SCOPE, SEQUENCE, and COORDINATION

A National Curriculum Project for High School Science Education

This project was funded in part by the National Science Foundation. Opinions expressed are those of the authors and not necessarily those of the Foundation. The SS&C Project encourages reproduction of these materials for distribution in the classroom. For permission for any other use, please contact SS&C, National Science Teachers Association, 1840 Wilson Blvd., Arlington, VA 22201-3000.

SCOPE, SEQUENCE, and COORDINATION

SS&C Research and Development Center
Gerry Wheeler, *Principal Investigator*
Erma M. Anderson, *Project Director*
Nancy Erwin, *Project Editor*
Rick McGolerick, *Project Coordinator*
Arlington, Va., 703.312.9256

Evaluation Center
Frances Lawrenz, *Center Director*
Doug Huffman, *Associate Director*
Wayne Welch, *Consultant*
University of Minnesota, 612.625.2046

Houston SS&C Materials Development and Coordination Center
Linda W. Crow, *Center Director*
Godrej H. Sethna, *School Coordinator*
University of Houston-Downtown, 713.221.8583

Houston School Sites and Lead Teachers
Jefferson Davis H.S., Lois Range
Lee H.S., Thomas Ivy
Jack Yates H.S., Diane Schranck

California Coordination Center
Tom Hinojosa, *Center Coordinator*
Santa Clara, Calif., 408.244.3080

California School Sites and Lead Teachers
Sherman Indian H.S., Mary Yarger
Sacramento H.S., Brian Jacobs

Iowa Coordination Center
Robert Yager, *Center Director*
University of Iowa, 319.335.1189

Iowa School Sites and Lead Teachers
Pleasant Valley H.S., William Roberts
North Scott H.S., Mike Brown

North Carolina Coordination Center
Charles Coble, *Center Co-Director*
Jessie Jones, *School Coordinator*
East Carolina University, 919.328.6172

North Carolina School Sites and Lead Teachers
Tarboro H.S., Ernestine Smith
Northside H.S., Glenda Burrus

Puerto Rico Coordination Center*
Manuel Gomez, *Center Co-Director*
Acenet Bernacet, *Center Co-Director*
University of Puerto Rico, 809.765.5170

Puerto Rico School Site
UPR Lab H.S.

* * * * * * * * * * * *

Pilot Sites
Site Coordinator and Lead Teacher
Fox Lane H.S., New York, Arthur Eisenkraft
Georgetown Day School, Washington, D.C., William George
Flathead H.S., Montana, Gary Freebury
Clinton H.S., New York, John Laffan*

*not part of the NSF-funded SS&C Project.

Advisory Board

Dr. Rodney L. Doran (Chairperson), University of Buffalo

Dr. Albert V. Baez, Vivamos Mejor/USA

Dr. Shirley M. Malcom, American Association for the Advancement of Science

Dr. Shirley M. McBay, Quality Education for Minorities

Dr. Paul Saltman, University of California-San Diego

Dr. Kendall N. Starkweather, International Technology Education Association

Dr. Kathryn Sullivan, Ohio Center of Science and Industry

Project Associates

Bill G. Aldridge
SciEdSol, Henderson, Nev.

Dorothy L. Gabel
Indiana University

Stephen G. Druger
Northwestern University

George Miller
University of California-Irvine

National Science Education Standard—Physical Science

Chemical Reactions

Chemical reactions occur all around us, for example in health care, cooking, cosmetics, and automobiles. Complex chemical reactions involving carbon-based molecules take place constantly in every cell in our bodies.

Teacher Materials

Learning Sequence Item:

931

Physical vs. Chemical Change

March 1996
Adapted by George Miller

Mass and Number Conservation in Chemical Reactions. Students should observe matter undergoing change and classify the change as chemical or physical from observation of the products and the energy absorbed or released. They should infer that mass is conserved when reactions producing a gas or a precipitate are observed *(Chemistry, A Framework for High School Science Education, p. 64).*

Contents

This micro-unit was adapted by **George Miller** (Univ. of California, Irvine)

931

Learning Sequence

Mass and Number Conservation in Chemical Reactions. Students should observe matter undergoing change and classify the change as chemical or physical from observation of the products and the energy absorbed or released. They should infer that mass is conserved when reactions producing a gas or a precipitate are observed *(Chemistry, A Framework for High School Science Education, p. 64).*

Science as Inquiry	Science and Technology	Science in Personal and Social Perspectives	History and Nature of Science
What You See Is What You Record **Activity 1**		Analysis of a Burp **Assessment 8**	Conservation Principles **Assessment 3**
Now You See It, Now You Don't **Activity 2**		Salt **Reading 2**	Chemical History of a Candle **Reading 1**
What Can Be Put Together Can Be Pulled Apart **Activity 3**			
Is It Physical or Chemical? **Activity 4**			
The Cannon and Friends **Activity 5**			
Writing with Color **Activity 6**			
The Good, the Bad, and the Ugly Popcorn **Activity 7**			
Physical and Chemical Change **Assessment 1**			
Chemical Change **Assessment 2**			
Sugar as Food **Assessment 4**			
Chemical Reactions as Change **Assessments 5, 6**			
Performance Task on Mixing **Assessment 7**			
Physical and Chemical Change **Assessment 9**			

Suggested Sequence of Events

Event #1

Lab Activity

1. What You See Is What You Record

Event #2

Lab Activity

2. Now You See It, Now You Don't (45–90 minutes)

Alternative or Additional Experiment

3. What Can Be Put Together Can Be Pulled Apart ((2 sessions, if desired)

Event #3

Class Discussion

4. Is It Physical or Chemical? (45–90 minutes)

Event #4

Demonstrations

5. The Cannon and Friends (up to 45 minutes)

Alternative or Additional Demonstration

6. Writing with Color (up to 45 minutes)

Event #5

Lab Activity

7. The Good, the Bad, and the Ugly Popcorn (90–120 minutes)

Event #6

Readings from Science as Inquiry, Science and Technology, Science in Personal and Social Perspectives, and History and Nature of Science categories

The following readings are included in the student version of the unit:

Reading 1 Chemical History of a Candle
Reading 2 Salt

Suggested additional readings:

Graveson, Dan, "Manufacturing Memories." *Chem Matters*, February 1990, pp. 4-7.
Catelli, Elizabeth, "Peanut Brittle." *Chem Matters*, December 1991, pp. 4-7.
"Popping Corn." Excerpt from *Science Resources for Schools: Ideas in Sci ence*, Vol. 3, No. 3. Washington, D.C.: AAAS, 1986.
Sibley, Lynn K., "Popcorn." *Chem Matters*, October 1984, pp. 11-13.
"The Industrial Science of Corn." Excerpt from *Science Resources for Schools: Ideas in Science*, Vol. 3, No. 3. Washington, D.C.: AAAS, 1986.

