CHEMISTRY THAT APPLIES

NEW DIRECTIONS
TEACHING UNITS

Michigan Science Education Resources Project

Michigan Department of Education

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(See Inside Back Cover)

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How to use the "Chemistry That Applies" unit
(8th, 9th or 10th grade)

The student book: Each student should have a copy of the student book. This book includes reading, lab activities, and discussion questions, all integrated into lessons. The lessons are clustered into four sections (simply called "Clusters"), each based on a key question.

Student lab notebooks: The student books have no space for writing answers to questions, so that they can be used by several classes. For writing answers, recording data from investigations, and posing new questions, we recommend that students use a lab notebook or journal. Notebooks have several advantages over single sheets of paper handed out and collected on a daily basis: They let students compile their work, as in a portfolio, gaining some sense of pride in their collection; and they allow students to look back on their early ideas, appreciating the way their understanding grows. In a few lessons, prepared handouts are available for students' use (in the appendix), which can be kept in a pocket in their lab notebook.

Annotated teacher's edition of the student book: The teacher's guide contains several pieces of information that should be helpful to teachers as they prepare and teach this unit. They include:

- **background information** to help teachers see the broad directions and intent of the unit;
- **lesson background and lab preparation** (on yellow sheets prior to each cluster) to prepare for the hands-on activities in each lesson;
- **lesson statement, purpose, and approximate time** for each lesson;
- **margin notes** on student thinking and content; and
- **answers to questions** posed in the text.

Overhead transparency masters: The appendix contains three drawings of the human body, one showing the digestive system, one showing part of the circulatory system, and one showing the lungs. These three can be overlaid to illustrate discussions in the text.

Feel free to contact Mr. Theron Blakeslee, Project Director, at (517) 373-0454 with any questions, suggestions for improvements, or concerns.

CHEMISTRY THAT APPLIES

8th, 9th, or 10th grade

Michigan Department of Education

Artwork by Mark Galik (except pages 53 and 54 by Anjela Curtis).

Philosophy and Rationale

New Directions teaching materials have been created to help teachers develop scientific literacy and conceptual understanding for all of their students. As companions to the new Michigan Essential Goals and Objectives for K-12 Science Education, they illustrate the ideas about teaching, learning, and curriculum that underlie the new objectives.

Chemistry That Applies is an 8th, 9th, or 10th grade unit that helps students construct a clear understanding of how new substances form from the old ones and how the Law of the Conservation of Matter applies to all of these situations. It also helps students learn to pose questions, search for solutions to problems, work together with others, and value the need for evidence in making decisions.

Specifically, it illustrates the four important goals for science education listed in the Introduction and Rationale of the new state science objectives:

1) SCIENTIFIC LITERACY FOR *ALL* STUDENTS

Scientific literacy includes the ability to **use** scientific ideas to understand the world around us, **construct** new ideas by asking questions and searching for answers, and **reflect** on the adequacy of explanations and solutions. In this unit, students perform four reactions—combining baking soda with vinegar, burning butane, rusting iron, and decomposing water. They learn how to write good descriptions of reactants and products as a way to predict whether new substances have formed. They trace the atoms from reactants to products and see how the reactions observe the Law of the Conservation of Matter. They build molecular models that simulate chemical change in order to understand how new substances form. As they do this, they make predictions and learn how to test their predictions through experiments they design. They sharpen their abilities to ask questions and construct answers, and reflect on the evidence needed to support arguments and decisions.

Scientific literacy is not just for those who show an early interest in science or those who might pursue science-related careers. It is for *all* students. Because fewer and fewer young women and minority students develop an interest in science and technology, these **New Directions** units incorporate materials and approaches to support and encourage them to succeed and stay in science.

2) UNDERSTANDING OVER CONTENT COVERAGE

To be scientifically literate, students need to have a deep and connected understanding of the "big ideas" of science. In this unit, these ideas include

1) that matter is conserved in all chemical reactions;
2) that all matter is composed of atoms that join together to form molecules;
3) that new substances form when the atoms of the reactants come apart and reassemble in new arrangements to make the products; and
4) that all chemical reactions involve energy changes and usually they need "boosters" to get them started.

This kind of conceptual understanding takes time. That's why these units are relatively long. For some teachers, 6 to 8 weeks for one unit in science seems like a sacrifice of other important content. But to really understand the big ideas, students need to understand theoretical concepts, such as chemical change and conservation of matter and energy, and be able to translate this understanding to real-world situations, like conserving resources and getting rid of trash. They need to see how the concepts they learn make sense in terms of what they are already familiar with, whether that is baking cookies or watching a fire burn or recycling pop cans. This kind of learning fundamentally differs from science teaching that skims across many topics, often overwhelming students with chemical formulas and equations. It is especially important for developing scientific literacy in *all* students.

