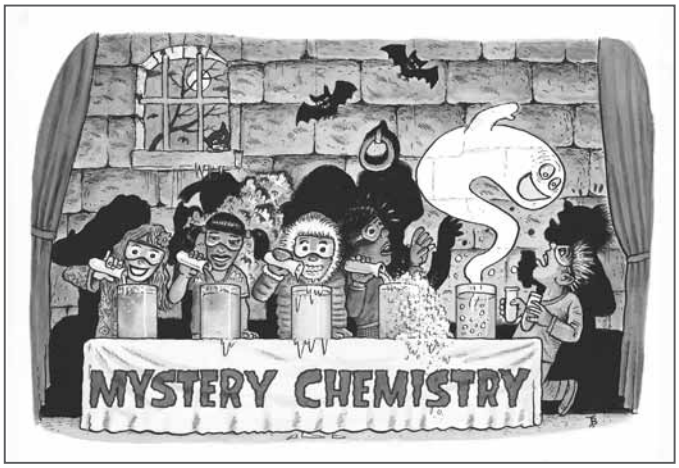
Active Chemistry Cool Chemistry Show

Activity 1 Chemical and Physical Changes



GOALS

In this activity you will:

- Learn to differentiate between chemical and physical changes.
- Make observations and cite evidence to identify changes as chemical or physical.
- Explore the new properties exhibited when new materials are made from combinations of two or more original materials.
- Design an experiment to test properties of different combinations of materials.

What Do You Think?

There are two basic types of changes that matter can undergo: chemical change and physical change. Consider two wooden matches. One is broken in half and the other is ignited by striking it along the side of the matchbox. In both of these instances matter has changed.

- Which match has undergone a chemical change and which has undergone a physical change? Give specific reasons to support your answer.

Record your ideas about this question in your *Active Chemistry* log. Be prepared to discuss your responses with your small group and with the class.

Investigate

1. Listed on the following page are 15 opportunities for you to observe changes in matter. Your teacher may choose to do some or all of these as a demonstration or set up stations for you to visit. Notice that the directions call for small amounts of substances.

Safety goggles and a lab apron must be worn during this activity.

What Do You Think?

If the students have misconceptions it would be good to note these and observe how their thinking develops as they complete the activity. Chemical changes occur when materials are converted into new materials. The ignition of the match causes a chemical change. It irreversibly changes the form and properties of the match. Breaking a match only makes the pieces smaller and leaves its properties unchanged. This is a physical change.

Student Conceptions

Students tend to focus on the tangible visual features accompanying chemical changes. Molecular changes are not visible, therefore these chemical concepts are abstract. Students often believe that the particles possess the same properties associated with the macroscopic matter. (Examples: gold atoms are shiny and hard; water molecules are tiny droplets of water.)

Students often do not understand that new substances can form by recombining the atoms in the old substances. They tend to see chemical change as resulting from a separate change in the original substance, and believe that properties exhibited after a chemical change result from a material gaining or losing matter. For example, many students will believe that the mass of rust from a completely rusted iron nail will be less than that of the original nail.

The following are common misconceptions regarding physical changes:

- As a material goes from solid to liquid to gas, the molecules change in size.
- Expansion is due to the expansion of particles rather than the spacing of the particles.
- Covalent bonds are broken in the process of melting and boiling.
- When a material dissolves in solution, that material changes from a solid to a liquid.
- The bubbles in boiling water are composed of air.

Many students do not make a distinction between a solution and a pure liquid. Having them evaporate a pure liquid and then a liquid solution will help because they can see the residue left behind from the solution. Most students will be unaware that solutions are not limited to liquids, but can also be gaseous or solids.

Investigate

Teaching Suggestions and Sample Answers

1. - 2. It is not necessary to demonstrate or observe all the changes listed. Choose those best suited for your class. Alternatively, you may wish to do one or two demonstrations at the beginning of each class during the next couple of weeks.

