Interactions of Matter/ Chemistry Grade 8

The activities in this teacher's guide were created by the Center for Inquiry-Based Learning (CIBL) to accompany the materials in the Interactions of Matter/ Chemistry kit for Grade 8. The Interactions of Matter/Chemistry kit was specifically designed to meet the North Carolina Essential Science Standards for grade 8 physical science. Activities in this guide require students to think and assume responsibility for investigating interactions of matter and chemistry. These materials and activities are available only with prior professional development. The goal is to help students deepen their understanding of underlying concepts through concrete experiences.

This pilot version is under development, and CIBL welcomes any feedback you are willing to provide. We may be contacted through the CIBL web site on the "contact us" tab at http://ciblearning.org. If you have questions, feel free to call 919 294-9881.

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Throughout the guide, teaching tips are in red.

Activity Description & Estimated Class Time

Students will use one 50-minute class period to view the world of chemistry as the ancients did and analyze materials based on an early theory.

Objectives

Students will consider what things are made of by asking questions about matter in the same way that people in early cultures did. Questions include:

- What are the smallest bits of things?
- If more than one kind of part makes up a thing, what are those parts?
- What can we consider as evidence for identifying unseen constituent parts?

Students demonstrate this knowledge and understanding by analyzing common materials to determine their composition of earth, air, fire, and water. Afterward, they consider the problem of determining the smallest bits of things and of determining the components of materials that are combinations.

Correlations to North Carolina Science Standards

8.P.1 Understand the properties of matter and changes that occur when matter reacts in an open and closed container.

8.P.1.1 Classify matter as elements, compounds, or mixtures based on how the atoms are packed together in arrangements.

8.P.1.4 Explain how the ideas of atoms and a balanced chemical equation support the law of conservation of mass.

Brief Science Background

Long ago, ancient people of many cultures looked at the world and tried to figure out what things were made of. They began with simple questions such as, "If you cut a piece of cheese in half, and divide a resulting piece in half again, and keep doing that, can you keep dividing it until what is left is no longer cheese?" One early idea they had was that some combination of four basic elements - Air, Earth, Fire, and Water - makes up everything. The ancients developed this idea from looking at the world just as scientists today develop theories from evidence and observations. The ancients noticed that a piece of wood that burned produced fire, smoke (air), and ash (earth). From that, they thought that wood must be made of some proportion of fire, air, and earth. They noticed that oil used in lamps is liquid like water, and it makes fire and smoke (like air) when it burns, so it must be made of some combination of water, fire, and air. This idea lasted thousands of years and appeared among many different kinds of people all around the world. Early alchemists were especially interested in what matter is made of because they were working feverishly to find ways to change cheap metals like iron and lead into gold.

The Four Elements (20-minutes)

Materials

Materials for the whole class

- science notebooks (supplied by teacher)
- BLM 1 to project for the whole class (optional)

Procedure

1. Explain the ideas presented in the Science Background section to the class, either verbally, or if you prefer, project and read BLM 1 as an option.
2. Present the whole class with examples of natural things to analyze for these four elements that might make them up: a potato, a rock, a piece of silver. Ask them to analyze these things thinking as an ancient person and give their evidence for their analysis.

potato

is wet when cut so it must have water
can burn so has fire
produces steam when hot and cut open so it has air
turns to ash when burned so it has earth

rock

no water in it
can't burn, so no fire in it
falls in air, so no air in it
only made of earth

silver

can't burn, so no fire
melts in heat, so must have some water
makes no smoke or bubbles, so no air
heavy like earth, so it must have earth

Challenge pairs of students to think of three natural objects and use the four element approach to describe what they could be made of.

Wrap-Up

Ask volunteers to present their analysis and accept all answers.

After this discussion, point out that people began to see limitations of the four element system. For example, lead and gold were both made of earth and water, and the model didn't explain the differences. Early alchemists were eager to get rich, so they worked very hard to turn metals such as lead into gold. They never did make gold from lead, but their hard work produced some discoveries about matter. Over a long period of time, as they developed better systems to classify what matter was made of, their work began to look a little more like the science we know as chemistry. Over time, chemists began to make more things that people needed, such as dyes and gunpowder. As we will see, chemists now have models that work well to explain how matter interacts, and people continue to explore what stuff is made of.

BLM 1

Ancient people of many cultures looked at the things around them and tried to figure out what those things were made of. They asked questions such as, “If you cut a piece of cheese in half, and divide each resulting piece in half, and keep doing that, can you keep dividing until you are left with something that is no longer cheese?” They thought that things might be made of basic parts that are too small to see. One reason they worked so hard on this was because they wanted to get rich. They thought they might be able to rearrange the tiny basic parts of things to turn a cheap metal like lead into gold. People doing this were called alchemists.

The alchemists had an idea that four basic elements make up everything: Air, Earth, Fire, and Water. Ancient people got this idea from looking at the world around them, just as scientists today explain what they see using evidence collected from observations. The ancient people noticed that burning wood made fire, so it must have fire in it. They noticed that ashes were left over after the fire. The ashes came from the wood and ashes are like earth. They saw that burning wood made smoke, and smoke is like air. From this, they thought that wood must be made of fire, earth, and air. Thinking in this way, they noticed that oil burned in lamps is liquid, so it must have water. Because it burns, it must have fire. It makes smoke, so it must have air. Ideas like this lasted for thousands of years. People in different parts of the world came up with very similar ideas about this, even though they did not talk to each other.

Appendix

Common Student Preconceptions About This Topic

Children have difficulty distinguishing between elements, compounds, atoms, and molecules for reasons having to do with basic language. For example, elements are described as "pure" substances, meaning "made of only one thing." For many children, the term "pure" means "without harmful contents," or "clean, bright, and as-it-should-be." In addition, children have difficulty with the idea of "substance." For example, some middle school children see ice and water as different substances. In general, most children understand matter in a macroscopic way, not at a microscopic level. As a result, they tend to view chemical combination as a kind of mixing, with only a hazy idea of microscopic internal chemical bonds. For example, many think that burning is like evaporation, only faster because of the heat. Although they know that oxygen is necessary for combustion, they have little or no sense that it is interacting with the material that is burning.

Throughout the guide, teaching tips are in red.

Activity Description & Estimated Class Time

Over the course of two 50-minute class periods, students will combine unknown reactants (two white solids, a clear liquid, and a bright red liquid) and experience them reacting in a closed plastic bag. Several different changes will take place. Students are challenged to write a description of the reaction and its products, then try to determine what reactants are responsible for the products and changes observed.

Objectives

Students will demonstrate knowledge and understanding of the following ideas and content:

- Chemical reactions produce observable changes in matter.

Students demonstrate this knowledge and understanding by recording observations during a chemical reaction and adjusting proportions of reactants to determine which combinations produce the different reactions and products.

Correlations to North Carolina Science Standards

8.P.1.3 Compare physical changes such as size, shape and state to chemical changes that are the result of a chemical reaction to include changes in temperature, color, formation of a gas or precipitate.

Brief Science Background

In a chemical reaction, ingredients (reactants) both break *and* form chemical bonds. Changes in chemical bonds often cause the result (product) to have characteristics that are different from the reactants. Some reactions occur spontaneously, others require some input of energy to begin. When reactants produce a chemical reaction, the reaction often causes observable changes such as color change, a temperature change, production of gas, an odor, light, or a precipitate.

In the chemical change demonstrated in this investigation, a careful observer may see many of the changes listed above.

Details of the reaction are complicated, *not important* at this time, and should not be discussed with the students. However, for reference, the reaction is:

$$CaCl_2 + 2NaHCO_3 \rightarrow 2NaCl + CaCO_3 + H_2CO_3$$

$$H_2CO_3 \rightarrow CO_2 + H_2O$$

Calcium chloride (*Powder A*, $CaCl_2$, a salt) and sodium bicarbonate (*Powder B*, $NaHCO_3$, baking soda, a salt) combine, in the presence of water (*Liquid C*), to produce sodium chloride (NaCl, table salt), calcium carbonate ($CaCO_3$, lime, a salt), and carbonic acid (H_2CO_3). Carbonic acid is unstable and breaks down to carbon dioxide (CO_2) and water (H_2O). Phenol red (*Liquid D*) is a pH indicator and does not take part in the reaction.

