Introduction

Chemicals in a ziplock bag bubble; change color; and produce gas, heat, and an odor. People of every age squeal with delight as the plastic bag they hold gets hot and inflates with gas, and its bubbling contents change color while they watch!

In this activity, your students observe changes and design experiments to explain their observations. They pursue their own experimental plans in an exciting, fun, and safe situation. The first part of the activity emphasizes the process of observation; the second part involves experimenting and making inferences.

Summary Outlines to help you guide your students through these activities in an organized manner have been added to this revised edition. Additional, removable copies of student data sheets are included in the back of the booklet.

This dramatic chemical reaction is an exciting introduction to the processes by which new substances are formed. Use it as a motivating first encounter with chemistry or combine it with the "Going Further" suggestions and your own ideas to create a dynamic unit on chemical reactions.
Time Frame

Teacher Preparation: 30 minutes

Part 1: Discovering the Chemical Reaction 20–30 minutes

Part 2: Investigating What Causes the Heat 20–30 minutes

What You Need

For the class:

(These quantities are enough to conduct each activity 2–3 times with a group of 30 students.)

☐ 1.5 lbs. (about 750 g) sodium bicarbonate (baking soda)
☐ 3 lbs. (about 1.5 kg) calcium chloride (available at chemical supply houses and some hardware stores—see the “Behind the Scenes” section on page 24 for notes on acquiring and storing this chemical)
☐ phenol red powder or concentrate to make one gallon (about 4.5 liters) of dilute phenol red solution (available at pool supply stores and chemical supply houses)
☐ masking tape or several sheets of self-adhesive mailing labels
☐ 1 one-gallon, plastic container for mixing phenol red solution
☐ 1 plastic bucket
☐ access to a sink or 2 additional buckets
☐ water
☐ paper towels
☐ 1 or 2 pairs of rubber gloves
☐ chalkboard and chalk

Water can be used instead of phenol red solution, but the resulting reaction will have no color changes.
For each group of 4–6 students

- 2 wide-mouthed, plastic containers (8–12 oz. yogurt or cottage cheese containers work well)
- 2 teaspoons
- 2 plastic stir sticks (such as coffee stirrers)
- 2 4–8 oz. (250–500 ml) squeeze or dropper bottles
- 1 graduated cylinder (for measuring 10 ml quantities)
- 6–9 small ziplock bags (one-quart capacity storage bags—1.75 ml plastic)
- 4–6 plastic vials (discarded pill containers from hospitals or new ones purchased from scientific supply companies)
- 4–6 copies of the "Chemical Reactions" data sheet (master included, page 20)
- 4–6 copies of the "Heat Experiments" data sheet (master included, page 21)
- 1 tray
- Optional: 4–6 pair of safety goggles (See "Safety Considerations," page 6)

For follow-up activities

- 1 thermometer per pair of students
- 1 styrofoam cup per pair of students
Notes on Assembling Materials

Ziplock sandwich bags are less expensive than the storage variety but are slightly smaller and made of thinner plastic. These bags may break their ziplock seal or burst if a student adds double the amount of chemical that is indicated.

Wide-mouthed containers are easier for students to use, but one-quart capacity ziplock storage bags can be used instead to contain the baking soda and calcium chloride. These bags are easily labeled with an indelible marker, can be used to store the chemicals after class, and allow the students to "feel" the chemicals from the outside of the bags.

Graduated cylinders may be eliminated if you have difficulty acquiring a class set. Use an indelible marker to draw a 10-ml line on each vial. Ten ml is approximately one third of a fluid ounce. Have your students fill the vial up to its 10-ml line.

Inexpensive plastic spoons can be used in place of teaspoons if you have difficulty getting enough to use in the activity. If you have a set of balances available for class use, you might want to have your students use this more accurate method for measuring gram amounts of baking soda and calcium chloride.