Assessment items can be found at the back of this volume.

Assessment Recommendations

This teacher materials packet contains a few items suggested for classroom assessment. Often, three types of items are included. Some have been tested and reviewed, but not all.

1. Multiple choice questions accompanied by short essays, called justification, that allow teachers to find out if students really understand their selections on the multiple choice.

2. Open-ended questions asking for essay reponses.

3. Suggestions for performance tasks, usually including laboratory work, questions to be answered, data to be graphed and processed, and inferences to be made. Some tasks include proposals for student design of such tasks. These may sometimes closely resemble a good laboratory task, since the best types of laboratories are assessing student skills and performance at all times. Special assessment tasks will not be needed if measures such as questions, tabulations, graphs, calculations, etc., are incorporated into regular lab activities.

Teachers are encouraged to make changes in these items to suit their own classroom situations and to develop further items of their own, hopefully finding inspiration in the models we have provided. We hope you may consider adding your best items to our pool. We also will be very pleased to hear of proposed revisions to our items when you think they are needed.

Teacher Sheet

Science as Inquiry

What You See is What You Record

Overview:

Students revisit, explore, and measure examples of physical and chemical properties and change. This activity provides opportunities for teachers to assure that students establish proper observing, recording, and reporting practices they will use throughout high school.

Materials:

Per lab group:
candle, matches
triple beam or other centigram balance
pan lid for candle holder/drip catcher
toothpick
metric ruler
string
graph paper
access to clock or watch for timing

Procedure:

Students should observe an unlit candle using both qualitative observations and quantitative measurements. Have them record all the observations in an organized manner, so someone else could easily reproduce their observations. Include labeled drawings or diagrams.

Have students light the candle, let a few drops of wax fall onto the can lid, and place the base of the candle on the molten wax drops. This will form a firm base for the lighted candle as the wax sets hard. This is the “candle system.” They should make additional observations and record these. When finished, they should compare their records to those in the reading of Michael Faraday’s 100 observations of a burning candle.

After blowing out the candle, students should determine the mass of the system. They should then light the candle again and allow it to burn for three minutes. They should blow out and repeat obtaining the mass, doing this until they have obtained five masses. Have students prepare a table and graph of the data to show how the mass of a burning candle changes with how long it burns. The graphs should have properly drawn and labeled axes and include ***all*** of the data points.

Students should prepare two graphs—one as if they were trying to sell long-lasting candles so that someone looking at the graph will conclude that the mass changes very little as it burns, and one as if they were trying to show how quickly the mass of the candle was changing, so that the person looking at the graph will conclude this is very fast.

Background:

Observations are frequently incomplete (students often notice only the dramatic) and lackadaisically reported. Students should be encouraged to challenge each other to be more observant and to make more thorough reports. Quantitative observations are called measurements; other observations are classified as qualitative information. Both are important, but by mutual agreement scientists seek to establish measurements when qualitative observations can be usefully scaled. Recording and reporting, both written and oral, are also vital skills needed to progress in science. Students need to be continually reminded that records and reports are made primarily for communication with others, not for their own benefit. Thus the only appropriate records are those that communicate effectively.

Observations should be related to the methods used, otherwise they are less useful on subsequent communications. For example, it is much more informative to state “the rock could not be scratched with a pin,” than “the rock was hard.”

For ***each*** system students observe, they should:

- make both qualitative (visual and by touching with a probe) and quantitative (measuring) observations—they will be deciding which observations can be made on which system
- describe the system in writing as a result of their observations
- organize descriptions clearly so they can be easily understood by someone else, who can then set up an identical system
- include in their descriptions details of ***how*** they made the observations, and any other actions they took or changes they made
- conclude whether or not their system is undergoing change and state the evidence on which this conclusion is based

For example, in the case of the unlit candle, students can record color, shape, length, circumference (measuring with string and ruler) and/or diameter, mass, resistance to toothpick, etc.

Science makes clear distinctions between observations and inferences, but making these distinctions requires thought and practice. For example, it is an observation that a clear substance in a tube transmits light readily; it is an inference that it is a liquid. When you try to transfer it, or place a rod in it, you may obtain more information that enables you to conclude whether it is a solid or a liquid.

The characteristics of an object or system that are used to describe it are called properties. Some properties, such as mass, volume, and pressure, depend on the amount of material present. Some such as color and density do not.

Properties are usefully classified as physical or chemical. Physical properties are those described for a stable, unchanging system. Chemical properties refers to the potential of a substance for participating in a chemical change. In a chemical change, a reordering of atoms/molecules takes place, usually in terms of breaking and forming chemical “bonds.” In physical change, the chemical entities within the system are essentially unchanged.

Students should be encouraged to recognize that the time scale of the observation is crucial in noting the presence or absence of change. For instance, a glass of water at room temperature seems unchanging if observed over minutes, but over hours or days, changes may be readily observable.

Modern techniques enable experimenters to explore the nature of substances at the atomic and molecular levels, so that the strict distinction between physical and chemical categories becomes less meaningful and useful. A modern ion beam implantation instrument, for example, can displace a few atoms in a solid, so that most of the bulk properties remain unchanged even though some atomic reordering has occurred and electrical properties may be changed dramatically.

We are also able to demonstrate that phase changes in even a pure substance, formerly classified as "true" physical changes, involve changes in bonding on a local level between "clusters" of molecules or atoms in the various phases.

Adapted from *Oklahoma Project Chemistry, Top Chem.* Oklahoma State Department of Education, 1987.