Part 1 — Chemical Change (30-minutes)

Materials

Materials for the whole class

- Powder A, calcium chloride, $CaCl_2$
- Powder B, sodium bicarbonate, $NaHCO_3$
- Liquid C, water
- Liquid D, phenol red (500 ml)
- pre-printed labels for A, B, C, and D
- large zip lock bags for storing powders
- candle in a 3.5 oz plastic cup
- long match
- pint Mason jar with a new lid
- electronic balance
- copies of student instruction sheets (2 per team)

Materials for groups of 4 students

- 1 Powder A in a labeled and capped 3.5 oz cup
- 1 Powder B in a labeled and capped 3.5 oz cup
- 1 Liquid C (water) in a labeled 125ml dropper bottle
- 1 Liquid D (phenol red) in a 125 ml dropper bottle
- 2 medicine cups
- 2 zip lock sandwich bags
- 2 sets of measuring spoons
- 2 student instruction sheets (BLM 1)
- safety glasses (supplied by teacher)
- science notebook (supplied by teacher)

Preparation

1. Prepare the phenol red solution by filling the 500 ml bottle, which already contains the phenol red powder, with water. Use this stock solution to fill the dropper bottles labeled Solution D.
2. Fill the Liquid C bottles with water.

Procedure

1. Demonstrate the setup for the students:
2. Put 5 ml (1 teaspoon) of Powder A and 2.5 ml (1/2 teaspoon) of Powder B in the sandwich bag.
3. Put 5 ml of Liquid C and 10 drops of Liquid D together in a medicine cup.
4. Set the medicine cup containing the liquid in the bag, but DO NOT turn it over.

Procedure Cont.

5. Flatten out the bag between your hands and seal the bag.
6. Tell students that when they get this far they will turn over the cup of liquid so it pours onto the dry ingredients and observe what happens.
7. Before handing out the materials, tell students to put on eye protection and that they should avoid either ingesting or inhaling any of the "ingredients" for the experiment. Hand out the materials and the student directions and let the students go to work.
8. As students finish watching the reactions ask them to write a list of the changes they observed. Discuss the students' lists of observed changes. Here are changes that students might notice:
   - The reaction fizzes, producing bubbles of gas that partially inflate the bag if it was well zipped.
   - When one of the white powders dissolves in the liquid and gas is released, the chemicals cool a little and part of the bag feels cool. When the other white powder dissolves in the liquid, the bag gets warm. Depending on how reactants mix in the bag, students may feel both hot and cool at different places in the same bag at the same time.
   - The liquid changes from bright red to orange or yellow.
   - A white substance forms and makes the liquid cloudy. This might be hard to see because some of the reactants may still be undissolved.
9. If some students disagree on what they observed, ask the whole class to run the procedure again to see if everyone can observe the same changes. If there are no disagreements about observations, there is no need to run the standard bag setup a second time. If the class does a second run of the procedure, discuss any new observations.

There is no need at this time to discuss why students observed what they did. For the teacher's information only, the following points explain some of the students' observations:

- The reaction produces enough bubbles of carbon dioxide (CO_2) to partially inflate the bag.
- The act of dissolving the baking soda in water causes cooling. The reaction between calcium chloride and water produces heat.
- The product of the reaction between calcium chloride and sodium bicarbonate in water is carbonic acid, which changes the pH from basic to acidic and causes the phenol red to change from bright red to orange or yellow.
- The carbonic acid in solution rapidly breaks down to produce carbon dioxide gas which bubbles and fills the bag.
- One reaction product is calcium carbonate, a white precipitate that clouds the water. Leftover calcium chloride and sodium bicarbonate make this hard to see. Sodium chloride is also a product, but it tends to remain dissolved and does not cloud the water.

Wrap-Up

1. Say that early chemists first observed reactions, and then tried to figure out what caused each part of them. They investigated the reactants in one way, the reaction another way, and analyzed the products in another way. This approach led them to understand what different substances were made of. For

example, an early chemist produced an unknown gas in a chemical reaction. To find out what the gas might be, he placed a candle in a jar of the gas. He saw that the candle burned more brightly than usual. From this, he thought that the gas might be something in air that allows things to burn. Eventually, this led to the discovery of oxygen.

2. Ask students to write some procedures that they might use to investigate the reaction they have observed.

Part 2 — Chemical Change 2 (30-minutes)

Materials

Materials for groups of 4 students

- 1 Powder A in a labeled and capped 3.5 oz cup
- 1 Powder B in a labeled and capped 3.5 oz cup
- 1 Liquid C (water) in a labeled 125 ml dropper bottle
- 1 Liquid D (phenol red) in a 125 ml dropper bottle
- 6 medicine cups
- 6 zip lock sandwich bags
- 2 sets of measuring spoons
- 2 student instruction sheets (BLM 1 from previous lesson)
- safety glasses (supplied by teacher)
- science notebook (supplied by teacher)

Preparation

1. Prepare the phenol red solution by filling the 1 liter bottle with water. Use this stock solution to fill the dropper bottles labeled with Solution D.
2. Fill the Liquid C bottles with water.
3. Fill 3.5 oz labeled cups with Powder A and Powder B.

Procedure

1. Ask students to share their ideas of what they might do to investigate the reaction in the bag to try and figure out what reactants caused the changes they observed. Hopefully, students will come up with the idea of changing the recipe to observe what happens differently. For example, they might leave out a reactant. If they do not come up with recipe changes on their own, explain that early chemists tried simplifying reactions by using fewer reactants and observing the reaction and products.
2. Challenge pairs of students to work together to develop three new recipes that might help them study the reaction. Tell them that they can leave out whatever they want but that they are not allowed to more than double any reactant. The limit on amount of reactants helps to avoid exploding bags due to gas buildup caused by large amounts of reactants.
3. Ask the students to record their recipes in their notebooks with detailed entries of their observations.

Wrap-Up

1. Ask students to write their conclusions in the form of, "Reactant X + Reactant Y results in _____" on strips of paper and have them post the strips where students can see them all together and compare them. Discuss what students observe. In the discussion try to bring out two things:

   a. a class consensus about what each reactant brings to the reaction and its products

   b. ideas about what to do when results using the same reactants differ.

2. Explain that chemists often use different types of equipment to study a reaction. Inside the mason jar, carefully place the same reactants in the same containers that were used in the bag. Tighten the lid down very hard. Take care when tightening the lid not to tip over any ingredients in the bottle. You do not want a reaction yet.

3. Display the mason jar with lid on and explain that, in a few minutes, you will tip the jar to start the reaction. Ask the class for possibilities of what might happen when the reactants combine. Students might say:

   - The reaction will be as usual.
   - There will be no reaction because there is no room for the gas.
   - The reaction will be as usual and jar will explode because it can't expand like the bag.

4. After this discussion and before starting the reaction say, "Early chemists were interested in the amounts of reactants and products in reactions. If I weigh the jar before and after the reaction what might the results be?" Ask for student answers and their reasoning. Keep pushing to get all three possibilities: same weight, more weight, or less weight. Weigh the jar and record the weight before the reaction. Inform students that the scale is accurate within 0.1 g.

5. Tip the jar and shake the reactants to start the reaction. Ask students to point out what is happening in the jar. Weigh the jar again. The weight should be unchanged. Say that other early chemists also observed this. If they caught all of the reaction products of any chemical reaction, the starting and ending weights were the same. Whenever all reactants and products are weighed and not allowed to escape, the setup always weighs the same before and after. This is called conservation of matter. In a chemical reaction, matter changes but is never lost. It is always "conserved." This was a strong clue that matter is made up of parts that can rearrange.

6. Finish discussing all questions about conservation of matter and inform the class that we can still investigate the gas that was produced.

7. Say, "We know some gas was produced because we saw bubbles. Early chemists often used a candle to test an unknown gas. Light a candle and place it in a 3.5 oz plastic cup. Ask the class what could happen when you open the lid and pour the gas out of the jar and what each of the possibilities mentioned could indicate. Possibilities include:

   a. Nothing happens so the gas must be just like the air around us.

b. The candle burns brighter so the gas contains more of what a candle needs to burn.

c. The flame explodes, so the gas must contain some fuel.

d. The candle burns dimmer, so it must not be like the air around us.

e The candle goes out so the gas must be something that inhibits burning.

8. Open the lid slowly to release some pressure. Ask the class what the sound indicates. After the pressure is released, slowly tip the jar over the edge of the cup. You are pouring carbon dioxide, which is heavier than air. As the carbon dioxide fills the cup, the candle will go out. Be careful to not pour the liquid out of the jar. After the candle is extinguished light a long match and place it in the jar and watch it extinguish.
9. Ask the class for detailed descriptions of what they have just observed. They should see that an invisible gas was poured out of the jar and it extinguished the candle and then it extinguished a burning match.
10. Ask for predictions on what the weight of the jar is now. The weight will be between several tenths of a gram and nearly a gram less.
11. Ask what this tells us about the gas produced in the reaction. Students should notice that it has weight, it is invisible, it seems to be heavier than air (it pours down through the air) and it can extinguish a flame.
12. Say, "When early chemists discovered this kind of information, they started to wonder things such as:

    a. What makes gases different from each other?

    b. How are gases different from solids?

    c. What makes substances different from each other?

