sugars in the bottle. Write your answer in the "What Did You Observe?" section.

5. Place the scale on a sturdy table or desk.
6. Use the tongs to add sugar cubes one by one to the scale . Watch the numbers on thescale, and keep adding sugar cubes until the reading on the scales is equal to the number of grams of sugar in the bottle of soda.
7. Count the number of sugar cubes in the weighing pan, and write your answer in the "What Did You Observe?" section. Compare this number with the guess you made at the beginning of the activity.
8. Thoroughly clean the work area, and wash your hands.

We have many food choices today, and most of them contain sugars. Naturally occurring sugars, like those in fruits, are better for us than the processed sugars and syrups found in candy and soda. We can find out how much sugar a product contains by reading the "Nutrition Facts" label on the item. We can also recognize the names of many different sugars by looking at the list of ingredients. The names of most sugars end in –ose.

Commonly added sugars are sucrose, fructose, and glucose. The name of the sugar found in milk is lactose. Look at the nutrition labels on some of your favorite foods. Can you find the names of any sugars? Can you find any sugars other than those named above?

WHAT DID YOU OBSERVE?

Before you begin:
How many sugar cubes do you think are in a bottle of soda? _________

From the Nutrition Facts label:
Number of servings in bottle: _________
Grams of sugar in one serving of soda: ___________g

Calculate:
Number of grams of sugar in the bottle: ___________g
(**Hint:** number of servings in bottle × grams of sugar in a serving = grams of sugar in the bottle.)

Count:
Number of sugar cubes on the scale: ________

Report:
Which was greater: the number of sugar cubes that you thought would be in the bottle of soda, or the number of sugar cubes that you weighed on the scale? ____________

Try this...

Repeat this experiment to find the amount of sugar in other beverages, or in foods such as ice cream or a candy bar.

⚠ CAUTION! HEALTH & SAFETY

Be sure to follow Milli's Safety Tips, and do this activity with an adult! Safety goggles are required.

Grades K-5

Super Shrinkers

Introduction

The word plastic comes from the Greek word meaning “able to be molded”. Plastics are popular materials because they can be molded or shaped in many different ways. For instance your pencil box and the desk you write on at school are most likely made out of plastic. At home, the handle of your toothbrush and the one gallon container of milk are almost certain to be made out of it. What about your games and toys? Their parts and pieces may contain plastic too. Plastic is all around us! In this activity, you will turn a piece of plastic into a piece of art.

CAUTION! HEALTH & SAFETY: **Be sure to follow Milli’s Safety Tips and do this activity with an adult! Do not eat or drink with any of the materials used in this activity.**

Materials

Conventional or toaster oven
Clear polystyrene (PS) containers (#6 recycle code)
Blunt-ended scissors
Colored permanent markers
Metric ruler
Cookie sheet or metal tray
Aluminum foil
Oven mitts

NOTE: Make sure your container is a “number 6” recyclable plastic. Look for the number on the bottom of the container. Other types of plastics will not work. Good places to look for “number 6” containers are at your local deli or grocery store salad bar. If the edges of your final product are rough, your adult partner can help you to smooth them with sandpaper.

Procedure

1. Have your adult partner preheat the oven to 325° F.
2. Make sure the piece of plastic is clean and free of dust.
3. Carefully cut a design of your choice from the plastic.
4. Use permanent markers to draw or write something on your piece of plastic. The more color you use, the more intense your final piece will be. If you write something, make your letters big and thick.

5. Measure and record the length and width of the plastic with the ruler at the longest and widest parts.
6. Cover a cookie sheet or metal tray with aluminum foil and place your design on the foil.
7. Ask your adult partner to place the tray in the oven. If you have a glass oven door, you will see the plastic curl at the edges and then flatten again. When this happens, the plastic is finished shrinking. This should take less than two minutes.
8. Have your adult partner take the tray out of the oven using the oven mitts. Be careful. It will be hot! Place the hot tray on a heat-resistant surface.
9. Do not touch your newly created piece of art until it has completely cooled. Your adult partner will tell you when it is ready to be touched.
10. When it has cooled, take your design off the cookie sheet and measure the length and width as you did in Step 5.
11. Thoroughly clean the work area and wash your hands.