3) LEARNING THAT IS USEFUL AND RELEVANT OUTSIDE OF SCHOOL

Scientific literacy means an understanding of science that can be put to good use outside of school. For that reason, we have chosen topics for the **New Directions** teaching materials that connect scientific ideas, skills, and habits of mind with important real-world systems, events, and problems.

But research continues to show that students bring to the classroom theories about how the world works that are sometimes at odds with scientific explanations. In this unit, for example, students often believe, naively, that matter changes into heat and energy when it burns and therefore weighs less. They fail to recognize that new molecules form from the old ones and that the heat and energy released come from the energy involved in holding the atoms within the molecules together. One of the important goals of these new materials is to connect students' developing scientific ideas with the ideas they already use to make sense of the world. Sometimes this involves relatively little change; sometimes it involves "mind-bending" change.

4) INTERDISCIPLINARY TEACHING

The world is interdisciplinary. Chemistry alone, or physics alone, or social science alone, does not provide the answers to important social questions. And students should not see the world as compartmentalized, with language arts occurring between 9 A.M., mathematics between 10 A.M. and 11 A.M., and science only after lunch.

These units draw from as many scientific disciplines as necessary to dig deeply into the topic. In this unit, chemistry, physics, and environmental science are closely woven together. The unit also provides multiple opportunities for using and strengthening students' expressive and quantitative abilities.

On the whole, we hope that these units provide new resources to teachers to improve student achievement in science. The outcome we are all striving for, though, is not just better test scores. What we really want are scientifically literate citizens.

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About This Unit

What's going on when iron rusts or fires burn or cakes bake or caves form? And where does trash go when it burns up or when we throw it away?

How do hand and toe warmers work? Does a house really turn into heat and energy when it burns? Where does the light in a light stick come from?

These ordinary questions arise from the things that happen around us everyday. But one's ability to answer them requires a deep understanding of scientific knowledge, especially chemistry and physics. As an introduction to chemistry, this unit gives students opportunities to explore various everyday chemical reactions, contrast them to physical changes, and construct explanations for them in terms of changes in the molecules that make up the substances. Current research reflects how students typically describe and explain everyday chemical reactions. This research will help pinpoint the difficulties that students typically have in learning about chemistry.

This unit focuses on important, everyday reactions rather than obscure "chemistry set" reactions or those that come out of the mysterious chemistry stock room. This is not meant to suggest that theoretical chemistry research or chemical engineering with complex substances is unimportant. But students' introduction to chemistry should be in an everyday context so that it does not seem remote or magical. By focusing on just a few reactions in depth, students will probably be able to extend their knowledge to understand the world around them in a more scientific way.

Equally important in understanding chemistry in the world around us are certain skills and habits of mind—the ability to make predictions and then test them to see if they are right, to pose questions and design experiments to answer those questions, to demand evidence and logical reasoning to support assertions, and to think critically about others' claims or ways of thinking. This unit will also help students develop these abilities.

Cluster by Cluster

This unit is composed of four clusters, each building toward a comprehensive story of how changes in matter relate to atoms and molecules and energy—one of the key questions in the Framework of the Michigan Essential Goals and Objectives for K-12 Science Education. As a unit, these materials put the goals for Michigan science education into practice (see the Michigan Essential Goals and Objectives for K-12 Science Education, page 1, Philosophy and Rationale).

How the unit works:

To develop a broadly-connected understanding of how new substances form, this unit applies ideas about atoms, molecules, chemical reactions, and energy changes to four relatively simple reactions: burning, rusting, the decomposition of water, and the "volcano" reaction of baking soda and vinegar.

Students will, in general, have studied changes of state (melting, freezing, evaporating, condensing) and other physical changes (dissolving, crushing, coloring, etc.) prior to doing this unit. They usually will not, however, have studied the properties of many everyday substances (such as gasoline, baking soda, bleach, metals, bread, wood, paper, etc.) or the chemical changes that take place with them (burning, rusting and other oxidation reactions, baking, the effects of acids, etc.)

In Cluster 1, students are asked to develop descriptions of various substances and changes that occur in those substances, with the purpose of eventually being able to recognize when chemical reactions have occurred—that is, when new substances are produced. This is often difficult because students typically use the language of physical changes to talk about what scientifically literate people recognize as chemical changes. For example, students may say that rust is nothing more than discolored or flaky metal, or that when an egg white cooks it goes through a phase change from liquid to solid, or that gasoline goes through a phase change from a liquid to a gas when it burns. They fail to understand that chemical changes produce new substances or how those substances form. Students learn to write more accurate descriptions of reactants and products and use their descriptions to find evidence for the formation of new substances.