Process	Observations	Change
a) Heat an ice cube in a beaker	Liquid formation	Physical
b) Boil a small amount of water	Liquid vaporizes	Physical
c) Melt candle wax and cool	Liquid form back to solid	Physical
d) Break wood splints	Smaller pieces	Physical
e) Wood splint in flame	Wood burns	Chemical
f) Add a small amount of lemon juice to milk	The milk appears to form curdles	Chemical
g) Add a small amount of vinegar to baking soda	Bubbles are released	Chemical
h) Add a small amount of salt, boil and cool	Dissolves into the water	Physical
i) Add several drops of iodine solution to starch	The starch reacts with the iodine	Chemical
j) Add zinc to hydrochloric acid	Gas bubbles released	Chemical
k) Phenolphthalein added to sodium hydroxide	Solution turns pink	Chemical
l) Sodium carbonate added to sodium hydrogen sulfate	No apparent reaction noted	Physical
m) Ammonia added to copper sulfate	Solution becomes very dark blue	Chemical
n) Vinegar added to chalk	Gas bubbles form	Chemical
o) Sharpen pencil and collect shavings	Wood is smaller pieces	Physical

Discussion:

a) This is a physical process since the solid water changes to the liquid state.

b) This change of liquid water into gaseous water is a physical process. Make certain students understand that "steam" refers to gaseous water. Gaseous water is invisible; what most people call steam is small water droplets suspended in air. A good example is boiling water in a whistling teapot. The invisible steam comes out through the opening and then condenses farther out in the cooler air.

c) It has the same properties it had before it was broken; therefore the change is physical.

d) It still has the same property that it had when it was all one piece.

e) Combustion of the wood splint changes its original properties and forms new substances – in this case, carbon dioxide, soot, and water. This change is chemical.

f) Milk contains two types of proteins – whey and casein proteins. The casein proteins cause curdling when lemon juice is added. This same chemical process is used to make cheese. You can point out that if you burn milk on the bottom of a pot, some lemon juice or vinegar will help to clean it.

g) The acetic acid in vinegar reacts with the sodium hydrogen carbonate to produce carbon dioxide, water and sodium acetate. This is a chemical change.

h) The salt dissolves in the water and to make an electrolytic solution containing sodium and chloride ions. You recover the salt by evaporating the water. Dissolving is a physical change.

i) The polysaccharide of glucose can be either cellulose or starch. The iodine test identifies the starch form. This chemical process will also be used later for the clock reaction.

j) The acid oxidizes the zinc and forms hydrogen gas. This change is chemical.

k) The phenolphthalein is a very weak acid. The sodium hydroxide neutralizes this acid and releases the anion that changes the solution to a pink to red color. This is a chemical change.

l) The sodium carbonate and the sodium hydrogen sulfate should combine to release carbon dioxide but the students may have trouble detecting this chemical reaction. The hydrogen sulfate releases hydrogen ions and reacts with the carbonate ions to form the intermediate carbonic acid, which then breaks down into carbon dioxide and water.

m) When copper sulfate is dissolved in water the copper ions it forms are hydrated which produces the blue color. If ammonia is added, it displaces the water molecules and forms a very deep blue color $[Cu(NH_3)_4]^{2+}$ complex. This is a chemical change.

n) Vinegar (acetic acid) chemically reacts with the calcium carbonate contained in chalk to produce carbonic acid. Carbonic acid is unstable and breaks down into carbon dioxide and water.

o) The shavings have the same properties as the wood in the pencil. The change is physical only.

Chem Tip:
If you use the microscale setup, a piece of white paper placed under the cell plate makes it easier to observe the changes. As an alternative to cell plates, you could perform each step on a sheet of plastic.

Make a data table to organize your observations of the matter before and after any change(s) that may occur. Be detailed in your observations.

- Heat an ice cube in a beaker.
- Boil a small amount of water.
- Melt a small amount of candle wax. Then allow the melted wax to cool.
- Break a wooden splint into several pieces.
- Hold a wooden splint in a flame.
- Add a few drops of lemon juice to a small amount of milk.
- Add a few drops of vinegar to a small amount of baking soda ($NaHCO_3$).
- Add a small amount of table salt to water; stir; boil the solution to dryness; cool and record the result.
- Add several drops of iodine solution to a small amount of starch.
- Add a small piece of zinc to a small amount of hydrochloric acid (0.1 M HCl).
- Add a drop of phenolphthalein indicator solution to a solution of sodium hydroxide (0.1 M NaOH).
- Add two drops of sodium carbonate (0.1 M Na_2CO_3) to two drops of sodium hydrogen sulfate (0.1 M $NaHSO_4$).
- Add a few drops of household ammonia to a small amount of a copper (II) sulfate (0.1 M $CuSO_4$) solution.
- Add a few drops of vinegar to a small piece of chalk.
- Sharpen a pencil and collect the shavings.