Getting Ready

1. Gather the materials.

2. Prepare the phenol red solution. You can purchase phenol red in powder form or as a concentrated solution. Dilute the concentrated solution with water (about 1 part phenol red to 10 parts water). If you have the powder, dissolve a "pinch" of it in about two liters of water; keep adding water until the color turns from red to slightly reddish-orange. The exact concentration is unimportant.
3. Label the containers:

- Use masking tape or self-adhesive mailing labels to label wide-mouthed containers for each group of 4–6 students:
  
  "BAKING SODA—NaHCO₃"

  "CALCIUM CHLORIDE—CaCl₂"

- Use masking tape or self-adhesive mailing labels to label squeeze bottles for each group of 4 students:
  
  "PHENOL RED SOLUTION—C₁₉H₁₄O₅S"

  "WATER—H₂O"

4. Fill containers with chemicals. [Note: students tend to use up whatever amounts of chemicals are available to them. About 20–25 teaspoons of each solid and 100–150 ml (3–5 oz.) of each liquid should be sufficient for them to complete their experiments.]

5. Make one copy each of the "Chemical Reactions" and "Heat Experiments" data sheets for each pair of students from the masters on pages 20 and 21.

6. Place the following materials on a tray for each group of 4–6 students:
   
   baking soda
   calcium chloride
   phenol red solution
   2 stir sticks
   4–6 "Chemical Reactions" sheets

Set the trays and all remaining materials in a centrally located area.

7. Arrange the room by pushing desks together or moving tables so that there is one flat work area for each group of 4–6 students.
Safety Considerations

Baking soda, calcium chloride, and phenol red are considered to be relatively safe substances. However, chemical safety is important enough to warrant careful consideration by students and teachers even when using safe substances.

Address the issue of safety with your students before distributing the chemicals. Tell the students that they will be working with chemicals and that safety is very important. Explain that all of the chemicals they'll be using could be hazardous if proper safety guidelines are ignored. Good chemical safety practice means:

- keeping chemicals off clothes and skin,
- rinsing with water if chemicals do make contact,
- wiping up spills as they happen,
- washing hands at the end of the activity.

Often students will challenge the need to treat a chemical such as baking soda any differently than other food products. This offers a good opportunity to point out such issues as possible contamination of chemicals or lab equipment, assumptions made about unlabeled and mislabeled substances, and the need for establishing good work habits in the lab. The importance of these issues cannot be overemphasized.

The chemicals used in this experiment are potentially less irritating than, for example, vinegar or lemon juice. However, legally you must find out about your state's educational safety guidelines regarding eye protection and follow them. Some states require using eye protection when working with any chemical.
Part 1: Discovering the Chemical Reaction

Overview

Students carefully observe three chemicals using several of their senses. They combine these chemicals in a ziplock bag, then excitedly watch the chemicals in the bag change color and bubble. They feel the chemicals get hot and wonder what's happening when the bag grows bigger in their hands.

This experience leads students to discover firsthand what a chemical reaction is; you just need to give them a name for what they have observed! Students are usually full of questions about the reaction, providing you with a natural way to provide information about reactants, products, and the meaning of endothermic and exothermic. In a larger thematic context, this experiment also provides direct experience for discussion and increased understanding of systems, as well as the relationship between matter and energy.

Observe the Chemicals

1. Ask your students what might happen when two chemicals are mixed together. Record their ideas on the chalkboard. Tell them that in this activity they will combine three chemicals one by one, deciding at each step whether or not they can observe any of the things that were listed on the board.

2. Tell the class that before they get started working with the chemicals, you’d like to point out some safety guidelines. Go over the safety guidelines for working with chemicals listed in the “Safety Considerations” section on page 6.

3. Often students of this age scoff at the caution to avoid getting chemicals on or in oneself. Dramatize how easy it is to unknowingly contaminate oneself by acting out the following sequence:
Show a heaping teaspoon of baking soda to the group. Ask if that is how they should measure a level-teaspoon quantity.

Ask the students how you should level it off. [Turn down suggestions of using your finger; suggest, if no one else does, that you use your pencil.] Demonstrate with the pencil and ask “Where is the chemical now?” [On the pencil.]

Write something with that pencil. Ask, “Where is the chemical now?” [On your hand.]

Tell the group that after class you’ll be eating your lunch. “Where will the chemical be then?” [On your sandwich and in your mouth.]

Emphasize how easy it is to unknowingly contaminate oneself. Tell students that good chemical safety involves not only avoiding direct contact with chemicals, but also making sure that one doesn’t touch items that came into contact with certain chemicals.

4. Explain that getting a “noseful” of chemical will also contaminate your body. Demonstrate the safe way to smell a chemical: use your hand to push the air from over the chemical towards your nose. This method provides you with some warning if a chemical has a very strong odor.