Guided Practice

Guided Practices are similar to typical tests, but require students to reveal their thinking about content. They serve as a practice before a test and should not be graded. They are intended to expose misconceptions *before* an assessment and to provide opportunities for discussion, re-teaching, and for students to justify answers. They are best given as individual assignments without the manipulatives used in the activity. In that context, pose the following "test items" to the class. Ask them to write responses in notebooks.

1. Early alchemists and chemists often observed reactions and then worked backwards to figure out what was happening. They did this especially where many reactants were involved, as in our bag reaction. Comment on how each procedure might give insights into what reactions are happening in our bag:

    a. Double the dry ingredients. Mix them together in the bag and let them sit for a week.

    b. Double the amount of one reactant and see what happens.

    c. Open the bag when you turn over the liquids.

d. Double one reagent and see if the bag inflates more.

2) A teacher was trying to convince students that conservation of matter always occurs in a chemical reaction. To do this, the teacher mixed vinegar and baking soda in a cup. Students had carefully weighed the ingredients and cup, and recorded the weight before the reaction. They combined the reactants in the cup and got a fizzing reaction. When the reaction was over, the class couldn't see any baking soda. However, the cup of mixed compounds weighed less than it weighed before the reaction. The teacher still says that whenever a chemical reaction occurs, what you start with (reactants) and what you end with (products) have the same weight. Which explanation below would be best for students to use to help their teacher understand why the law of conservation of mass appeared not to work?

a. Part of the cup dissolved into the vinegar so it all weighed less.

b. The fizzing is a gas produced during the reaction, so she needs to catch the gas to weigh it.

c. The baking soda disappeared so it all weighed less.

3) Students started proposing new experiments that would allow this reaction to prove the law of conservation of matter in a chemical equation. Which experiment or combination of experiments might supply evidence supporting the law, and why?

a. Do the reaction in a container made of glass.

b. Do the reaction with more reactants so they are easier to weigh.

c. Do the reaction in a container with a tightly closed lid.

d. Weigh all reactants and products before and after the reaction.

BLM 1

Student Instructions for Chemical Change

1. Put on your safety glasses.
2. Place 5 ml (1 teaspoon) of Powder A in the sandwich bag.
3. Place 2.5 ml (1/2 teaspoon) of Powder B in the same sandwich bag.
4. Put 5 ml of Liquid C and 10 drops of Liquid D together in a medicine cup. Place the cup in the same bag, but **keep it upright**!
5. Press the air out of the bag and zip the bag closed.
6. Tip the cup over and mix all the chemicals.
7. In your science notebook, write detailed descriptions of *everything you observed*.

Appendix

Common Student Preconceptions About This Topic

Children have difficulty distinguishing between elements, compounds, atoms, and molecules for reasons having to do with basic language. For example, elements are described as "pure" substances, meaning "made of only one thing." For many children, the term "pure" means "without harmful contents," or "clean, bright, and as-it-should-be." In addition, children have difficulty with the idea of "substance." For example, some middle school children see ice and water as different substances. In general, most children understand matter in a macroscopic way, not at a microscopic level. As a result, they tend to view chemical combination as a kind of mixing, with only a hazy idea of microscopic internal chemical bonds. For example, many think that burning is like evaporation, only faster because of the heat. Although they know that oxygen is necessary for combustion, they have little or no sense that it is interacting with the material that is burning.

Throughout the guide, teaching tips are in red.

Activity Description & Estimated Class Time

In this 50-minute activity, students combine two liquid reactants and measure the amount of gas produced. Their goal is to find a combination of reactants that produces the greatest volume of gas. The activity allows students to experience early experimenters' empirical approach to determining a chemical formula and the use of chemical equations to describe a reaction. It also provides a basis for understanding one of the keystones in the development of the atomic theory.

Objectives

Students will demonstrate knowledge and understanding of the following ideas and content:

- Chemical compounds are composed of proportional amounts of substances.

Students demonstrate this knowledge and understanding by determining, through experimentation, the proportion of reactants that produce the largest volume of a gas. They explain this result as evidence that matter combines chemically in specific proportions. After this, they can explain that one logical explanation has each kind of matter composed of tiny particles, each of which possesses the property of combining with other particles in specific proportions.

Correlations to North Carolina Science Standards

8.P.1.3 Compare physical changes such as size, shape and state to chemical changes that are the result of a chemical reaction to include changes in temperature, color, formation of a gas or precipitate.

8.P.1.4 Explain how the ideas of atoms and a balanced chemical equation support the law of conservation of mass.

Brief Science Background

Early experimenters in chemistry used empirical evidence to develop the atomic theory that explained the interactions of matter in chemical reactions. Early on, scientists like Proust deduced that compounds are formed in exact proportions that do not change (his law of definite proportions). This concept gave support to Dalton's theory that matter is made of atoms of different elements that combine in definite proportions. This early experimentation provided evidence for the atomic theory that would be developed later.

Part 1 — Putting Chemicals Together (50-minutes)

Materials

Materials for the whole class

- 2 half-gallon bottles of 1.66% sodium bicarbonate solution
- acetic acid solution (vinegar)
- universal indicator solution
- silicone lubricant

Materials for groups of 2 students

- 1 reaction bottle (4 oz clear plastic)
- 1 rubber stopper with a hole
- 1 syringe, 60 ml
- 1 syringe, 20 ml
- a 9 oz cup half filled with acetic acid solution (vinegar) that is colored with universal indicator (see step 3 under Preparation below)
- a 9 oz cup half filled with sodium bicarbonate solution that is colored with universal indicator (see step 4 under Preparation below)

Materials for each student

- safety glasses (supplied by teacher)
- science notebooks (supplied by teacher)

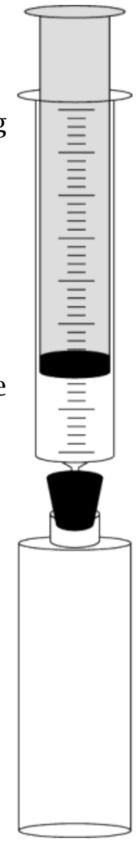
Preparation

1. Prepare two half-gallon bottles of 1.66% sodium bicarbonate solution. Place 33.5 g of sodium bicarbonate in each of two half-gallon containers, then fill both containers with water to the half-gallon line. This needs to be accurate. To compare results, both bottles of sodium bicarbonate solution should be very close to the same concentration.
2. Remove plungers from the large syringes and lightly spray silicone lubricant on the rubber part of the plungers. The plungers must be lubricated to accurately measure the amount of gas produced.
3. Half-fill 9-oz cups with acetic acid solution (one cup per pair of students) and add 5 drops of universal indicator to make it pink. Each pair of students will use this as a stock solution for the investigation
4. Half-fill a 9-oz cup with 1.66% sodium bicarbonate (1 cup per pair of students) and add 5 drops of universal indicator to make it green. Each pair of students will use this as a second stock solution for the investigation.

Procedure

1. Tell students that they will try to make the most gas they can by mixing a red and a green chemical. Their job is to discover the right amount of red to mix with the right amount of green to do that. Tell them that you will demonstrate the apparatus that they will use for this. As you demonstrate, do not tell students how much of each reagent you are using.
2. Use the 20ml syringe to measure out 10 ml of the green sodium bicarbonate solution and squirt it into the reaction bottle. Place the rubber stopper firmly into the reaction bottle.

Procedure Cont.