Where's the chemistry?

Plastic is a lightweight material that can be shaped, stretched, or bent into many different things. The material that you used to make your design is recyclable plastic called polystyrene. It is a polymer, a chemical made out of repeating chemical units. Polystyrene can be stretched or shrunk when heated. Not all plastics behave this way. Different types of plastic may melt into liquid or stay just the way they are even after you heat it.

Try this…

You can also create designs using colored pencils. Use sandpaper to scratch the surface of plastic where you would like to draw. After you heat the plastic, does the surface still appear scratched? Make a charm or necklace by punching a hole(s) in the plastic before you place it in the oven. After the plastic shrinks and cools, thread a string through the hole.

HEALTH

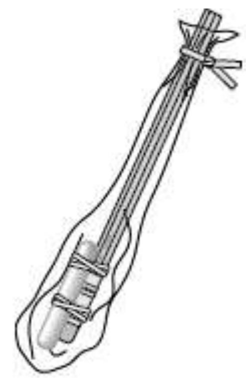
Grades K - 12

Iron for Breakfast

Introduction:

Our bodies need iron. An iron deficiency can result in anemia, a fairly common condition for adolescent girls. Iron-deficiency anemia can cause fatigue during sports activities because iron is necessary for the blood to carry oxygen to the muscles. Some foods are fortified with iron and can help prevent anemia. In this activity, you'll verify the presence of iron in iron-fortified cereal.

Materials:



- Cocoa Wheats® or other iron-fortified food that lists iron or reduced iron as an ingredient, such as Total®, Carnation® Instant Breakfast, or iron-fortified grits
  Note: Cereals that contain ferric (iron) phosphate will not work!
- 2 plastic containers or cups, about 500 mL (2 cups) in volume
- 1 unsharpened pencil
- 1 cow magnet
- 1 plastic bag
- 1 magnifying lens
- 3 twist ties or rubber bands
- 1 piece of white paper or paper towel
- water

Procedures:

1. Make a magnetic stirrer by attaching a magnet to an unsharpened pencil using twist ties or rubber bands. Insert the stirrer into a small plastic bag.
2. Remove as much of the air inside the bag as possible and fasten the bag snuggly around the stirrer with a twist tie or rubber band.
3. Crush the flakes as fine as possible. Pour ¼ of a cup of crushed cereal (or 2 inches) into a plastic cup followed by 1/2 cup of water.
   Note: If using Cocoa Wheats® skip the crushing step and don't add water.
4. Stir the cereal-water mixture with the stirrer assembly made in step 1 for about 1 minute or until the cereal is a fine slurry.
5. Remove the stirrer from the cup and gently swirl it in another cup of clean water to remove the cereal. Gently shake off excess water or allow to air dry. Do not wipe the stirrer!
6. Over the sheet of white paper, undo the tie from the plastic bag and pull the stirrer out of the bag, allowing any iron filings to fall onto the paper.
7. Do not let the magnet directly touch the iron filings, because once in contact with the magnet, the filings are extremely difficult to remove.
8. Place the magnet under the paper and move it around, observing the magnetic behavior of the filings. Examine the filings with a magnifying lens.

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Where's the Chemistry?

Iron is an essential element. Every molecule of hemoglobin (the compound in red blood cells that carries oxygen from the lungs to the tissues) has four iron ions in it. A healthy adult needs about 18mg of iron each day. If all of the iron from your body were extracted and converted into elemental iron, you would have enough iron to make two small nails.
This amount is about 5–7 g. Dietary iron is found in red meats, egg yolks, shellfish, and vegetables such as beans and spinach. Under normal conditions our bodies absorb only 5–15% of the iron in the foods that we eat. To ensure that we have adequate iron in our diets, many foods are iron fortified. Iron can occur in several chemical forms. The iron in the iron-fortified cereal is typically elemental or metallic iron (Fe). While the body is unable to directly absorb elemental iron, the reaction that occurs with hydrochloric acid (HCl) in the stomach produces ferrous iron ($Fe2^{+}$), which is absorbed in the small intestines.