Reaction in a Bag

Introduction to the Scientific Method

Introduction

When three substances—solid calcium chloride, solid sodium bicarbonate, and a solution of phenol red in water—are mixed in a closed container, a complex series of changes is observed. Observations include temperature changes, color changes, and changes in state. What individual interactions are responsible for each observation? In this fun and easy activity, students not only hold an experiment in their hands to see and feel what chemistry is all about, they also practice the key skills that are the backbone of the scientific method. Students: (1) observe phenomena and ask questions, (2) design experiments to answer their questions, (3) collect data, and (4) analyze and summarize the results.

Concepts

- Scientific method
- Observation
- Experiment

Materials

Calcium chloride (solid), $CaCl_2$, 30 g
Phenol red, 0.02% aqueous solution, 60 mL
Sodium bicarbonate (solid), $NaHCO_3$, 20 g
Water, distilled
Graduated cylinder, 10-mL
Sealable, zipper-lock plastic bags
Teaspoon and tablespoon scoops

Safety Precautions

Calcium chloride is slightly toxic by ingestion. Phenol red is a dye solution and will stain skin and clothing. Avoid contact of all chemicals with skin and eyes. Be careful to mix the chemicals in the amounts called for in the procedure. Adding too much of the solids may result in excessive release of gases that are difficult to contain and may cause chemical splashing. Wear chemical splash goggles, chemical-resistant gloves, and a chemical-resistant apron. Please review current Material Safety Data Sheets for additional safety, handling, and disposal information. Wash hands thoroughly with soap and water before leaving the laboratory.

Procedure

1. Observe and describe the appearance of calcium chloride, sodium bicarbonate, and phenol red solution.
2. Place the following three substances **in separate locations** in a sealable plastic bag.
   1 tablespoon (or 3 teaspoons) of calcium chloride
   1 teaspoon of sodium bicarbonate
   10 mL of phenol red indicator solution
3. Squeeze out as much air as possible from the zipper-lock bag and seal it. Allow the contents to mix thoroughly.
4. Carefully observe (by means of sight and touch) the changes that take place in the zipper-lock bag. *Note:* If the bag gets too tight due to the build-up of gas pressure, open the bag and then reseal it.

   What questions arise concerning the changes that were observed during the reaction in the bag?
5. Think of at least *four questions* that could be investigated to determine the individual interactions that are responsible for the observed changes.
6. Design and carry out a set of control experiments to determine the interactions that are responsible for each of the observed changes. Mix two or three chemicals at a time and use the same quantities of chemicals as in Step 2.
7. *Note:* Because phenol red is a solution of the dye compound dissolved in water, it is actually composed of two pure substances. Thus, water may be considered as a fourth variable in the overall reaction, and its effect should also be examined. If water is tested, use the same amount as of phenol red solution in step 2.
8. Construct a chart to indicate the substances used in each control experiment and the resulting observations.

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Disposal

Please consult your current *Flinn Scientific Catalog/Reference Manual* for general guidelines and specific procedures governing the disposal of laboratory waste. All solutions may be rinsed down the drain with excess water according to Flinn Suggested Disposal Method #26b.

Tips

- This activity may be performed either as a demonstration or as a student experiment. It is not necessary to understand the precise chemical events that take place in this reaction in order to appreciate the essence of this activity, which is the nature of scientific inquiry.
- The three substances that are used in this demonstration are all common chemicals. Sodium bicarbonate, or baking soda, is used as a food additive in baking. It is also used as a natural deodorant, which absorbs and removes odor-causing chemicals in refrigerators and in carpets. Calcium chloride ("road salt") is a salt-like compound that is used as a de-icer for sidewalks and roads. Phenol red is a naturally occurring dye that is used as an indicator—it changes color under diferent conditions.
- Exact quantities are obviously not necessary for this reaction. The key is about 3 X (1 tablespoon or 3 teaspoons) of calcium chloride to sodium bicarbonate (1 teaspoon).

Discussion

There is an immediate color change from red to yellow as the substances are mixed. The solids initially "disappear" into solution and the bag gets very hot; a great deal of heat is produced. The mixture looks like it is fizzing and a slight fizzing noise is heard. The bag begins to expand and feel "tight" as gas pressure builds up. The final solution appearance is a "chalky" yellow liquid.