3. Draw 10 ml of red acetic acid up into the 60 ml syringe. Explain that the total amount of chemicals they can use is 20 ml.
4. Taking care not to touch the plunger, fit the 60 ml syringe containing the measured amount of acetic acid into the rubber stopper and push the rubber stopper firmly into the mouth of the reaction bottle without pushing down on the syringe plunger. Check to be sure that the stopper is pushed firmly into the mouth of the reaction bottle. Push the plunger all the way down and leave it down. All of the red solution will go into the bottle.
5. Swirl the bottle until all bubbling stops. As the reaction proceeds, the plunger moves up. When the plunger no longer rises, press it down and let it spring back up twice. That number is the volume of gas produced in ml.
6. Tell students that they will do what you just did multiple times, and gather data each time. When teams finish, they should have enough data to help them determine the proportion of red and green that produces the most gas.
7. Tell students to start and remind students of these rules (if it helps, project BLM 1 for the whole class to see):
   - ***For each test, the amount of red and green must add up to 20 ml. No more. No less.***
   - Use the small (20 ml) syringe *only* for green solution
   - Use the large (60 ml) syringe *only* for red solution
   - Always put the green solution in the bottle first, then seal the bottle and add the red solution.
   - The large 60 ml syringe always measures the volume of gas produced.
   - For each trial, record three things:
     - the volume in ml (e.g. 12 ml) of red solution used for that trial
     - the volume in ml of green solution used for that trial
     - the volume in ml of gas the trial produced

Wrap-Up

1. Explain that historically, chemists measured the relative amounts of reactants needed to achieve a complete reaction, and they used this information to calculate the proportions of different substances in unknown products. For example, experimenters combined varying amounts of hydrogen and oxygen (explosively) to make water. When some unreacted hydrogen or oxygen remained afterward, they adjusted the proportions of hydrogen and oxygen until at last the reaction went to completion with no reactants remaining. They found that two volumes of hydrogen ($2H_2$) mixed with one volume of oxygen ($1O_2$) exactly combined with no unreacted hydrogen or oxygen left over. In that way, they experimentally determined that the formula for water is H_2O.
2. Ask, "What do our results tell us about the proportions of red and green reac-

tants? How could we express that without a lot of words?" Allow students to write what they think in their notebooks and use whatever shorthand they develop to express their ideas. Depending on what the students generate, a discussion of how to write chemical equations using simple terms can help. Teams should come close to 15ml green to 5ml red, which you can simplify to something like: 3 G + 1 R = Most Gas.

3. Say, "The proportion of red and green liquids that makes the most gas always seems to be the same. What reasons might you give for this?" **This question is intended to get students to think about this. Answers at this time do not need to be correct.**

4. Explain that experiments like these suggested that matter acted as discrete units or pieces that combined in specific ways that could be determined experimentally. This evidence helped generate the atomic theory.

Guided Practice

Guided Practices are similar to typical tests, but require students to reveal their thinking about content. They serve as a practice before a test and should not be graded. They are intended to expose misconceptions *before* an assessment and to provide opportunities for discussion, re-teaching, and for students to justify answers. They are best given as individual assignments without the manipulatives used in the activity. In that context, pose the following "test items" to the class. Ask them to write responses in notebooks.

Some industrious students are working to create a perfect liquid glue recipe. They mix 1 gram of Gl (a white powder) with 1 gram of Ue (a green powder) in 100 ml of water and shake the mixture well. The product is a very sticky blue liquid super glue with some of the original white powder at the bottom of the mixing jar. When they pour off the glue and dry and weigh the white powder they find that it weighs .5 grams. Which of the student suggestions below might improve the recipe? Support your idea with evidence.

a. Add more water to make more glue and dissolve the white powder better.

b. Increase the amount of white powder.

c. Decrease the amount of white powder by half.

d. Shake the mixture for a longer time.

e. Increase the amount of green powder.

Answer Key

Either c. or e. would work. Some white powder was left because the green and white powders do not combine in a 1:1 proportion by weight, but more like twice as much green as white powder.

BLM 1

- For each test, the amount of red and green must add up to 20 ml. No more. No less.

- Use the small (20 ml) syringe *only* for green solution.

- Use the large (60 ml) syringe *only* for red solution.

- Always put the green solution in the bottle first, then seal the bottle and add the red solution.

- The large 60 ml syringe always measures the volume of gas produced.

- For each trial, record three things:
    - the volume in ml (e.g. 12 ml) of red solution used for that trial
    - the volume in ml of green solution used for that trial
    - the volume in ml of gas the trial produced.

Reaction Rates

Throughout the guide, teaching tips are in red.

Activity Description & Estimated Class Time

Over two 50-minute class periods, students time the rate of a reaction (the dissolving of an antacid tablet) in different temperatures of water. They gather data and use it to generate a graph. They use the graph to predict either time or temperature when given the other variable.

Objectives

Students will demonstrate knowledge and understanding of the following ideas and content:

- Temperature affects the rate of a reaction.
- Control of variables is important in an experiment.
- Graphs of data can be used to predict results.

Students demonstrate this knowledge and understanding by agreeing on a procedure to determine the effect of temperature on the reaction of an effervescent tablet in water. They will use their collected data to generate a graph that can be used as a predictive tool.

Correlations to North Carolina Science Standards

8.P.1.3 Compare physical changes such as size, shape and state to chemical changes that are the result of a chemical reaction to include changes in temperature, color, formation of a gas or precipitate.

Correlations to Common Core State Standards for Mathematics

Statistics and Probability 8.SP Investigate patterns of association in bivariate data.

1. Construct and interpret scatter plots for bivariate measurement data to investigate patterns of association between two quantities. Describe patterns such as clustering, outliers, positive or negative association, linear association, and nonlinear association.

2. Know that straight lines are widely used to model relationships between two quantitative variables. For scatter plots that suggest a linear association, informally fit a straight line, and informally assess the model fit by judging the closeness of the data points to the line.

Brief Science Background

In general, most chemical reactions speed up as temperature rises. At higher temperatures, particles collide more often, and more molecules have enough energy for bonds to form or break. Students will observe how temperature affects the rate of reaction between the sodium bicarbonate and citric acid in an effervescent tablet. In water, these two compounds combine as follows:

sodium bicarbonate + citric acid → carbon dioxide + water + sodium citrate

$$3\ NaHCO_3 + H_3C_6H_5O_7 \rightarrow 3\ CO_2 + 3\ H_2O + Na_3C_6H_5O_7$$

The CO_2 gives the tablets their fizz, and the sodium bicarbonate helps to neutralize an overly acid stomach.

Part 1 — Reaction Rates (50-minutes)

Materials

Materials for the whole class

- 1 hot pot
- 1 gallon thermos bottle with hot water (60-70 ˚C)
- ice water (supplied by teacher)
- room temperature water (supplied by teacher)

Materials for tables of 4 (2 teams per table)

- 1 dump bucket (supplied by teacher)

Materials for groups of 2 students

- 1 thermometer
- 6 effervescent tablets
- 2 Styrofoam cups, 8 oz, for hot and cold water
- 1 plastic cup, 9 oz, for mixing
- 2 plastic cups, 3.5 oz, for running the trials
- 1 graduated cylinder, 50 ml
- 1 stopwatch

Preparation

1. Prepare hot water in the hot pot and transfer it to the thermos container for distributing to students.
2. Prepare some bottles of ice water.
3. Allow a water supply to sit at room temperature overnight.

Procedure

1. Ask students to fill a 3.5 oz cup with 50 ml of room temperature water. Tell them that they will drop an effervescent tablet in the water and time how long the reaction takes from beginning to end. Ask them to describe in their notebooks the conditions in the cup at the moment they declared the reaction “stopped.” Students will get a wide range of results. Asking the class to agree on how they want every team to determine the endpoint can produce a very useful discussion. If they cannot agree, the easiest reaction endpoint to determine is when the tablet can no longer be seen. The tablet disappears before the bubbles stop, and it is easier to measure. Once an endpoint is agreed upon, the class can practice determining the endpoint together using room temperature water.
2. Tell students that they will investigate how temperature affects the speed of the chemical reaction in an effervescent tablet. Before the students begin, ask them what factors they need to consider so that different groups’ results will be comparable. What factors could vary from experiment to experiment? What would everyone need to try to make the same? The discussion helps students think about controlling variables in an experiment. Make a list with the class from student input. The list should include:

Procedure Cont.

- The amount of water (try to get the class to agree on something near 50 ml).
- The temperature of the water (try to get the class to agree on four 10 ºC intervals—for example, 5, 15, 25, and 35 ºC).
- How beginning and end times of the reaction are determined.
- What the beginning and end of the reaction look like.