Science as Inquiry

Now You See It, Now You Don’t

Overview:

In this activity, groups of students observe a variety of systems undergoing physical and chemical change.

Materials:

Per lab group:

test tube, test tube holder (clothespin)
small beakers or cups
candle or burner, matches
thermometer
naphthalene mothballs
watch glass
toothpicks
beral transfer pipette
plastic baby food jar, baby bottle, or other wide-mouth jar
seltzer tablet
large balloon
small amounts of chemicals in labeled containers: sugar, salt, distilled water, cornstarch, baking soda, ammonium nitrate, iron (III) chloride, potassium thiocyanate

Procedures:

Depending on the time and facilities available, different groups can investigate different systems and share results, or each group can do all the systems. Students may be encouraged to suggest additional items for testing or additional tests for the items involved (observing proper safety practices and with prior teacher approval).

Assign students to groups and assign each group certain systems to study. Cards with descriptions can be prepared in advance. Groups could each take a card and then exchange it for a second system card upon completion. Emphasize that they will need to observe both static and changing systems—before, during, and after some action.

The following procedures can be copied on cards or distributed as separate pages.

In all cases using liquid water (2–9), students should measure the temperature of the water before and after mixing with other substances.

1. **Observations on naphthalene mothballs (preferred to paradichlorobenzene):**
   Place about one-fourth of a mothball in a test tube. This is the *system*. Record observations and measurements of the system. Hold the test tube in a holder and heat in the candle or low burner flame until crystals appear on the walls of the test tube above the liquid mothball. Carefully measure the temperature of the mothball in the test tube. Not all has to be melted. Record observations

and measurements. Remove the flame and allow to cool. Record observations and measurements approximately every 50 °C until about room temperature again.

Describe the physical and chemical properties of the naphthalene (mothballs) and the physical and chemical changes that have occurred (if any) from start to finish of this “cycle.”

2. **Observations on sugar and sugar solutions:**
Place a very small scoop (0.25 g) of sugar in a small cup, jar, or test tube. Add about 1 mL of water. Stir with a toothpick. Record all observations and measurements. Make a small trough by folding a strip of aluminum foil. Place a drop of water at one end of the foil. Hold this carefully in a candle flame or low burner flame. Record observations and measurements. Repeat, but use a drop of the sugar solution instead of water. Keep heating until no more change seems to occur. Record all observations and measurements.

   Describe the physical and chemical properties of the water, sugar, and sugar solution, and all the physical and chemical changes that have occurred (if any) from the beginning to the end of your experiments.

3. **Observations on salt and salt solutions:**
Place a small scoop (0.25 g) of salt in a small cup, jar, or test tube. Add about 1 mL of water. Stir with a toothpick. Record all observations and measurements. Make a small trough by folding a strip of aluminum foil. Place a drop of water at one end of the foil. Hold this carefully in a candle flame or low burner flame. Record observations and measurements. Repeat, but use a drop of the salt solution instead of water. Keep heating until no more change seems to occur. Record all observations and measurements.

   Describe the physical and chemical properties of the water, salt, and salt solution, and all the physi cal and chemical changes that have occurred (if any) from the beginning to the end of your experi-ments.

4. **Observations on cornstarch and cornstarch solutions:**
Place a small scoop (0.25 g) of cornstarch in a small cup, jar, or test tube. Add about 1 mL of water. Stir with a toothpick. Record all observations and measurements. Make a small trough by folding a strip of aluminum foil. Place a drop of water at one end of the foil. Hold this carefully in a candle flame or low burner flame. Record observations and measurements. Repeat, but use a drop of the cornstarch solution instead of water. Keep heating until no more change seems to occur. Record all observations and measurements.

   Describe the physical and chemical properties of the water, cornstarch, and cornstarch solution, and all the physical and chemical changes that have occurred (if any) from the beginning to the end of your experiments.

5. **Observations on baking soda and baking soda solutions:**
Place a small scoop (0.25 g) of baking soda in a small cup, jar, or test tube. Add about 1 mL of water. Stir with a toothpick. Record all observations and measurements. Make a small trough by folding a strip of aluminum foil. Place a drop of water at one end of the foil. Hold this carefully in a candle flame or low burner flame. Record observations and measurements. Repeat, but use a drop of

the baking soda solution instead of water. Keep heating until no more change seems to occur. Record all observations and measurements.

Describe the physical and chemical properties of the water, baking soda, and baking soda solution, and all the physical and chemical changes that have occurred (if any) from the beginning to the end of your experiments.

6. **Observations on ammonium nitrate and ammonium nitrate solutions:**
   Place a small scoop (0.25 g) of ammonium nitrate in a small cup, jar, or test tube. Add about 1 mL of water. Stir with a toothpick. Record all observations and measurements. Make a small trough by folding a strip of aluminum foil. Place a drop of water at one end of the foil. Hold this carefully in a candle flame or low burner flame. Record observations and measurements. Repeat, but use a drop of the ammonium nitrate solution instead of water. Keep heating until no more change seems to occur. Record all observations and measurements.

   Describe the physical and chemical properties of the water, ammonium nitrate, and ammonium nitrate solution, and all the physical and chemical changes that have occurred (if any) from the beginning to the end of your experiments.

7. **Observations on seltzer tablets:**
   Break off about one-fourth of a seltzer tablet. Work this piece into a large balloon. Place about 10 mL of water into a wide-mouth jar (old chemical container, nalgene, or baby bottle). Put the neck of the balloon over the mouth of the jar—without letting the seltzer tablet fall into the jar! Place the entire assembly on a balance and record the mass. Record observations on the system. Lift the balloon so that the tablet falls into the water in the jar (be careful that the balloon doesn't pull off the jar). Record your observations and measurements (what else can you measure besides mass?). Release the balloon from the jar, remass all the system as at the start. Record all observations and measurements.

   Describe the physical and chemical properties of all the substances and the physical and chemical changes that you have observed from the beginning to the end of your experiment.