5. Explain to the students that before mixing the chemicals together, you’d like them to work with a partner to describe each of the three chemicals. Each pair of students should use all of their senses except tasting and directly touching the chemicals to come up with at least five observations of each chemical. Show how the plastic stir stick can be used to “feel” a solid chemical by poking and probing to make inferences about its texture. Hold up a “Chemical Reactions” data sheet and explain that you’d like them to record on this data sheet their detailed observations about how the substance looks, feels, smells, and sounds.
6. Ask students to choose a partner, and explain that they will share materials with the other pairs of students at their work station.

7. Recruit students to help you place one tray at each station. Then have students begin making their observations.

8. Circulate around the room, helping your students to be specific and descriptive in taking notes. For example, discourage vague observations such as “looks weird,” or “smells bad.” Suggest more specific phrasing such as “looks like little styrofoam balls,” or “has strong odor.”

**Mixing the Chemicals**

1. After most students have had enough time to record about five descriptions of each chemical, get the attention of the entire class. Explain that now they will add the chemicals one by one to a ziplock bag and see what happens as they mix.

__Note:__ You can either have the class go through the following procedure together, waiting for all groups to finish one step before going on to the next, or you can have pairs of students proceed at their own pace, following the step-by-step procedure on their data sheets. Many students are very eager to proceed, while others are more careful and deliberate. Choosing one pace at which the class proceeds is rarely satisfactory to either extreme. If your students have experience measuring liquids with a graduated cylinder, can independently follow a written procedure, and are somewhat familiar with the vocabulary used, we recommend that you make a few introductory remarks and allow them to set their own pace. If their experience is limited, have student volunteers read each step aloud and discuss unknown vocabulary and techniques as you go.

2. Point out that a stir stick can be used to level a teaspoon quantity when measuring baking soda and calcium chloride.

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**Chemical Formula:** Scientific shorthand describing the chemical content of a substance. Numbers and letters stand for how many and what kind of atoms are in one molecule of the chemical. Example: In water—${H_2O}$—the H stands for hydrogen and the O stands for oxygen. There are two atoms of hydrogen for every one atom of oxygen.

**Milliliter:** A metric unit of measure used to measure liquids. There are one thousand milliliters in a liter. About five milliliters fill one teaspoon.

**Graduated Cylinder:** A cylindrical tube with lines on it, used to measure liquid volume.

**Vial:** A small cylindrical container.
3. Have several students help you distribute one graduated cylinder and two teaspoons to each station, and one ziplock bag and a vial to each pair of students. Waiting until this point in the activity to distribute the bags and measuring equipment prevents the students from mixing the chemicals before it is time to do so.

4. Set your students to work, using a structured or self-paced approach:

   a. Put one teaspoon of baking soda (NaHCO₃) into a bag.

   b. Put two teaspoons of calcium chloride (CaCl₂) into the same bag.

   c. Measure 10 milliliters of phenol red solution and pour it into a vial.

   d. Put the vial into the bag (standing upright) and seal the bag.

   e. Tip the vial of phenol red.

5. After your students finish mixing the chemicals, encourage them to record at least five observations of what happens when the chemicals are mixed.

6. Tell your students that, after the chemicals have reacted, they can open the bag to see if an odor was produced. Demonstrate how to carefully open the seal, pointing the opening away from your eyes. Remind them of the technique chemists use to smell, by wafting with their hands.
Telling What Happened

1. Collect the bags in a bucket, and focus the group's attention on the chalkboard. Have the students share observations they made of what happened when the chemicals mixed. Record their observations on the board. Compare this observation list with the list of predictions they generated at the beginning of the activity.

2. Introduce the concept of a chemical reaction by presenting the following information:

- Evidence such as color changes, production of a gas, and odor are all clues that chemicals are reacting.

- When chemicals react, new substances are created. Temperature change indicates that energy is being released or used as new substances form.

- Chemicals that take part in chemical reactions are called reactants; the new substances that form are called products.

- A reaction in which heat energy is released is called an exothermic reaction. A reaction in which heat energy is absorbed is called an endothermic reaction. Endothermic reactions feel cool because heat energy from your hand is absorbed by the reaction.

Note: This is a good break point for those not going on to Part 2 right away. If you're stopping here, have your students help you clean up.
Cleanup

1. Assign two students to remove the vials from the bags and to rinse the vials at a sink. **Make sure the students wear rubber gloves.** The bags can be discarded.