3. When students are ready to begin, distribute hot and cold water in Styrofoam cups. These may need to be refilled from time to time during the trials.
4. Students should mix hot and cold water in the 9 oz plastic cup, using the thermometer to get the correct temperature. They then measure 50 ml of this water with the graduated cylinder and pour it into a 3.5 oz reaction cup. Students should check the temperature of the water in the cup one final time before dropping in the tablet.
5. Tell students that for each trial, they will time the reaction from start to finish and record the data (time and temperature) in a table. Ask them to record any special observations they make in their notebooks.
6. Ask students to collect time data at four different temperatures. Stress that the temperatures should be different by at least 5 degrees C. A natural break in the activity is the point when students have collected all of their data.
7. Begin the next class period by asking students to describe their results. Ask how these results would look on a graph. Discuss how to set up a graph so that graphs from different teams can be compared. Tell the class to always put what they know before the experiment (temperature in this case) on the horizontal X-axis, and put what they find out (time in this case) on the vertical Y-axis.
8. Post all of the graphs and discuss them with the class. Ask about how the graph might be used. Ask about points between and beyond those that are on the graph (interpolate and extrapolate).
    - Have a cup of known temperature water and ask the class to use their graphs to predict how long it will take the tablet to dissolve. Do the test and compare the results with predictions.
    - Ask teams to set up a cup of known water temperature and record that temperature, then trade water with another team. Teams will run the reaction without measuring the starting temperature and use their graph to determine what the starting temperature must have been.

Wrap-Up

1. Discuss the accuracy of predictions made by the graphs. Ask students what could be done to make the graph predictions more accurate.
2. Ask students for their ideas on why an increase in temperature speeds up the reaction. Discuss the notion that higher temperature in a system indicates more energy in the system. Explain that the discovery that higher temperatures sped up reactions supports the idea that matter is made of small bits that can interact to produce chemical changes. **The higher the temperature, the more often particles collide. In addition, the higher the temperature, the more molecules have enough energy to form or break bonds.**

Guided Practice

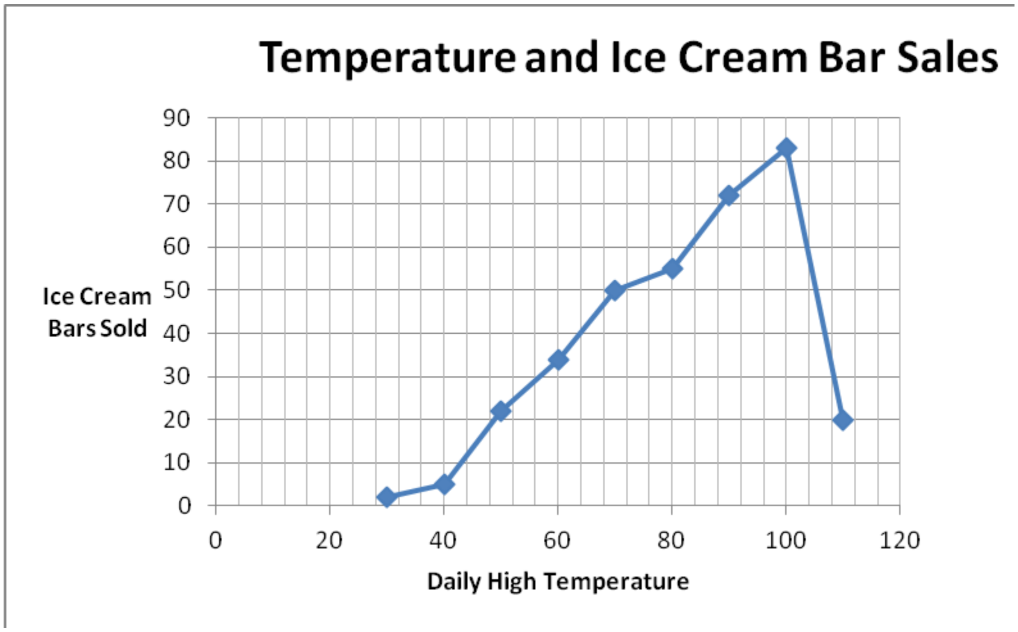
Guided Practices are similar to typical tests, but require students to reveal their thinking about content. They serve as a practice before a test and should not be graded. They are intended to expose misconceptions *before* an assessment and to provide opportunities for discussion, re-teaching, and for students to justify answers. They are best given as individual assignments without the manipulatives used in the activity. In that context, pose the following "test items" to the class. Ask them to write responses in notebooks.

This guided practice can be assigned in two different ways. Give raw data if students need practice making a graph. Give the pre-made graph of the same data if students need practice interpreting a graph. The analysis questions are the same in both cases.

Three students made a graph of the ice cream sales from their bicycle ice cream cart. They want to be better at ordering the right amount of ice cream bars based on the predicted temperature for the day. The data are presented below and the graph is on the next page.

1. What general trends are shown by the graph?
2. The predicted temperatures for a three day weekend are 75 degrees, 85 degrees and 95 degrees. About how many ice cream bars should the students order so they won't run out but not have too many extra?
3. Between what two temperatures do sales increase the most?
4. Between what two temperatures do sales decrease the most?

Daily High Temperature	# Ice Cream Bars Sold
30	2
40	4
50	22
60	34
70	51
80	55
90	72
100	83
110	20


Temperature and Ice Cream Bar Sales
Ice Cream Bars Sold
90
80
70
60
50
40
30
20
10
0
0
20
40
60
80
100
120
Daily High Temperature

Throughout the guide, teaching tips are in red.

Activity Description & Estimated Class Time

During five 50-minute periods, students will investigate properties (physical appearance, solubility, conductivity, reactions with water, reaction with acid, pH, and reaction with iodine) of nine white powders. They will then use this data to solve a riddle based on unknown mixtures of the powders.

Objectives

Students will demonstrate knowledge and understanding of the following ideas and content:

- Different compounds have different measurable properties.
- Properties of compounds remain consistent, and can be used to identify them.

Students demonstrate this knowledge and understanding by collecting data on properties of some compounds, then using this information to solve a complicated riddle.

Correlations to North Carolina Science Standards

8.P.1.2 Explain how the physical properties of elements and their reactivity have been used to produce the current model of the periodic table of elements.

8.P.1.3 Compare physical changes such as size, shape and state to chemical changes that are the result of a chemical reaction to include changes in temperature, color, formation of a gas or precipitate.

Brief Science Background

Physical properties of matter are determined by the electrons of the atoms that make up that matter. These properties are a constant and consistent for each material, and can be measured. Combining materials in a chemical reaction produces a chemical compound. In a chemical compound, the components *do not* retain their individual properties. However, combining materials where no chemical reaction takes place produces a mixture. In a mixture, the components *do* retain their individual properties. Understanding this will help students solve the riddle of the mystery mixtures.

Part 1 — Properties of Powders (50-minutes)

Materials

Materials for groups of 4 students (2 pairs)

- 1 labeled cup, 3.5 oz, of baking powder
- 1 labeled cup, 3.5 oz, of sodium bicarbonate (baking soda)
- 1 labeled cup, 3.5 oz, of cornstarch
- 1 labeled cup, 3.5 oz, of Epsom salt
- 1 labeled cup, 3.5 oz, of flour
- 1 labeled cup, 3.5 oz, of powdered sugar

Materials Cont.

- 1 labeled cup, 3.5 oz, of salt
- 1 labeled cup, 3.5 oz, of sugar
- 1 labeled cup, 3.5 oz, of sodium carbonate (washing soda)
- 9 small scoop spoons, one for each cup of powder
- toothpicks for stirring
- 1 wash bottle
- acetic acid solution (vinegar) in a 1 oz cup
- 1 labeled dropper bottle of iodine solution
- droppers

Materials for pairs of students:

- 1 Chem Plate
- 1 conductivity tester
- 1 labeled dropper bottle with water
- pH paper test strips

Materials for each student

- 1 photocopy of the reaction chart BLM 1(supplied by teacher)
- science notebook (supplied by teacher)

Preparation

Make copies of BLM 1

1. Fill and label all of the 3.5 oz cups of powders. Make up sets of labeled cups for each table (group of 4). Each set includes 1 labeled cup of each of the following:
    - baking powder
    - sodium bicarbonate (baking soda)
    - cornstarch
    - epsom salt
    - flour
    - powdered sugar
    - salt
    - sugar
    - sodium carbonate (washing soda)

2. Fill and label dropper bottles with water, iodine solution, and vinegar.

Procedure

Students work in pairs to test the properties of the white powders.

The order of chemical tests depends on class time available. It is most efficient and informative to go test-by-test so that the teacher can discuss the setup and significance of each test. Going test-by-test also helps clarify interpretations of test results so that the class can agree. This way, students can compare results of the same tests for different compounds. For example, soluble compounds may dissolve in as little as 1 drop of water or as much as 20 drops of water. Similarly, students can compare the relative conductivity of various solutions by the relative brightness of the conductivity test bulb.