8. **Observations on iron chloride and baking soda and solutions:**
   Place a small scoop (0.25 g) of baking soda in a small jar or test tube. Add about 1 mL of water. Stir with a toothpick. Record all observations and measurements. Place a small scoop (0.25 g) of iron chloride in a second cup or test tube. Add about 1 mL of water. Stir with a toothpick. Record all observations and measurements. Pour this into a large balloon. Put the neck of the balloon over the mouth of the jar or tube (without letting the solution pour out!). Place the entire assembly on a balance and record the mass. Record observations on the system. Lift the balloon so the solutions mix in the jar (be careful that the balloon doesn't pull off the jar). Record observations and measurements (what else can you measure or observe besides mass?). Release the balloon from the jar and remass all the items of the system as at the start. Record all observations and measurements.

   Describe the physical and chemical properties of all the substances and the physical and chemical changes that you have observed from the beginning to the end of your experiment.

9. **Observations on iron chloride and potassium thiocyanate and solutions:**

Place a small scoop (0.25 g) of potassium thiocyanate in a small jar, or test tube. Add about 1 mL of water. Stir with a toothpick. Record all observations and measurements. Place a small scoop (0.25 g) of iron chloride in a second cup or test tube. Add about 1 mL of water. Stir with a toothpick. Record all observations and measurements. Pour this into a large balloon. Put the neck of the balloon over the mouth of the jar or tube (without letting the solution pour out!). Place the entire assembly on a balance and record the mass. Record observations on the system. Lift the balloon so the solutions mix in the jar (be careful that the balloon doesn't pull off the jar). Record observations and measurements (what else can you measure or observe besides mass?). Release the balloon from the jar and remass all the items of the system as at the start. Record all observations and measurements.

Describe the physical and chemical properties of all the substances and the physical and chemical changes that you have observed from the beginning to the end of your experiment.

Background:

See background for Activity 1.

This activity provides a wide variety of experiences with chemical change—energy changes, color changes, gas evolution, and precipitate formation. Students are to make observations at the start, during, and at the final conditions of the experiment. They should be able to discuss chemical and physical properties as well as changes as a result of their observations. Properties relate to potential behavior (established by seeing it happen) or static observations. Be on guard for inferences from students who "know a lot of chemistry." The observations here do not allow one to establish, for example, that a substance is an acid or an oxidizing agent, that the gas is CO_2, or to determine the exact nature of a precipitate.

Further Variations:

Substitutions can be made based on local availability of chemicals and apparatus. Those chosen should be readily available and safe.

Adapted from:

Oklahoma Project Chemistry, Top Chem. Oklahoma State Department of Education, 1987.

Alyea, Hubert N., *Armchair Chemistry,* Sixth Edition, 1990.

Kardos, Thomas, *Physical Science Lab Kits.* New York: Center for Applied Research in Education, 1993.

Ciardullo, Carmen V., *Micro Action Chemistry*, Flinn Scientific Inc., 1990.

an alternative/extension activity for Event 2

Teacher Sheet

Science as Inquiry

What Can Be Put Together Can Be Pulled Apart

Overview:

Students investigate the synthesis and decomposition of zinc oxide.

Materials:

Per lab group:

For the synthesis:
powdered zinc (Zn)
iodine crystals (I_2)
funnel and filter paper to fit funnel
3 watch glasses or small Petri dishes
small beaker (100–250 mL)
medicine dropper or beral pipette
glass stirring rod
distilled water

For the decomposition:
glass stirring rod
copper wire: two 1- to 2-inch pieces
9-volt battery with battery clip
alligator clips and connecting wires
masking tape or modeling clay (small amount)
watch glass or Petri dish

Procedures:

This may be done in two separate sessions, if desired.

Students should follow the following directions:

1. Synthesis

Put small samples (about 0.25 g) of zinc powder and iodine powder onto watch glasses. Record measurements and observations of the properties of the two substances. Mix the two by stirring together with the glass rod. Record observations. Place the watch glass on a white paper in a well-ventilated area. Add about 1 mL of water from a dropper, one drop at a time. Record observations. When all the water has been added, stir the mixture again. Record observations. Pour the mixture into the filter paper, folded correctly in the funnel. Catch the filtrate (the liquid that comes from the funnel) in a clean beaker. Record observations. Discard the filter paper and its contents into the approved waste container. Carefully pour the filtrate onto a clean, previously weighed watch glass. Place this in a clean area where the water can evaporate. If your lab has a heat lamp, this can be used to speed up the process. Observe the material left after the water evaporates. Record observations and mass measurements. Note whether it is different from the starting substances.

2. Decomposition.

Use the dropper to add small amounts of water to the white residue formed in the procedure above. Stir with a glass rod to dissolve completely. Attach short copper wires to two alligator clips, connecting wires, and battery clips as shown in the diagram. Fasten the clips and leads so they stay apart in the dish. When the battery is clipped on, observe the solution and record observations.

The diagram below shows how a well tray can be used with a Radio-Shack battery clip and alligator clips to carry out this experiment. The battery should be placed behind the well as shown in Figure 3. Be sure the rods do not touch each other.

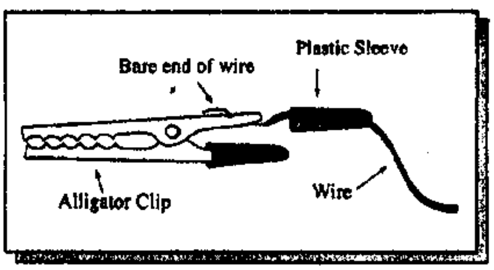

FIGURE 1

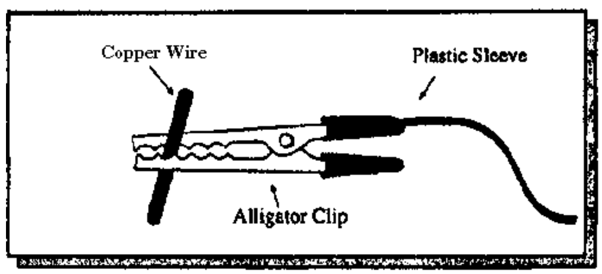

FIGURE 2

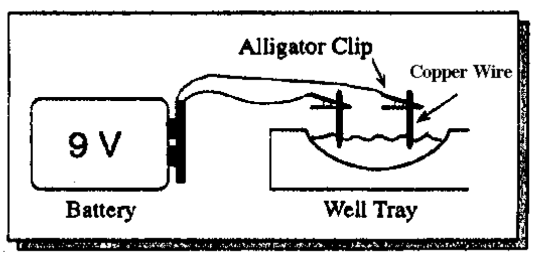

FIGURE 3

Background:

Zinc reacts with iodine to form zinc iodide (ZnI_2), a white crystalline powder soluble in water. Left on the filter will be residues or impurities from the starting zinc and iodine. Heating the two substances together directly will also work, but water acts as a catalyst here to provide energy for the reaction to proceed at room temperature. Since heat is released, a small amount of iodine may be vaporized in a violet "smoke," so ventilation is important, though the amount is small. The reaction is an oxidation-reduction reaction where the zinc loses two electrons, one each to each iodine atom to form the ionic compound. Students at this level do not need to understand the reaction in this way. It is sufficient to have the atoms from the elements combining to form a different compound.