Calcium chloride produces heat when it dissolves in water, while baking soda absorbs heat as it dissolves. Calcium chloride, sodium bicarbonate, and water combine to produce carbon dioxide gas. Phenol red is an acid-base indicator that changes color in the presence of acids and bases. Sodium bicarbonate is a base, so it maintains the bright red (basic) color of phenol red at first. As sodium bicarbonate reacts with calcium chloride in water, acidic substances are produced and the color of the phenol red indicator changes from the basic form to its yellow, acidic form. Carbon dioxide is one of the acids produced—it dissolves in water and reacts to form carbonic acid, H_2CO_3, which makes the water acidic. As carbon dioxide is allowed to escape, the solution may turn slightly orange or pink again.

The products of the overall reaction include sodium chloride (NaCl), table salt; calcium carbonate ($CaCO_3$), the main component of chalk; and carbon dioxide (CO_2), the metabolic "waste" gas exhaled during respiration. The following equation provides a snapshot of the initial and final composition but does not show any possible intermediate products that may be formed.

$$CaCl_2(aq) + 2NaHCO_3(aq) + \text{phenol red (basic form)} \rightarrow$$

$$CaCO_3(s) + 2NaCl(aq) + H_2O(aq) + CO_2(g) + \text{phenol red (acidic form)}$$

Answer the following questions based on the results of the control experiments (See Chart).

What interaction among the substances is responsible for the observed temperature change in the overall reaction? Is there a temperature change observed in any of the control experiments that is NOT observed in the overall reaction? What color change is observed in the overall reaction? What interaction(s) is responsible for the observed color change? Does the formation of gas bubbles occur independently of the observed temperature and color changes? Does any reaction occur in the absence of water? Is there any evidence that a new chemical substance is produced in the overall reaction? What interaction among the four components must be responsible for the new substance?

Number	Calcium Chloride	Baking Soda	Phenol Red	Water	Observations
1	✓	✓			No reaction. White solids retain their individual appearance after mixing.
2	✓		✓		White solid mostly dissolves; final mixture is slightly cloudy. Bag is quite hot. Final color is red (no change from initial indicator color).
3	✓			✓	White solid "disappears" into solution and dissolves. Bag feels quite hot. Final solution is colorless but slightly cloudy.
4		✓	✓		White solid begins to disappear into solution, but does not dissolve completely. Final solution is cloudy or "chalky" pink (white solid and red liquid). Bag is cold to the touch.
5		✓		✓	White solid partially dissolves. Bag gets noticeably cold to the touch. Final solution is chalky white.
6			✓	✓	Liquids mix, form one solution. Color changes to paler red, almost orange color.
7	✓	✓		✓	Solution bubbles and fizzing noise is heard. Bag expands and feels tight. Bag is warm (hot) to the touch. Solids combine or react with each other; final solution is chalky white.
8	✓		✓	✓	White solid dissolves. Bag feels hot to the touch. Color changes to paler shade of red.
9		✓	✓	✓	White solid partially dissolves. Cup feels slightly cold. Final solution is chalky and pink due to white solid and red liquid.

Connecting to the National Standards

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

Unifying Concepts and Processes: Grades K–12
Systems, order, and organization
Evidence, models, and explanation
Content Standards: Grades 5–8
Content Standard A: Science as Inquiry
Content Standard B: Physical Science, properties and changes of properties in matter
Content Standards: Grades 9–12
Content Standard A: Science as Inquiry
Content Standard B: Physical Science, chemical reactions

Materials for *Reaction in a Bag* are available from Flinn Scientific, Inc.

Catalog No.	Description
AP6167	Observation and Experiment—Introduction to the Scientific Method,
C0018	Calcium Chloride, Lab Grade, 500 g
P0101	Phenol Red Indicator Solution, 500 mL
S0043	Sodium Bicarbonate, Lab Grade, 500 g
AP8130	Graduated Cylinder, Polypropylene, 10-mL
GP2050	Graduated Cylinder, Glass, 10-mL
AB1004	Specimen bags, reclosable, 60 × 120, pkg. of 50
AP9284	Measuring Spoons, Set of 4
AP9285	Plastic Spoons, pkg. of 24

Consult the Flinn Scientific website for current prices.