If you have 90 minutes of class time, it is expedient to run batteries of tests sequentially. For example, you could start with the water reaction test (using 1 drop of water), then use the same samples for the solubility test and simply keep track of how many more drops are added. You can then use the solubility test wells for the conductivity test (the wells need at least 10 drops of water). Finally, you can check pH in these same wells. Tests for the acid and iodine reactions change reagents, and therefore need to be done on separate samples.

1. Keep a dedicated scoop in each cup to be used with that cup only. Explain that cross contamination can confuse results, and it is critical to keep everything clean and separate. Preview each test before turning the students loose. Recap results after each test. Tests are as follows:

   - Visual inspection: Just looking at or smelling samples (but not touching or tasting them) can tell you a lot.
   - Reaction with water: Ask how each of the compounds might react with a drop of water. Place a small level scoop of each compound in separate wells of the Chem Plate. Use the water dropper bottle to add 1 drop of water to each sample, one at a time. Note any reaction. Only baking powder will bubble. (It contains both an acid and a carbonate base that react in the presence of water to produce gas).
   - Solubility in water: Ask students what they think "solubility" means. Is it "all or nothing?" How might someone find differences in solubility between compounds? Continue questioning until students come up with a way to compare amounts of water (e.g., counting drops) needed to dissolve equal amounts of different compounds. They'll need to limit amounts of compounds to a single level small scoop. They may refine this procedure. For example, rather than proceed by single drops, it's quicker to add 5 drops, stir, and then stir in another 5 drops up to a maximum of 25 drops. Through their investigations, students should discover the following:
     - Cornstarch and flour are not soluble.
     - Powdered sugar dissolves very quickly but produces a residue that does not dissolve because it contains cornstarch to prevent caking. (Do not tell the students this, but let them discover it themselves. If no one notices, you will have to tell them, because the cornstarch will influence a later test.)
     - Baking powder will look insoluble because it contains cornstarch, but some of its ingredients are soluble.
     - The other compounds are more or less soluble in 5 to 25 drops of water per level small scoop.

- Conductivity: Water solutions of some compounds (ionic compounds) can conduct electricity. Before doing these tests, discuss with students what it means to conduct electricity. Could you light a bulb connected to a battery through a conductor? What are some conductors? They will probably think of metal, but maybe not liquids, so give some examples (e.g. battery acid or saltwater). Could you light a bulb connected to a battery through a liquid conductor? Ask which compounds students predict will conduct in solution. Students can test the dry powders, which should not conduct, before testing the powders in water.

  Demonstrate the technique for testing conductivity. First, test the tester by touching the clean wires to see if the bulb lights. Show how to connect the battery properly. To avoid confusing results due to contamination, dip wire ends in clean water and dry with a paper towel between tests. Test the tester again between trials. For storage after you're done, disconnect batteries from bulbs and be sure wire ends are clean. **Wire ends may need to be cleaned with sandpaper. Some of the solutions corrode wire.** The flour, cornstarch, powdered sugar and sugar solutions will not conduct. The others will conduct and there may even be a noticeable difference in the brightness of the light with highly conductive solutions being brightest.

- pH: The same solution used for conductivity can be used to check pH. Students can use a toothpick to put a drop of solution on the test strip or they can dip an end of the strip into the Chem Plate well. Test paper can be conserved by using half a piece for each test. The color should be checked with the scale chart soon after dipping in the well. Most solutions are around neutral (6 to 7). Baking powder and sodium bicarbonate have a pH around 8 or 9 and sodium carbonate has a pH around 10 or 11.

- Reaction with iodine: You'll only have 1small dropper bottle of iodine and 1 small cup with acid per table of 4 students (2 teams of 2), so the pairs of students will have to switch off using the iodine and the acid. One pair can test with iodine while the other tests with acid, and then they can switch and compare results.

  Students might know that iodine turns dark blue, purple, or black in the presence of starch. It is a good example of a reaction that produces a color change. Ask students to predict which compounds they think will turn color with iodine.

  Student teams should put small level scoops of compounds into separate wells and put a drop of iodine solution on the samples. They need to record all results in their notebooks. Students should discover the following:

  - Baking powder, cornstarch, and flour give an unequivocal positive reaction, turning deep purple.
  - Powdered sugar gives a faint positive reaction because it has a little cornstarch in it to prevent caking, but regular granulated sugar does not.
  - Sodium bicarbonate, Epsom salt, table salt, and granulated sugar yield a negative starch test; they may turn pale yellow to orange.
  - Sodium carbonate turns the iodine solution clear.

  Confirm results with the whole class and ask what these results tell them about baking powder and powdered sugar. Someone may want to check the label on the box, and if so, let them.

- Reaction with acetic acid: Ask the students about the types of things that react with acids. Might any previous results give clues as to which compounds will react with acid? What kind of reaction might you expect?

  Student teams should put one small level scoop of each compound in separate wells, add 1 drop of acetic acid solution (vinegar) from the cup with a dropper to each well, and look for a reaction. Sodium bicarbonate, baking powder, and sodium carbonate all react with the acid to produce bubbles.

Wrap-Up

The class should agree on results after each test. After all tests are complete, display BLM 2 so all students can compare this chart with their results. These results are critical information for the next part of the activity.

Part 2 — Mystery Mixtures

Materials

Materials for groups of 4 students (2 pairs)

- 1 covered cup, 3.5 oz, of mystery powder 1
- 1 covered cup, 3.5 oz, of mystery powder 2
- 1 covered cup, 3.5 oz, of mystery powder 3
- 1 covered cup, 3.5 oz, of mystery powder 4
- 1 covered cup, 3.5 oz, of mystery powder 5
- 1 covered cup, 3.5 oz, of mystery powder 6
- 6 small scoop spoons, one for each cup of powder
- dropper bottle with water
- toothpicks for stirring
- 1 wash bottle
- acetic acid solution (vinegar) in a 1 oz cup
- 1 labeled dropper bottle of iodine solution
- droppers

Preparation

Mix and fill mystery mixtures in 3.5 oz cups. Each group of 4 students needs a cup of each mixture. Make mixtures of the following in a 1:1 ratio, a cup of each ingredient should yield enough mixture for all classes. Store these.

- flour + sodium bicarbonate (baking soda) – labeled mystery powder 5
- flour + baking powder – labeled mystery powder 2
- flour + sodium carbonate (washing soda) – labeled mystery powder 6
- cornstarch + sugar – labeled mystery powder 4
- cornstarch + salt – labeled mystery powder 3
- sugar + sodium bicarbonate (baking soda) – labeled mystery powder 1

Procedure

1. Tell students: You have just become the CEO of the Half-Baked Cookie Company. On your first day on the job, you walk through the plant munching on a macaroon, and see six large tanks of what might be cookie ingredients pushed aside and labeled with question marks. You ask a worker what the tanks are. The worker says the last CEO had the mixtures made to save time. The idea was to mix dry ingredients first to have them ready for the batter. Unfortunately, the ex-CEO wrote the mixtures on a dollar bill, and his 8th grade child bought a soda from the vending machine with that dollar. The vats are now "mystery mixtures" that have sat for a year. It's known what the mixtures are, but no one knows which is which. The worker hands you a list of the mixtures:
   - four + sodium bicarbonate
   - flour + sodium carbonate
   - flour + baking powder
   - cornstarch + sugar
   - cornstarch + salt
   - sugar + sodium bicarbonate
2. You scurry back to your office, remembering that in 8th grade you learned how to figure out what's in each tank. That's why you get the big bucks. What's your plan?
3. Project BLM 3 and let the students plan tests for a few minutes. After they've had time, ask what they've planned. Which tests might be useful to find out what is in the mixtures?
4. The degree to which you walk the students through the testing process depends on the class, but try to make the students do the work. One way would be to have all the students do a test of their choice, and then ask: a) why did they choose that test and b) what do they think the results showed? Given a few examples, they will be able to devise and conduct a test plan that will identify the mystery powders.

Wrap-Up

1. Project BLM 3 and discuss students' ideas of which mixture is which.
2. Reveal the identity of the mystery mixtures.
3. Ask students to explain the steps they took to solve the riddle and how each test helped them solve the riddle.