Not all the mass will be recovered in the product because of the I_2 vaporization and because not all the material reacts. That left on the filter paper is unreacted, or impure. The white solid is redissolved in water for the decomposition step.

The decomposition uses the stored chemical energy of the battery to provide electrons at a voltage potential sufficient to reverse the synthesis reaction. Electrons are removed from I^- ions and added to Zn^{2+} ions to form zinc metal, which plates onto the copper wire. The neutral I atoms combine to form I_2 molecules, which may be observed to form dark crystals on the copper wire. Some dissolve in the water to form a yellow-brown solution around the copper wire. The zinc coating and the iodine crystals look familiar—we're back to the original starting materials.

This is clearly a chemical process, forming new compounds from atomic re-arrangements in both the synthesis and the decomposition process. However the entire process has been reversed. So, the idea of irreversibility is not a single reliable indicator of a chemical change. A simple example of an irreversible (temporarily) *physical* change is the melting of an ice cube in a warm room. Unless the water is put back in a freezer, the water will never become ice again. Electrical energy must be used to carry out the reverse process, just as in this chemical change.

Adapted from:

Borgford, Christie L. and Summerlin, Lee**,** *Chemical Activities.* Washington, DC.: American Chemical Society, 1988.

Science as Inquiry

Is It Physical or Is It Chemical?

Overview:

Students study various examples of physical and chemical change and share their findings with the class.

Materials:

cards with challenge system changes printed on each (see below for examples)

Procedure:

Have individual students or groups select a card. Give them five minutes to draft a presentation on whether the system change is physical or chemical (it might be both). If groups are formed, they can discuss this among themselves. They should also be able to suggest observations or tests that might be done to help the decision. Then cycle through the class, having each group present their case and other students, or you, challenging the decision.

As a writing assignment, the group/individual could be asked to prepare a "formal" answer based on the class discussion. Copies of this could be provided for every student or bound as a set for the class.

If the results of Activity 1 were not fully discussed, this should also be done as part of this activity.

Alternative Procedure:

Demonstrate the change before the class, or assign pairs of students to do the demonstrations. Be sure they observe proper safety precautions. Have the rest of the students take notes and prepare reports as listed in the student sheet.

Suggestions for Assignments:

- putting a marshmallow in a hot camp fire
- sharpening a pencil
- writing on paper with a ballpoint pen
- boiling an egg
- adding lemon to iced tea
- mixing flour and water to a paste
- pouring a can of soda into a glass
- tearing paper into strips
- eating a hamburger
- making a salad at a salad bar
- adding dishwashing liquid to water in a bowl
- deep-frying French fries
- adding ice to boiling water
- adding ice to cold water
- placing a strip (liquid crystal) thermometer on someone's forehead
- drying damp clothes on a clothesline

- rust forming on an iron fence that hasn't been painted
- steam escaping from a steam vent in the city, or in a hot springs area

(If Activities 2 and 3 have not been used, those systems can be used as further assignments)

Background:

It is important that this exercise be seen primarily as one that enhances a student's ability to think and talk scientifically about concrete situations. The purpose is not to have them learn or memorize a specific definition of physical or chemical change, or to memorize specific scenarios or changes as belonging to one or the other category. An important part of the discussion should lead to proposals for tests or experiments to confirm inferences or conclusions. Some might be performed as extra assignments.

Technically, the simplest way to look at the distinction between chemical and physical change is to examine the chemical molecules of the system. If the molecules are essentially unchanged by the change process, then the process is physical. However, at this level, students will not have a good way to grasp the molecular concept, nor is it often directly observable. Thus the emphasis is on raising, but not necessarily settling, the issues. No other single rule is adequate by itself, and the suggestions made can have exceptions.

Further Variations:

As an extension, students can be asked to propose new scenarios to challenge other sections or for next year's class. These situations should be reflect their own experiences rather than be "science fiction." The readings (see Event #5) can be one source.

Observing the changes directly and gathering the evidence is obviously preferable if time permits.

Adapted from:

Oklahoma Project Chemistry, Top Chem. Oklahoma State Department of Education, 1987.

Alyea, Hubert N.**,** *Armchair Chemistry, Sixth Edition*, 1990.

Kardos, Thomas, *Physical Science Lab Kits*, New York: Center for Applied Research in Education, 1993.

Teacher Sheet

Science as Inquiry

The Cannon and Friends

Overview:

These teacher demonstrations illustrate physical and chemical changes.

Materials:

Demo 1: Chemical and Physical Cannon
Erlenmeyer flask with rubber stopper to fit neck
paper or mylar streamers, taped to top of stopper
baking soda
white vinegar
small paper towel or tissue

Demo 2: Chemical and Physical Cannon II
cannon (see procedures below for construction)
drops of alcohol (ethanol)
rubbing alcohol (isopropanol) or perfume (in alcohol)

Demo 3: Oxygen Gas from Bleach Solution
filter flask
rubber or tygon tube
shallow pan filled with water
gas collecting tubes filled with water
stopper for the flask
sodium hypochlorite bleach solution (about 5%) (100 mL)
cobalt nitrate (5 g)

Demo 4: Pipe or Bottle Uncorking
access to freezer
strong glass bottle with well-fitting cork

Procedures:

Demonstrate the following changes before the class. Have students take notes and discuss each event as they have seen it. ***Follow good safety practices in all demonstrations.***

A wrap-up session should follow. What did these demonstrations have in common? (Chemical change, new substances being formed.) In what fundamental ways were they different? (Gas release, color change, etc.)