2. Assign two students to pour any uncontaminated calcium chloride and baking soda remaining in the cups back into the stock containers.

3. Have the groups return all materials at their work stations to the trays. Set trays aside until you begin Part 2 of the activity.

4. Have the students wash their hands.
Part 2: Investigating What Causes the Heat

Overview

After experiencing the excitement of the chemical reaction, students are eager to investigate more about it. To structure their investigations, they are presented with the challenge of finding out which of the reactants caused the reaction to get hot. By combining the chemicals in different ways, the students encounter a range of different reactions, from hot to cold, pink to yellow, producing gas or not!

Through their own experiments and their own series of deductions, students are able to discover which reactants cause the reaction to get hot, and they come away from this session feeling confident and creative.

Experimenting

1. Ask your students to recall the reactants they used in Part 1. Write the names of the reactants on the board. Explain that since phenol red solution was prepared by mixing phenol red powder and water, they should consider both phenol red and water as separate reactants.

2. Have your students predict which of the reactants they think caused the reaction to get hot. Record their ideas on the chalkboard.

3. Ask for individuals to describe experiments that might determine which reactants are responsible for the production of heat. Each time someone suggests an experiment, ask the class how that experiment would provide useful information. A typical response might be: "If it got hot without the baking soda, we'd know that baking soda was not important for the heat." Reinforce experimental plans that investigate one variable at a time, and help your students relate their plans to the purpose of the experiment: What causes the heat?
4. Challenge each team to design and conduct two experiments to find out what causes the heat. [For less mature groups, structure this experimentation by instructing them to choose an ingredient to leave out.]

Caution students not to seal the bags this time, as greater amounts of ingredients might produce more gas and cause a sealed bag to burst. Alternatively, you can instruct your students to change the combination of ingredients they use but to keep the amounts the same.

Remind students that if they choose to leave out phenol red, they can use water instead. Point out the location of the water bottles.

5. Pass out a "Heat Experiments" data sheet to each student. Give the teams the following instructions:

- Design your first experiment, and write what you plan to do on the experiment sheet.
- Come get a clean vial and bag.
- Go back to your work station and do your experiment.
- Record the results of the first experiment, and then repeat this process for a second experiment.

If you have the space in your classroom, encourage the students to circulate around the room when they finish, observing the results of other teams' experiments. As students show you the results of their experiments, ask if they've narrowed the possibilities of what causes the heat and, if so, what their evidence is. Ask what experiment they could do to narrow it down even further.

6. Collect the bags and vials in a bucket.
Discussing the Results

1. Focus the students' attention on the chalkboard. Ask the class which teams think they've discovered the chemicals responsible for producing the heat in this chemical reaction. Poll the group for their opinions. Use the following procedure to collect evidence to support or refute the various opinions:

- Ask one team to describe an experiment they did and whether or not the bag got hot.

- Poll other teams to see if those that did the same experiment got similar results.

- Translate responses such as "I mixed everything except baking soda and it still got hot," to an equation form and write it on the chalkboard:

  \[ \text{CaCl}_2 \ + \ \text{phenol red} \rightarrow \text{hot} \]

- After recording the results of several different experiments, ask the students which reactants were used in every experiment that got hot.

2. Help the group summarize the results by asking: "So, what chemicals are necessary to produce the heat in this chemical reaction?" [See the "Behind the Scenes" section for an explanation of the reaction.]

  Often individual students will observe an incorrect result when they do the experiment; occasionally, entire groups will not observe what they're "supposed" to observe. Using contaminated measuring spoons or chemicals, not reading a label correctly, forgetting what chemical was used, or just not choosing experiments that provide useful information are all causes for incorrect results. In these situations, avoid telling the students that they're wrong. Invalidating students' experiences can leave them with a negative experience or rivet them on "getting the right answers" rather than on experimenting and drawing conclusions based on their observations. There are a variety of strategies you can use to structure a situation so that your students correct themselves.
Challenge the group to figure out what causes the yellow color, the gas, or the odor in the reaction. Use the same procedure as that used to find out what causes the heat.

For example, you can expose discrepancies between different teams' results. Ask how people can do the same experiment and come up with different results. Ask what scientists do when they can't agree on a result. If there's time, redo the experiment. If not, suggest that the result obtained by the majority be accepted as the best conclusion.