BLM 1

	Visual inspection	Reaction with water	Solubility with water	Conductivity	pH	Reaction with iodine	Reaction with acetic acid
Baking powder							
Baking soda							
Cornstarch							
Epsom salt							
Flour							
Powdered sugar							
Salt							
Sugar							
Washing soda							

BLM 2

	Reaction with water	Solubility with water	Conductivity	pH	Reaction with iodine	Reaction with acetic acid
Baking powder	bubbles	insoluble, though some soluble ingredients	positive	8-9	dark purple	bubbles
Baking soda	none	soluble 20-25 drops	positive	8-9	stays yellow or orange	bubbles
Cornstarch	none	insoluble	none	6-7	dark purple	none
Epsom salt	none	soluble 5-10 drops	positive	6-7	stays yellow or orange	none
Flour	none	insoluble	none	6-7	dark purple	none
Powdered sugar	none	soluble 5-10 drops with residue	none	6-7	turns slightly purple	none
Salt	none	soluble 5-10 drops	positive	6-7	stays yellow or orange	none
Sugar	none	soluble 5-10 drops	none	6-7	stays yellow or orange	none
Washing soda	none	soluble 15-20 drops	positive	10-11	turns iodine solution clear	bubbles

BLM 3

Flour + sodium bicarbonate (baking soda)

Flour + sodium carbonate (washing soda)

Flour + baking powder

Cornstarch + sugar

Cornstarch + salt

Sugar + sodium bicarbonate (baking soda)

Organize the Elements

Throughout the guide, teaching tips are in red.

Activity Description & Estimated Class Time

Students work for two 50-minute class periods to organize element cards and look for patterns in the periodic table that hint at principles of its organization. Students perform a task similar to Mendeleev's, except that they work with a different set of elements, some of which were unknown in Mendeleev's day. The exercise is intended to expose students to the names and properties of many of the most familiar elements so that they can begin to see how the elements relate to each other.

Objectives

Students will demonstrate knowledge and understanding of the following ideas and content:

- elements are composed of one kind of matter
- elements have specific measurable properties
- the periodic table is arranged by grouping elements with similar properties

Students demonstrate this knowledge and understanding by developing their own organizational scheme for a set of assorted element cards and by analyzing the current Periodic Table to look for organizational patterns.

Correlations to North Carolina Science Standards

8.P.1.1 Classify matter as elements, compounds, or mixtures based on how the atoms are packed together in arrangements.

8.P.1.2 Explain how the physical properties of elements and their reactivity have been used to produce the current model of the periodic table of elements.

Brief Science Background

In 1869, Dmitri Mendeleev designed a set of cards with descriptions of elements, and sorted them until he arranged the elements known at the time into the first periodic table. He arranged his table according to criteria such as atomic mass, physical properties, and chemical properties. He even left gaps in his table where the pattern suggested that yet undiscovered elements should be. Later, when these elements were discovered, it helped to confirm his system. Mendeleev did this work before atomic theory had been developed and accepted. In fact, his work, was fundamental to understanding atomic structure.

As of 2012, the standard form of the periodic table has 118 confirmed elements arranged by increasing atomic number (the number of protons in an atom of an element). The 7 horizontal rows, or "periods," are based on the number of electrons in the outer shell of the element. The first element in a period has one electron in the outer shell and the last element in a period has a full outer electron shell (the un-reactive noble gases). As you move down the table, the periods are longer due to increased electron shell capacity. The Lanthanides and Actinides are often shown below the table because they would make the last two periods longer than is practical on a chart.

The table is organized in 18 columns, or "groups." Elements in a group have similar numbers of electrons available to engage in chemical reactions. As a result, they show many chemical similarities. Larger groups, or "blocks," group elements with similar characteristics together. These have names such as metalloids, transition metals, halides, or noble gases.

Part 1 — Organize the Elements (50-minutes)

Materials

Materials for groups of 2 or 3 students

- element sorting card set (34 white element cards)

Preparation

Make sure each team has an element card set available. An area with large tables or floor space is helpful for this activity.

Procedure

1. To introduce the activity, tell this brief history of Mendeleev. “In our history of chemistry so far, we saw that people once believed that everything was made of 4 basic things, and that this system proved less useful as chemists discovered more kinds of matter. Eventually, chemists started to think that matter was made of small pieces that fit together in many combinations. By 1869, when Dmitri Mendeleev started his work, scientists had found that some matter could be broken down into pieces that all had the same characteristics. They called these substances elements, and they named them and made symbols for them. Elements could be solids, liquids, or gases, but always made of only one thing. Mendeleev had 63 known elements to work with when he decided that some principle must exist to organize them. To find that principle, he wrote down the properties of the elements on cards and started to work.”
2. Tell students that their job is to read their element cards, and like Mendeleev, group similar elements together in ways that make sense.
3. As you circulate among the groups, encourage students to break down larger groups into smaller ones. No hints are necessary as there is no correct answer. Your role is to keep them observing and thinking of new groupings. For example, solids, liquids, and gases is an obvious first grouping. These groups can be broken into sub groups based on other criteria. Depending on time, there are several things to do with students’ grouped element sets:
   - Ask students what they notice about the element cards and what characteristics they used to sort.
   - Ask a team to list the elements in one of their groups out loud and challenge the class to come up with the sorting characteristic for that group.
   - Ask teams to move from their table and look at another team’s classification scheme to identify characteristics the other team used to group elements.

This is a good breaking point.

Part 2 — What Mendeleev Did (50-minutes)

Materials

Materials for the whole class

- ability to project BLM 1 and 2
- large version of the periodic table (hidden until the end of the activity and supplied by teacher).

Materials for groups of 2 or 3 students

- element sorting card set (34 white element cards)
- newly-discovered element card set (6 yellow cards)
- handout version of BLM 1 (optional)

Preparation

Make sure teams have large tables or open floor space available.

Procedure

1. Project BLM1 and ask teams to arrange their cards in this order. **A paper copy of BLM 1 can be helpful for this.**
2. After students arrange their element cards, explain that this is the scheme, still used today, that Mendeleev developed. Challenge them to look at the arrangement and find criteria that Mendeleev used to set it up. Push them to find as many patterns as they can.
3. Tell students that part of Mendeleev's genius was to intentionally leave spaces in the table for elements that he hypothesized would be discovered. The gaps actually helped scientists look for and find these elements. Pass out the yellow cards and tell students that these new elements were just discovered. Ask them to put the new elements where they belong in the table.
4. Project BLM 2 and ask students what clues they used to place the new elements.

Wrap-Up

1. Reveal a larger version of the periodic table and talk with the students about what the numbers and symbols mean. This is a good time to describe the idea of an atom and fit it into the periodic table. Mention that in many ways, this table helped to shape atomic theory.
2. The most important points are:
   - In chemical reactions, electrons are the active parts of atoms.
   - Reactions tend to make stable arrangements of electrons by filling shells as much as possible.
   - Discuss the ideas of rows and groups with the class, giving examples of how the reactivity of different elements relates to the atomic theory.

BLM 1

A Partial Periodic Table of the Elements

H HYDROGEN																	He HELIUM
Li LITHIUM	Be BERYLLIUM											B BORON	C CARBON	N NITROGEN	O OXYGEN	F FLUORINE	Ne NEON
Na SODIUM	Mg MAGNESIUM											Al ALUMINUM	Si SILICON		S SULFUR	Cl CHLORINE	Ar ARGON
	Ca CALCIUM		Ti TITANIUM		Cr CHROMIUM		Fe IRON	Co COBALT		Cu COPPER	Zn ZINC			As ARSENIC		Br BROMINE	
					Mo MOLYBDENUM								Sn TIN				
									Pt PLATINUM	Au GOLD	Hg MERCURY		Pb LEAD				

			U URANIUM		Pu PLUTONIUM									

BLM 2

A Partial Periodic Table of the Elements

H HYDROGEN																	He HELIUM
Li LITHIUM	Be BERYLLIUM											B BORON	C CARBON	N NITROGEN	O OXYGEN	F FLUORINE	Ne NEON
Na SODIUM	Mg MAGNESIUM											Al ALUMINUM	Si SILICON	P PHOSPHORUS	S SULFUR	Cl CHLORINE	Ar ARGON
K POTASSIUM	Ca CALCIUM		Ti TITANIUM		Cr CHROMIUM		Fe IRON	Co COBALT	Ni NICKEL	Cu COPPER	Zn ZINC			As ARSENIC		Br BROMINE	Kr KRYPTON
					Mo MOLYBDENUM					Ag SILVER			Sn TIN			I IODINE	
									Pt PLATINUM	Au GOLD	Hg MERCURY		Pb LEAD				

			U URANIUM		Pu PLUTONIUM									

Appendix

Common Student Preconceptions About This Topic

Children have difficulty distinguishing between elements, compounds, atoms, and molecules for reasons having to do with basic language. For example, elements are described as “pure” substances, meaning, “made of only one thing.” For many children, the term “pure” means “without harmful contents,” or “clean, bright, and as-it-should-be.” In addition, children have difficulty with the idea of “substance.” For example, some middle school children see ice and water as different substances. In general, most children’s characterization of matter is at a macroscopic level, not a microscopic one. They tend to view chemical combination as a kind of mixing, with only a hazy idea of internal microscopic chemical bonds. For example, many think that burning is like evaporation, only faster because of the heat. Although they know that oxygen is necessary for combustion, they have little sense that it interacts with the material that is burning.