Demo 1. Chemical Cannon

Tape a few paper or mylar streamers to the top of a rubber stopper that fits well into the neck of an Erlenmeyer flask*. Wrap about 7–10 grams of baking soda in a small paper towel or tissue. Pour 150–20 mL of white vinegar into the Erlenmeyer flask. Drop the paper pack into the flask and quickly insert the stopper. It needs to be tight, but not too tight! Carefully point the stopper away from anyone in the room. Shortly it will shoot across the room. Have students feel the temperature of the flask before and after the reaction. They may be surprised!

* This can be done with a two-liter soda bottle or other firm-sided bottle but it needs practice to get the amounts and stopper fitting correctly.

Demo 2. Chemical Cannon II

Prepare a cannon in which a chemical fuel is ignited by a spark. Very few drops of fuel are needed (too much may not work). Two models are described here:

1. *Film Canister*. Connect wire leads from either side of a piezoelectric gas grill starter and insert the bare ends of the wires through small holes made close together in the bottom of a discarded film canister. Be careful the wires are not touching. Place a couple of drops of volatile flammable liquid in the canister—alcohol, isopropanol (rubbing alcohol), and perfume work. Put on the cap and operate the starter/sparker. The lid will fly off.

2. *Turkey Baster*. Obtain a flint starter/sparker unit for a Coleman camper lantern. Take the rubber bulb from a turkey baster. The right kind should hold a Ping-Pong™ ball comfortably in its neck with a tight fit (a little water or glycerin may help the ball fit tightly). The sparker can be installed in the bulb by punching a hole through the side and using the nuts supplied with the sparker to make a tight fit. Place a couple of drops of volatile flammable liquid in the canister (alcohol, isopropanol, etc.). Put the Ping-Pong ball tightly in the neck (see above) and operate the sparker. When conditions are right, the chemical explosion will fire the Ping-Pong ball across the room.

Demo 3. Preparation of Oxygen Gas from Laundry Bleach

Do this in a well-ventilated area. Set up a gas preparation and collecting apparatus. A large filter flask with a tube connected to its side arm and leading underwater in a shallow pan works well. Invert a water-filled tube over the end of the tube to collect the oxygen gas. Place 100 mL of the bleach solution in the flask along with about 5 g of cobalt nitrate solid crystals. Stopper quickly and swirl to mix. Allow some air to be displaced before collecting the oxygen evolved. Show the properties of the collected oxygen gas by reigniting a glowing splint and by quickly inserting hot fine steel wool into the gas (degrease the steel wool first by washing with solvent).

Demo 4. The Water Bottle Phenomenon

Be sure students follow this demo from begining to end, so it doesn't become "magic." Use either a bottle with a well-fitting cork (***not*** a screw cap) or a thin copper pipe (regular plumbing type) sealed at one end and with a tight screw fitting cap at the other. (Do not use steel pipe. as shrapnel fragments may be ejected.) Fill the bottle or pipe as completely as you can with water and seal tightly with the cork or cap, respectively. Place in a freezer. Examine after a few hours in the freezer (next day). The cork will have been ejected, with ice protruding, or the pipe will have fractured.

Alternative Procedure:

Assign groups of students to prepare and do the demonstrations before the class. Be sure they understand and observe proper safety precautions. Have the rest of the students take notes and prepare reports as listed in the student sheet.

Background:

Demo 1.
The reaction is between solid sodium bicarbonate and acetic acid (about 5%) in water to yield carbon dioxide and sodium acetate solution. This is an endothermic reaction. The solution gets cooler (*chemical change*). The pressure of the gas ejects the stopper (*physical change*). The paper towel helps you get the baking soda powder quickly through the neck of the flask and gives a little time, as the vinegar soaks through the paper, to get the stopper in. A plastic bottle is safer than glass. The Erlenmeyer design is strong and will not break.

Demo 2.
The reaction is rapid oxidation of hydrocarbon bonds in the alcohol molecules to form carbon dioxide and water. The cannon may feel warm afterwards (chemical change, exothermic reaction), and a light flash may be seen (especially if room is darkened). Energy is also transformed to sound energy. The pressure of the gas ejects the projectile (***not*** the spark!) (physical change).

Demo 3.
Bleach solution contains sodium hypochlorite (usually about 5%) in water. The reaction is hypochlorite ions in water catalytically decomposed to oxygen gas and chloride ions in water:

$$2ClO^-(aq) = O_2(gas) + 2Cl^-(aq)$$

Some of the cobalt nitrate is probably converted to cobalt oxide, which is a black precipitate. Leftover bleach solution may be diluted and disposed of in a sink. Adequate ventilation is needed so that chlorine released from the bleach solution does not build up, though the amount released is no more than in the laundry room.

Demo 4.
Students who live in cold climates may have seen this effect in real life! The expansion of water upon freezing is an anomaly (most liquid-solid transitions do not do this), but a very important one. It is also dealt with in other units. The point here is to observe the changes and identify them as physical—expansion of the water/ice, movement of the cork, or fracture of copper pipe. Emphasize the practical implications: need for antifreeze in water in automobile engines, for example. In “historical times” cracked engine blocks were not unheard of. Ask students why people living in cold climates thought that the pipe or engine ruptured only when the ice melted in the spring. (Ice doesn’t flow out through the crack so you don’t notice it until it thaws to liquid water—this may happen in your demo if you use the pipe version.)

Further Variations:

As an extension, students can be asked to propose or research new demonstrations to challenge other sections or for next year's class.

Adapted from:
Summerlin, Lee R. and Ealy, James L., *Chemical Demonstrations.* Washington, D.C.: American Chemical Society, 1988.

an alternative/extension activity for Event 2

Teacher Sheet

Science as Inquiry

Writing with Color

Overview:

This activity explores physical and chemical changes involving color and can be done either as a demonstration or as a student lab. Chemical solutions are used to draw or write on various writing surfaces.