Dispose of the materials as directed by your teacher. Clean up your workstation and then wash your hands.

2. Organize the information in your data table.

   a) Prepare and complete a chart that organizes your observations into separate columns — one that includes the situations where color changes occurred, one that notes the formation of precipitates (sometimes visible as a cloudy solution), one that includes gas formation (fizz), one to note other changes, and one where no visible change occurred.

3. A physical change involves changes in the appearance of the material but does not involve creation of new materials. A chemical change involves the formation of new materials. Chemical reactions are characterized by a number of changes, including color changes and the formation of a precipitate or gas.

   a) Which of the interactions you observed were chemical changes? Explain your answer.

   b) Which of the interactions you observed were physical changes? Explain your answer.

   c) When you placed the wooden splint into a flame, what other evidence (besides the color change) indicated that a chemical change took place?

   d) Imagine a situation where two colorless solutions are mixed

3. **a)** e, f, g, i, j, k, m, and n. See table and discussion.

b) a, b, c, d, h, l, and o. See table and discussion.

c) Smoke was released, the wood glowed, and then it crumbled into black soot.

d) This question should elicit some discussion. Heat is released if you add acid to water. This is a heat of hydration reaction and is usually classified as a physical change. However, adding sodium hydroxide solution to hydrochloric acid solution also releases heat, and this is a chemical reaction. Allow students to express their thoughts on this question. Their background at this time is weak and they will find it difficult to arrive at an acceptable answer. Another example of a physical reaction that releases heat is when you dissolve sodium hydroxide pellets in water. You can evaporate the water and recover the sodium hydroxide. Or you can dissolve barium nitrate in water, and drop the temperature of the solution. Caution students to avoid the conclusion that all processes that release or absorb heat are chemical reactions.

4. a–d) The size of the piece of diaper will determine the amount of water that it will absorb. Generally, 1 g of sodium polyacrylate can absorb 800 mL of water. Students will be surprised that the diapers can absorb so much water.

Chem Tip:
Make certain to closely monitor the use of sodium polyacrylate. If the contents go down the drain, major clogging can result.

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together. There is no color change, no precipitate is formed, and no gas is released. However, heat is released as the solutions are mixed. Is this an example of a chemical or physical change? Explain your choice.

4. Each group will be given a piece of disposable diaper. Place the piece in a beaker.

   a) Predict how much liquid the diaper will be able to hold. Record your prediction in your log.

   b) Design an investigation to measure the amount of liquid that the diaper can absorb. Record your procedure in your log.

   c) With the approval of your teacher, carry out your investigation. Record your results.

   d) Explain how your prediction compared with your observations.

   e) The diaper is made of a material called sodium polyacrylate. When it absorbs water, is this a physical or chemical change? Explain your answer.

5. Your teacher will show you a solution of sodium acetate in a 250-mL flask. Observe the solution carefully.

   a) Record your observations in your *Active Chemistry* log.

   Your teacher will then add one crystal of sodium acetate to the flask.

   b) What happens? Record your observations in your log.

   c) Was this a chemical or physical change?

6. In a large throwaway glass jar, mix 100 mL of sodium silicate (sometimes called water-glass solution) and 400 mL of water.

   Carefully drop solid-colored crystal compounds of cobalt, copper, nickel, iron, and/or manganese in different locations inside the jar.

   a) Is there evidence of a change immediately? In several minutes? In several hours? In several days? In your *Active Chemistry* log, describe the results.

   b) Is the phenomenon you see the result of a physical or a chemical change? Explain your answer.

4. **e)** This is a physical change. This material has found commercial applications for diapers. Plant nurseries also will encase roots and seeds with saturated sodium polyacrylate as a means of providing water.

Chem Tip:
Sodium polyacrylate is a chemical compound called a polymer. It is made up of many (poly) repeating units of a smaller group of elements (the monomer called acrylate). The monomer unit is $-(CH_2-CH-)$
CO_2Na
A single gram of sodium polyacrylate will absorb 800 g of distilled water, but only about 300 g of tap water.

5. **a)** This is a clear solution. To supersaturate the solution, dissolve sodium acetate at an elevated temperature. When the solution cools back to room temperature, an excess of sodium acetate will remain dissolved in the water. You can then carefully add a crystal of sodium acetate to the solution and it will immediately cause the excess sodium acetate to crystallize.

b) When the crystal of sodium acetate is added to the supersaturated solution of sodium acetate, it will cause solid sodium acetate to form and grow in the flask.

c) A physical change has occurred. If you evaporated the water, you could recover the sodium acetate.