Chemical Bonds

Throughout the guide, teaching tips are in red.

Activity Description & Estimated Class Time

Students use cards labeled with element names and the valence numbers to investigate chemical bonds and compounds. This lesson takes one 50-minute period.

Objectives

Students will demonstrate knowledge and understanding of the following ideas and content:

- Compounds are a chemical joining of two or more elements based on giving or sharing electrons between atoms.
- The location of an element in the periodic table gives a clue about how it will form compounds.

Students demonstrate this knowledge and understanding by creating compounds using a simple valence number model. They find the elements of the compound in the periodic table and use the atomic model to explain bonding tendencies.

Correlations to North Carolina Science Standards

8.P.1.1 Classify matter as elements, compounds, or mixtures based on how the atoms are packed together in arrangements.

8.P.1.2 Explain how the physical properties of elements and their reactivity have been used to produce the current model of the periodic table of elements.

Brief Science Background

Chemical reactions involve rearranging electrons among different atoms. Atoms can donate or share electrons. An element's reactivity is based on the available or active electrons in unfilled outer electron shells. The least reactive elements, the noble gases on the far right of the Periodic Table, have full outer electron shells. As a result, they are chemically inactive. The valence number of an element is generally regarded as the maximum number of bonds that element can form. However, elements are not always constant in this number. The elements and valence numbers used in this activity were selected as general models for simple ionic (giving and accepting electrons) and covalent bonds (sharing electrons). The nomenclature of these interactions can be confusing. A compound is formed by chemical bonds between two or more different atoms. An element is a substance composed of just one kind of atom. A molecule is the combination by chemical bonding of any two or more atoms. O_2 is a molecule but, by definition, not a compound. A mixture is just that, a mixture of matter without chemical bonds that can usually be separated by mechanical means.

Chemical Bonds (one 50-minute session)

Materials

Materials for the whole class

- large version of the periodic table (supplied by teacher) or photocopied versions for pairs of students

Materials for groups of 2 students

- a set of valence cards
- science notebook

Preparation

1. Check valence card sets to make sure they are complete. Shuffle them. Each set should contain the following 27 cards:

4 Hydrogen	1 Sodium	1 Calcium
1 Lithium	1 Magnesium	1 Zinc
1 Carbon	2 Aluminum	1 Bromine
1 Nitrogen	2 Silicon	2 Iodine
3 Oxygen	3 Chlorine	1 Mercury
1 Fluorine	1 Potassium	

Procedure

1. Pass out the card sets to pairs of students and ask them to look at them. Ask students for their observations of what is on the card. They should note that there are element names on the card and a mention of what that element does with its electrons. With regard to electrons, explain: "Chemists figured out that when elements are involved in a chemical reaction, electrons are the active part of the atoms."
2. Ask the students to organize the cards by what the elements like to do with electrons. Ask them to find the elements in their groups on the periodic table. Challenge the students to make some general rules about their observations. Students will notice that elements that like to do the same thing with electrons are in the same group. They will also note that electron donators are on the left and electron acceptors are on the right side of the table.
3. Say, "Somebody tell me a chemical formula name for a compound that everybody knows." Somebody will say, "H_20." When they do, take a little time to talk about such a formula and what the 2 signifies (2 hydrogen atoms, not 2 oxygen atoms).
4. Ask the students to find one Oxygen card and two Hydrogen cards, and have a student read the electron affinity on each card. Explain that math is used here: if two hydrogens want to give up an electron each, that makes a +2, and if the oxygen wants to accept two electrons, that makes a matching -2. Therefore, the water molecule adds up to zero and is balanced.

Procedure Cont.

5. Ask students to try another compound that we all use, which is salt, or NaCl. Have them check the math and see if it comes out to 0.
6. Challenge students to use the element cards to create compounds with two or more different atoms. Ask them to record their compounds in their science notebooks. Inform students that they have to be able to keep track of how many of each atom are in the compound and that they indicate this by writing the number as a subscript to the right of the element as in H_2O. Most of the possible combinations are listed in BLM 1: Sample Compounds.
7. Ask students to write their largest compound on the board and ask the class to check them for a zero balance.
8. Display the following formulas and ask the students to figure out if they can exist based on the idea of a zero molecule total: $NaHCO_3$ (sodium bicarbonate) and $H_2Al_2Si_2O_8$ (kaolin clay). They will not have enough of some of the cards so they will need to work mathematically.

Wrap-Up

Start with the simple compounds H2O and NaCl, and ask students to locate the elements they contain in the periodic table. Explain that early chemists realized that different elements could combine to make compounds, but they didn't know why some combinations were possible but others were not. After the development of the periodic table, though, the actual ways different elements combined (or didn't combine) started to make sense. This was because some elements, the ones in the same group, behaved chemically in one way, while other elements in a different group acted another way. The development of atomic theory and the understanding of how electrons behaved explained what people had noticed for a long time. For example, the ends of the rows (or periods) of the periodic table contained elements that had no active electrons because their outer shells were filled. With no electrons to either donate or accept, they could not form bonds with other elements.

Guided Practice

Guided Practices are similar to typical tests, but require students to reveal their thinking about content. They serve as a practice before a test and should not be graded. They are intended to expose misconceptions *before* an assessment and to provide opportunities for discussion, re-teaching, and for students to justify answers. They are best given as individual assignments without the manipulatives used in the activity. In that context, pose the following "test items" to the class. Ask them to write responses in notebooks.

1. Give the class the following statement from a student: A student said that any atom of an element in the first column of the periodic table can only react with the elements in the next-to-last column (reading left to right) to form a compound. When they react, only one atom of the element in the first column combines with exactly one atom of the element in the next-to-last column. This is

because elements in the first column want to donate one electron and elements in the next-to-last column want to accept one electron.

2. Ask the class: “What is wrong with this statement?” Take all answers, then use them to prompt a discussion.

Answer Key

The second part of the explanation is correct but the first part is not. As everyone saw when working with the cards, the elements in both of these columns can combine with other elements that are not in these columns. For example, H_2O, $Na_2(CO_3)$ or $CaCl_2$. When they make these combinations, it is not as a one-to-one compound, but in multiples (e.g. two hydrogens to one oxygen or two chlorines to one calcium).

BLM 1 Sample Compounds

Two elements, one atom each

Hydrogen Chloride (Hydrochloric Acid) .... HCl
Hydrogen Fluoride (Hydrofluoric Acid) .... HF
Lithium Bromide .... $LiBr$
Lithium Chloride .... $LiCl$
Calcium Oxide (Quicklime) .... CaO
Magnesium Oxide (Magnesia) .... MgO
Mercury Oxide (Mercuric Oxide) .... HgO
Potassium Bromide .... KBr
Potassium Chloride .... KCl
Potassium Fluoride .... KF
Potassium Iodide .... KI
Sodium Bromide .... $NaBr$
Sodium Chloride (Table Salt, Halite) .... $NaCl$
Sodium Fluoride .... NaF
Sodium Iodide .... NaI
Zinc Oxide .... ZnO

Two elements, more than one atom each

Calcium Chloride .... $CaCl_2$
Magnesium Chloride .... $MgCl_2$
Mercury Chloride (Mercuric Chloride) .... $HgCl_2$
Mercury Iodide (Mercuric Iodide) .... HgI_2
Silicon Dioxide (Quartz, Sand) .... SiO_2
Zinc Chloride .... $ZnCl_2$
Aluminum Chloride .... $AlCl_3$
Aluminum Oxide .... Al_2O_3

Three elements

Ammonium Chloride .... NH_4Cl
Calcium Carbonate (Lime, Limestone) .... $CaCO_3$
Magnesium Carbonate .... $MgCO_3$
Potassium Hydroxide .... KOH
Sodium Hydroxide (Lye, Caustic Soda) .... $NaOH$
Sodium Nitrite .... $NaNO_2$
Ammonium Hydroxide (Ammonia) .... NH_4OH

Four elements

Potassium Bicarbonate .... $KHCO_3$
Sodium Bicarbonate (Baking Soda) .... $NaHCO_3$
Kaolin clay .... $H_2Al_2Si_2O_8$

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