If only one team did a certain experiment or if there is agreement on "incorrect" data, quickly redo the experiment and pass the bag around for everyone to observe. Let your students draw their own conclusions.

Cleanup

1. Assign two students to remove the vials from the bags and to rinse the vials at a sink. Make sure the students wear rubber gloves. The bags can be discarded.

2. Assign students to pour any uncontaminated calcium chloride and baking soda remaining in the cups back into the stock containers.

3. Have several students collect the measuring spoons, stir sticks, graduated cylinders, empty chemical containers, and set them by the sink. Later the materials can be rinsed and left to dry on paper towels.

4. Have two students collect the water and phenol red solution bottles.

5. Assign several students to wipe up work areas.

6. Have the students wash their hands.
CHEMICAL REACTIONS

What do you observe?

Calcium Chloride (CaCl₂)

Baking Soda (NaHCO₃)

Phenol Red Solution

What You Do

1. Put 1 teaspoon of Baking Soda (NaHCO₃) into a ziplock bag.
2. Put 2 teaspoons of Calcium Chloride (CaCl₂) into the same bag.
3. Measure 10 ml of Phenol Red solution, and pour into a vial.
4. Put the vial into the bag (standing upright) and make sure the bag is well sealed.
5. Tip the vial of Phenol Red solution.

What happens?
HEAT EXPERIMENTS

Describe your first experiment:

What happened?

What can you conclude?

Describe your second experiment:

What happened?

What can you conclude?

What do you think causes the heat?
Summary Outlines

Getting Ready Before the Activity

1. Assemble the materials.
2. Prepare phenol red solution.
3. Label containers.
4. Fill containers with chemicals.
5. Duplicate data sheets.
6. Place materials on trays.
7. Arrange the room for team work.

Part 1: Discovering the Chemical Reaction

Observing the Chemicals

1. Ask students what might happen when two chemicals are mixed together. Record ideas on chalkboard. Tell them they will mix several chemicals to see what happens.
2. Point out safety guidelines for working with chemicals—avoid getting chemicals on or in oneself.
3. Dramatize unwitting contamination.
4. Demonstrate how to smell chemicals safely.
5. Explain that they should observe each of the three chemicals they'll be working with before mixing them. Demonstrate how they can use all their senses without actually touching chemicals.
6. Have students choose partners.
7. Distribute trays.
8. Have students begin making observations.
9. Circulate around the room helping students be specific and descriptive in their observations.

Mixing the Chemicals

1. Have student volunteers read procedure aloud, step-by-step. Use this time to introduce meanings of unfamiliar things, such as vial, graduated cylinder, chemical formula, milliliter, etc.
2. Point out that a stir stick can be used to level teaspoonful quantities.
3. Distribute the equipment.
4. Set your students to work, using a structured or self-paced approach.
5. After students have mixed chemicals, have them record at least five observations of what happened.
6. Allow students to carefully open bag and safely smell the contents using the technique you showed them.
Telling What Happened

1. Collect the bags in a bucket and focus the attention of the group.
2. Record the students' observations on the board. Compare this list to the list of predictions generated at the beginning of the activity.
3. Introduce the concept of a chemical reaction.
4. Collect the materials and clean up.

Part 2: Investigating What Causes the Heat

Experimenting

1. Ask students to recall the reactants they used. Write these on the board. Explain that phenol red solution contains water.
2. Have students predict which of the reactants caused the reaction to get hot.
3. Ask students to describe experiments that might determine which reactants are responsible for the production of heat.
4. Challenge each team to design and conduct two experiments to find out what causes the heat.
5. Caution students not to seal bags.
6. Distribute "Heat Experiments" data sheets. Have students design their first experiments on these sheets, get a clean vial and bag from you, do their experiment, then record the results.
7. After students complete one experiment, have them plan and carry out a second experiment.
8. Encourage students to circulate and observe each others' results firsthand.
9. Collect the bags and vials in a bucket.

Discussing the Results

1. Poll the group of their conclusions as to which reactants caused the heat.
2. Ask one team to describe an experiment they did and whether or not the bag got hot. Poll other teams to see if they got similar results.
3. Translate response to equation form. Record this equation on the board.
4. After recording the results of several different experiments, ask the students which reactants were used in every experiment that got hot. Help the group summarize the results. Let your students draw their own conclusions.