6. **a)** When the solids sink to the bottom they start to develop stringy substances.

b) The metal cations combine with the silicate ion. The process is a chemical reaction.

Chem Tip:
Purchase prepared sodium silicate solution because it is difficult to make.

Almost any soluble transition-metal salt that is placed in a silicate solution will develop columns of colored crystals from the bottom. The reason is that as the salts dissolve they release positively charged metallic ions. These ions combine with the negatively charged silicate polyatomic ions to form a partially insoluble silicate membrane (or gel-like structure) around the precipitating metal ion. The pressure on the sides causes this membrane to rise upward. The structural precipitates that form are quite complex. If you were to use an iron salt you would form a mixture of iron silicates and iron hydroxides. This mixture is the gel-like structure.

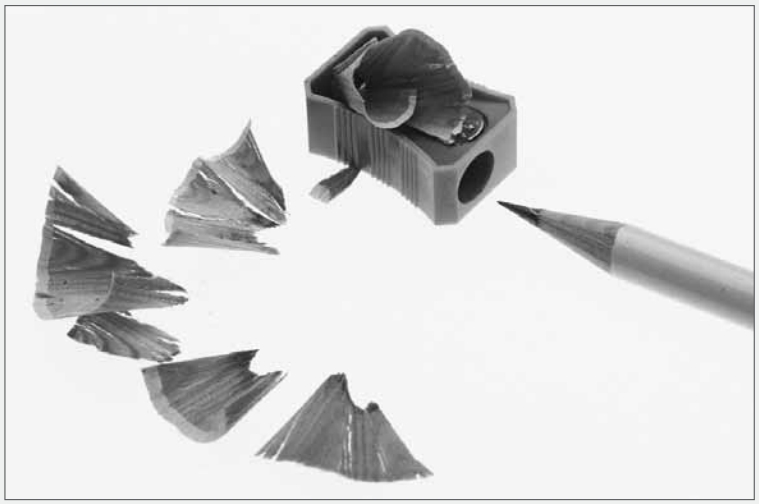
ChemTalk

CHANGES IN MATTER

Physical and Chemical Changes

In this activity you observed a number of situations that involved changes in matter, both physical and chemical. A **physical change** involves changes in the appearance of the material but does not involve creation of new materials. A change of a solid to a liquid is a physical change. When the candle wax melted it may have appeared different, but it was still wax. After it solidified, it had a similar appearance to the initial product. Dissolving is also a physical change. When you added the salt to the water, the salt crystals seemed to disappear as they dissolved in the water. However, they had only spread out into a solution. A **solution** is a homogeneous mixture of at least two different materials. The material being dissolved is called the **solute**, and the material present in the largest amount is called the **solvent**. When you boiled away the solvent, water, the solute, the salt crystals, remained the same as they were originally.

A **chemical change** involves the formation of new materials. The new materials are called **products** and the starting materials are



Chem Words

physical change: a change that involves changes in the state or form of a substance but does not cause any change in chemical composition

solution: a homogeneous mixture of two or more substances

solute: the substance that dissolves in a solvent to form a solution

solvent: the substance in which a solute dissolves to form a solution

chemical change: a change that converts the chemical composition of a substance into different substance(s) with different chemical composition

product: the substance(s) produced in a chemical reaction

NOTES

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Chem Words

reactants: the starting materials in a chemical reaction

chemical reaction: a process in which new substance(s) are formed from starting substance(s)

precipitate: an insoluble solid formed in a liquid solution as a result of some chemical reactions

concentration: a measure of the composition of a solution, often given in terms of moles of solute per liter of solution

saturated solution: a maximum amount of solute that can be dissolved at a given temperature and pressure

polymer: a substance that is a macromolecule consisting of many similar small molecules (monomers) linked together in long chains

called **reactants**. The process that brings about a chemical change is called a **chemical reaction**. Chemical reactions are characterized by a number of changes, including color changes, the formation of a **precipitate** or gas, a release of heat or light. Chemical changes are usually not easy to reverse. When you burned the wooden splint you could not put the charcoal together to form the original splint as you could when you simply broke the splint into pieces.