Materials:

poster paper samples (white)
goldenrod copy paper, other colors
swabsticks for painting/writing
gloves for handling dry chemicals (cheap plastic “disposables” are sufficient)
“magic” writing slate from toy store
small spray bottle
chemicals (solutions about 0.5 M should work): only small quantities are needed.
dilute acid (e.g., white vinegar)
dilute base (ammonia or sodium carbonate) solution
ferric chloride crystals
potassium thiocyanate (KSCN) solution
potassium ferrocyanide [$K_4(CN)_6$] crystals
tannic acid solution (try strong black tea)
ferric ammonium sulfate crystals
phenolphthalein solution (other indicators can be used)
cobalt chloride solution

Procedures:

The student sheet for this activity is a laboratory activity. You may wish to assign groups to do some of the exercises and provide time for sharing the results.

Various writing surfaces are prepared, and chemical solutions are used to draw or write on them, creating interesting color-change effects. Comparison is made to “conventional” writing or “magic slate” writing. See the student sheet for details.

A wrap-up session should discuss what these activities have in common (chemical change, color change, new substances being formed) and in what fundamental ways they were different (new substances vs. transfer of substances).

Alternative Procedure:

Assign groups of students to prepare and do the demonstrations before the class. (Be sure they understand and observe proper safety precautions.) Have the rest of the students take notes and prepare reports as listed in the student sheet.

Background:

These effects are mostly caused by chemical reactions with the transition element, iron. Transition elements form many complex ionic systems, most of which give rise to intense visible light absorption, hence they have bright colors (see a standard chemistry text for details). In this experiment, students are not expected to identify the reactions involved, but they should recognize that new chemical species are being formed from the initial reacting species, which themselves are disappearing (*chemical changes*). When only a transfer of material from one place to another occurs, as in preparing the surfaces, or writing with crayon, or the adhesion of the black paper to the translucent front paper in the "magic slate," no new chemical species are produced (*physical change*). A difficult case is the cobalt chloride color change on heating. In fact, in this case water molecules are being driven by the heat transferred from close incorporation with cobalt ions (probably in the pale pink hexa-aquato complex ($Co(H_2O)_6^{2+}$) to leave a bare cobalt II ion, which has blue color. Most chemists would call this a chemical change. This may be reversed by spraying the paper lightly with moisture.

The goldenrod copy paper apparently contains dyes that are weak acids or bases and change color on transferring a proton. This is how all acid-base indicators work; therefore the paper is an acid-base indicator. Since proton transfer is involved in acid-base chemical reactions to form a new chemical species, this is a chemical change, even though it is readily reversed. The students may discover similar dyes in other papers.

Further Variations:

As an extension, students can be asked to propose or research new demonstrations to challenge other sections or next year's class.

Adapted from:

Summerlin, Lee R., and Ealy, James L., *Chemical Demonstrations,* Vol. I. Washington, D.C.: American Chemical Society, Washington, DC, 1988.

Science as Inquiry

The Good, the Bad, and the Ugly Popcorn

Overview:

Students investigate popcorn before, during and after popping.

Materials:

Per class:

samples of at least two different kinds of popcorn (unpopped)
(more will be better for a class comparison and pooling of information; information from packets should be saved and given to students)
small cups or bags for samples
large cups or empty milk cartons for popped corn
tray for sorting and counting
teaspoon
popper device (commercial, or metal pan)
Erlenmeyer flask, one-hole stopper to fit, clamp or tongs to hold hot flask
heating device—either a burner or a hot plate
measuring cylinder
triple-beam balance or equivalent, or better balance (0.01 g needed)
paper towel
iodine test solution (dissolve 1.3 g of iodine and 1.7 g of potassium iodide in 500 mL of water)

Procedure:

The parts to be carried out may depend on equipment availability and time allotted. Ideally, the class groups would work on different samples. Class data would then be pooled during an extended post-lab discussion.

Each group is to determine the following parameters for at least one sample of popcorn:

1. The average mass and volume of unpopped corn.
2. The average mass and volume of popped corn.
3. Evidence for what happens during the popping process. What changes take place? Are they physical or chemical changes?
4. What is the percentage of unpopped kernels in a batch?
5. What evidence can be gathered as to why certain kernels don't pop?
6. Does the process used for popping affect the results (volume, mass, quality of popped corn)?
7. Are there any manufacturer's claims on the packet that can be tested or checked from the information determined above? Which is the best buy and why?

Students should devise their own procedures but have the teacher approve them before doing them.

Hints:

1. Volumes of cups may be calibrated using water and the measuring cylinder. Can you account for the air included with the popped corn?
2. Be sure to use masses that are well within the range of the balance provided.
3. Make observations at all times and record the observations for someone else to read.
4. If time permits carry out each test more than once. How do you handle the situation when the results are not the same?
5. If the kernels in a batch look as if they fall into different types, you may wish to sort them first and handle each type separately.
6. To gain evidence for the changes occurring, pop single kernels in the Erlenmeyer flask over a burner or hot plate (***use caution***). Stopper the flask with a stopper with one small hole in it. Use a clamp, or other holder to hold the hot flask. You may need to practice till you get “perfect” popping.
   The best procedure inverts the flask the moment popping occurs, which prevents burning of the popped corn. Then pop at least five weighted kernels, one at a time. Observe the flask closely for evidence of changes. Check mass of the kernels after popping.
7. To test for damaged kernels, place about 10 g of unpopped corn into the cool Erlenmeyer flask. Add 25 mL of iodine test solution (containing iodine and potassium iodide). Swirl well for at least two minutes. Decant the solution from the corn. It can be used again, so place in storage bottle in lab. Rinse kernels with water to remove any remaining test solution. Dry kernels on a paper towel and count the number that have purple color.

Alternative Procedure:

Do the entire labs as demonstrations, with students recording information.

Background:

It is important that this exercise be seen primarily as one that enhances a student’s ability to carry out proper scientific investigations and to think and talk scientifically about concrete situations. The purpose is not to have students learn or memorize specific information about popcorn. This is also a useful exercise for introducing simple statistical analysis procedures (averaging, sample size considerations, etc.). The post-lab discussion should lead to proposals for additional tests or experiments to confirm inferences or conclusions. Some might be performed as extra assignments or by other groups in other class sections.