Saturated and Supersaturated Solutions

The solution your teacher used in the demonstration was a supersaturated solution of sodium acetate. Solutions are commonly described in terms of **concentration**. The concentration of a solution is the ratio of the quantity of solute to the quantity of solution. A dilute solution has fewer solute molecules per volume than a concentrated solution. However, in both the dilute and concentrated solutions more solute can dissolve in the solvent. These solutions are unsaturated.

You probably recognize the term "saturated." When something is saturated, it is full. A saturated sponge is full of water; it can't hold any more. A **saturated solution** is one in which no more solute will dissolve under the given conditions. To say that the sodium acetate solution is supersaturated means that it is "over full." A supersaturated solution contains more solute

NOTES

particles than it normally would under the given conditions. A supersaturated solution can be made using some solutes. If a saturated solution at a high temperature is allowed to cool undisturbed, all the solute may remain dissolved at the lower temperature. The solution is then supersaturated. As you observed in the activity, such solutions are unstable. By introducing a "seed" crystal the extra solute particles "joined" the crystal and came out of the solution.

Polymers

The chemical material that you were working with when you investigated the absorbency of the diaper was sodium polyacrylate. It is a chemical compound called a **polymer**. It is made up of many (poly) repeating units of a smaller group of elements (the monomer called acrylate). This particular polymer has a unique property. It will absorb more than 800 times its own mass in distilled water. The fascinating ability of this polymer (sodium polyacrylate) to absorb large amounts of water has led to its use in a number of commercial endeavors.

Checking Up

1. What is a physical change? Provide two examples.
2. Explain the meaning of a solution, a solute, and a solvent.
3. What is a chemical change? Provide two examples.
4. What "clues" can you look for to determine if a chemical change has occurred?
5. How do you describe the concentration of a solution?
6. Explain the difference between a saturated and a supersaturated solution.

Reflecting on the Activity and the Challenge

Recall that the fourth-grade teacher has specifically requested that your chemistry show addresses chemical and physical properties and changes. You are right on track for the fourth graders. The fifth-grade teacher wants the students to learn more about chemical reactions that involve color changes. You have seen a few of those, too. If you had to conduct the show based on your experiences so far, which activity would you use? What additional information would you need to be able to explain the chemistry to fourth- and fifth-grade students?

Chemistry to Go

1. Which of the following are chemical changes and why?
   a) Toast turns black after being in the toaster too long.
   b) Water condenses on the outside of a glass of iced tea.

ChemTalk

Checking Up

1. The material may change from one state to another but does not change in character. Dissolving a salt in water will change its appearance but it can be recovered by evaporating the water. If you melt ice it will change to the liquid form. You can return the liquid back to the solid form by freezing it.

2. If a material is dissolved in water, the water acts as the solvent and the material is the solute. The dissolved material plus the water is a homogeneous solution if it forms a clear uniform solution. If the material remains undissolved in the solvent and instead forms a mixture with at least two distinct layers, it is called a heterogeneous mixture.

3. A chemical change is a process where a material reacts with another material or may decompose into new materials. The new materials have different properties from the original material. Examples: The decomposition of potassium chlorate yields potassium chloride and oxygen: or, the addition of barium nitrate solution to a solution of sodium sulfate yields a barium sulfate precipitate.

4. The formation of precipitate, the release of gas, and color change often accompany a chemical change. The exchange of heat can accompany either a chemical change or, as when salt dissolves in water, a physical change.

5. The amount of solute that is dissolved in a solvent can be expressed as grams per milliliter, percent of solution, or – as students will learn later – as moles of solute per liter of solution.

6. At a given temperature and pressure, a solvent can dissolve only a certain amount of solute. Elevating the solvent temperate will allow a greater amount of solute to dissolve. If it is then cooled, the solution will contain a greater amount of dissolved solute. This is commonly called a supersaturated solution.

Chemistry to Go

1. **a)** Chemical change. New materials are produced.
   b) Physical change. It maintains the same properties, and has only changed in state.
   c) Chemical change. The leaves are changing color and are changing into new materials.
   d) Chemical change. The color change occurs as the banana is being oxidized.
   e) Physical change. If the butter is cooled it will return to its solid form.

2. Answers will vary. Allow students to discuss their responses. Enzymes within their digestive systems change the food they eat into new materials. Stomach acids also

break down food into new materials. Food is physically changed when they cut it with a knife; melting ice cubes are also undergoing physical change. Cooking food brings about chemical change.

3. Have the students select a cake recipe. They can identify which steps are physical changes and which steps are chemical reactions.

4. The melting point and density are physical properties of aluminum. The reaction of aluminum with hydrochloric acid and oxygen is a chemical reaction. Physical properties and chemical properties are both used to identify elements and compounds. Some people like to categorize these properties as intensive and extensive properties. Extensive properties are properties that depend on mass and volume. Intensive properties are properties that are independent of sample size. Melting point, boiling point, electrical conductivity and density at a given temperature are all examples of intensive property. Color is usually classified as an intensive property but it is unreliable for identification purposes. An example is how fine powdered silver metal will appear black and sheets of silver will appear to be white.

5. You could test the density of the solution to determine if it is a water or sugar solution. Another method is to take a small sample, evaporate the water and see if a residue of sugar remains in the container. Emphasize that, for safety reasons, they should never taste samples in the laboratory.

Chem Tip:
Younger students might enjoy the following demonstration with sodium polyacrylate:

1. Set out three Styrofoam cups on the table. Mark them A, B, and C. Put 10 mL of water in cup A, 1 g of sodium polyacrylate in cup B, and leave cup C empty.

2. Turn the cups so that students do not see the letters. Tell them that the hands are faster than the eyes, then shuffle the cups and ask them which one contains the water. They should easily identify the correct cup. Pour the water into cup C and tell them they were just lucky to get the right one.

3. Repeat the process and they should again easily identify the correct cup. Now pour the water into cup B. The sodium polyacrylate will absorb it (which they do not know).

4. Repeat the shuffling and ask them which one contains the water. They will be surprised when you tip it upside down. Let them then lead you in a discussion of what happened.

Active Chemistry Cool Chemistry Show

c) Green leaves turn orange, yellow, and red in the fall.

d) Green bananas become yellow.

e) Butter melts on a hot summer day.

2. Think back to a recent lunch or dinner. Describe two physical and two chemical changes that were involved in the meal and explain why you think each was a physical or chemical change.
3. Write a paragraph describing a common activity (such as making a cake or driving a car). Underline the physical changes (use one line) and chemical changes (use two lines) taking place within the activity. Select and describe an activity that is sure to have at least two physical changes and two chemical changes.
4. The following information is obtained for the element aluminum. Identify which are physical (use one line) and which are chemical (use two lines) properties.

   Aluminum is a shiny silver metal and melts at 660°C. When a strip of aluminum is placed in hydrochloric acid, hydrogen gas is released. The density of aluminum is 2.70 g/cm^3. When polished aluminum is exposed to oxygen over a period of time it forms aluminum oxide (Al_2O_3) on the surface of the metal.
5. How would you determine whether a clear solution in a beaker is saturated sugar water or just water? Remember, you do not taste samples in the laboratory.

Preparing for the Chapter Challenge

Describe how you would demonstrate the difference between a physical and chemical change in a "cool" way.

Inquiring Further

Factors affecting solubility and the rate of dissolving

Understanding the factors that affect how quickly a solute dissolves in a solvent is important in many practical applications in manufacturing. Design an investigation to determine the factors that affect solubility. Consider the following:

- nature of the solute and solvent;
- temperature;
- agitation (stirring or shaking);
- surface area (for example, try using a sugar cube, granulated sugar, and icing sugar);
- pressure of gases.

Remember that your investigation must be controlled, if your results are to be reliable. What will be your independent and what will be your dependent variables?

Preparing for the Chapter Challenge

Answers will vary. They might think of reactions that emit gas, such as when vinegar reacts with baking soda. Another idea might be the sublimation of dry ice.

Inquiring Further

Factors affecting solubility and the rate of dissolving

- Nature of solute and solvent: The general rule is that like materials will dissolve each other. Ionic compounds will dissolve in water. Gasoline or hydrocarbons are insoluble in water.
- Temperature: Increasing temperature should cause a greater amount of solute to dissolve in the solvent.
- Agitation: The more the agitation the more the solute contacts the solvent and the faster the rate of dissolving.
- Surface area: The greater the surface area the greater the contact of individual particles with the solvent and the faster the dissolving.
- Pressure of gases: If you increase the pressure by decreasing the volume of the container, the gas molecules will be closer and have greater odds of colliding and possibly reacting.

The amount of solvent should remain constant. Collect data at room temperature and room pressure. Then vary the factors above to see the effect of each.