Further Variations:

There are other suggestions in the original sources (see below) for both simpler and more complex experiments with popcorn that could be turned into a sequence of investigations lasting several days.

This also could be an excellent assessment activity, as it encompasses information and skills gained over several units in this program.

Adapted from:

Evans, Thomas A., *Popcorn Experiment*. Granville, Ohio: Denison University, 1986.

American Chemical Society, "Popping Corn." *Science Resources for Schools: Ideas in Science*, Vol. 3, No. 3. Washington, D.C.: AAAS, 1986.

Science as Inquiry

Physical and Chemical Change

Item:
When working in the lab it is important to recognize when a chemical change occurs as a result of the actions you have taken. You can be *sure* a chemical change has occurred whenever:

A. a color changes,
B. a change of state occurs,
C. a new substance is formed, or
D. the system temperature changes.

Justification:
Give two examples of chemical changes.

Answer:
Choice C is correct. A chemical change is indicated by the creation of a new substance, which may have physical and chemical characteristics that differ from the substances from which it was made. Examples given will vary.

Science as Inquiry

Chemical Change

Item:
Which of the following is an example of a chemical change?

A. bubbles formed when opening a coke
B. the burning of paper
C. condensation of water on the outside of a glass
D. the pounding of a nail into wood

Justification:
Explain how the answers that you did ***not*** choose are ***not*** chemical changes.

Answer:
B. new chemical compounds (carbon dioxide, water, and others) are being formed from the original molecules in the paper.

In (A) bubbles are only a change in solution concentration of gas in water: in (C) water is undergoing a phase change from vapor to liquid; in (D) molecules are being pushed aside by the nail, but (in general) no new chemical bonds are formed (OK, at the micro level, maybe, but not at ninth grade!).

History and the Nature
of Science

Conservation Principles

Item:
Priestly heated red oxide of mercury and obtained a gas that was named oxygen. Lavoisier repeated these experiments and recognized that he could run the experiment two ways: heat measured amounts of mercury and oxygen to make the oxide, then decompose the oxide to get mercury and oxygen back. Lavoisier carefully collected the oxygen from the second experiment and found it was the amount used up in the first.

Explain how these experiments demonstrate conservation principles. Explain what was not understood about these experiments (that now seems obvious) that was recognized a few years later by Dalton.

Answer:
Lavoisier recognized that the masses all added up. The mass of oxygen that reacted with mercury in step 1 equaled the mass recovered by heating the oxide in step 2. All the mercury was still there, so conservation of mass was clear.

It is now obvious that atoms of each element were being conserved. The change was just in the arrangement. Dalton made this conclusion about four or five years later. Thus the atomic theory (or model) was revealed by experiments that almost paralleled famous alchemy experiments (Bronowski: *Ascent of Man)*.

Science as Inquiry

Sugar as Food

Item:

When you eat sugar or other carbohydrates, these foods are described as ‘sources of energy” for your body. Converting the sugar is an example of a chemical change.

What specific evidence is there to determine that this is actually a chemical and not a physical change?

How can modern technology help make it possible to examine changes, such as the digestion of sugar, going on at the molecular level?

Answer:

New intermediate chemicals can be found in the stomach, or mouth, as changes to the molecules occur. Simulating these in the laboratory can indicate energy changes (heat evolution) as the reaction occurs (e.g., saliva on foods).

Microprobes and mass spectrometers can assist in identifying new chemicals as intermediates and in looking at temperature changes. Infrared sensors are particularly helpful in finding where energy is released as heat is taking place.

Science as Inquiry

Chemical Reaction as Change

Item:
When a chemical reaction occurs, there is always a change in:

A. the kinds of atoms present
B. both the properties of the system and the energy
C. total mass of the system
D. the phase state of the reacting substances

Justification:
Describe what happens to paper when it burns by listing at least three observations.

Answer:
B. Because new substances are created, a change in properties is apparent. There are probably no instances where the energy content is exactly equal between reactants and products, or the reaction would not proceed.

Science as Inquiry

Chemical Reaction as Change

Item:
An example of a chemical reaction is:

A. bending
B. evaporation
C. melting
D. photosynthesis

Justification:
Tell what happens to water when it evaporates and tell what happens to ice when it melts. What happens to your middle finger when you bend it inward? What is a common factor in each of these three processes?

Answer:
D. Photosynthesis. New products are formed. Carbon dioxide is reduced to make sugar, and water is oxidized to oxygen.

$$6CO_2 + 6H_2O + 688\ \text{kcal} \longrightarrow C_6H_{12}O_6 + 6O_2$$

Science as Inquiry

Performance Task on Mixing

Item:

You are asked to design and test an experiment to test conservation principles, and to investigate chemical and physical change on mixing substances. You are to do this by mixing known masses of:

A. sand and water
B. salt and water
C. alcohol (rubbing) and water

Weigh the product mixtures and record your observations. Suggested observations include appearances, volumes, and temperatures. From your results write a report answering the following:

Which of these mixings demonstrate a chemical change and which are physical changes?

Why do you come to these conclusions?

Is mass conserved and what evidence do you have?

Is volume conserved and what evidence do you have?

Is energy conserved and what evidence do you have?

Science in Personal and
Social Perspectives

Analysis of a Burp

Item:

You prepare a solution of baking soda in your kitchen. When you swallow the solution, you note that a gas has formed in your stomach that causes you to burp. Has a chemical reaction occurred? Explain your answer.

Answer:

A chemical reaction has occurred. The reaction of the baking soda solution with the stomach fluids caused the formation of a new substance, carbon dioxide gas. A chemical property describes a chemical change (chemical reaction) that a substance undergoes.

Science As Inquiry

Physical and Chemical Change

Item:

Make two lists on a piece of paper. Title the lists *Physical Changes* and *Chemical Changes*. List all the characteristics of change you have studied under the appropriate columns. Under *Chemical Changes*, list the kinds of evidence that indicate that a chemical change has taken place.

Describe in detail ***two*** systems undergoing change for each of the two types of change. Make the descriptions easy to understand so that someone who has not studied science can see why physical and chemical change are different.