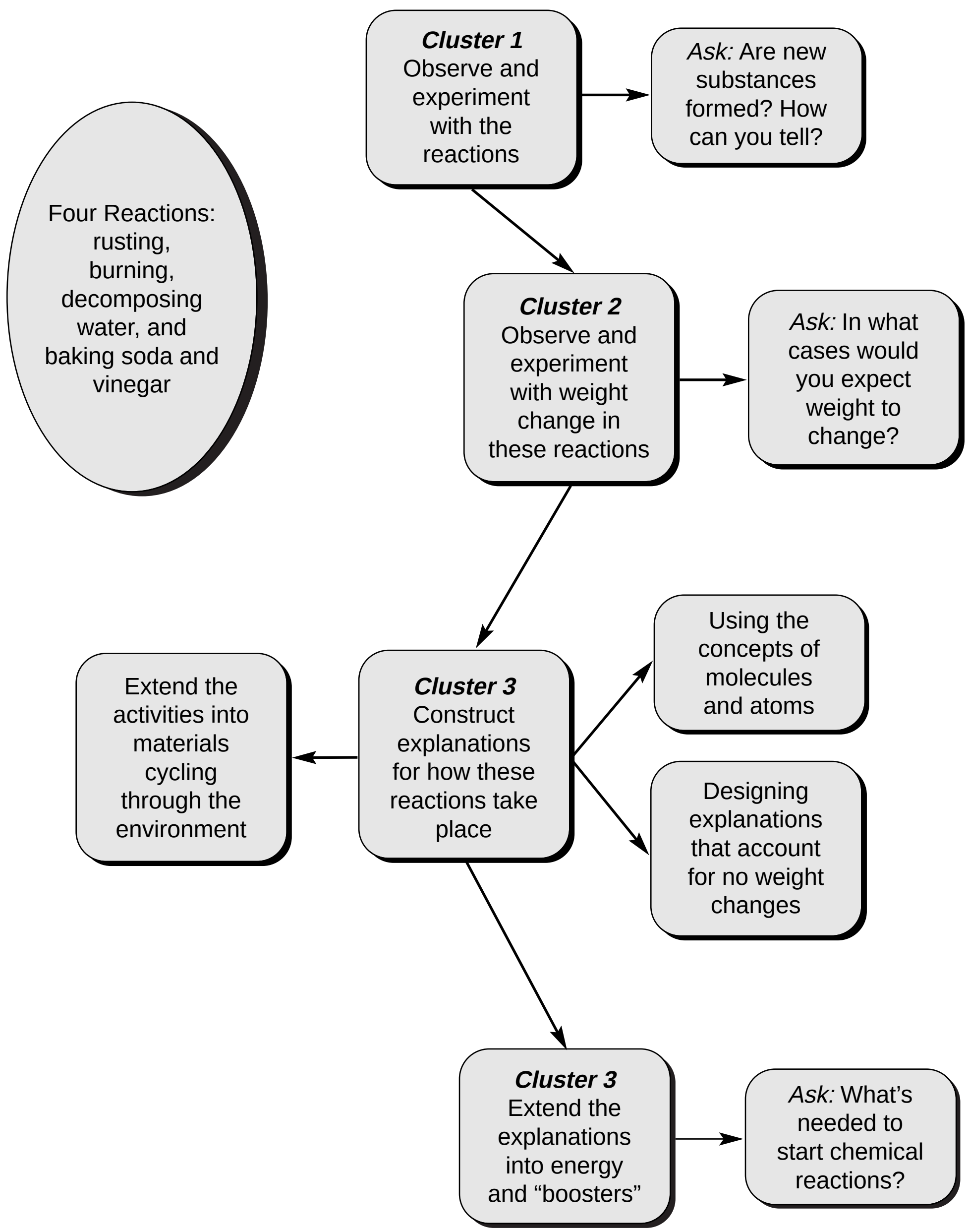
Cluster 2 asks whether the weight of substances changes during physical and chemical reactions. Students make predictions about weight changes and then actually weigh the starting substances and the ending substances to check their predictions. They learn to account for the invisible gases either as reactants or as products and are eventually led to the Law of the Conservation of Matter. Many students think that solids weigh more than liquids, that gases have no weight, and that burning makes things disappear. They often have great difficulty letting go of these misconceptions even when experimentation has shown them otherwise.

In Cluster 3, students construct explanations for both the formation of new substances and the Law of the Conservation of Matter. These concepts are explained and understood in terms of the rearrangement of atoms in molecules during chemical reactions. The cluster introduces molecules as a way to distinguish between substances and as a way to account for what happens during chemical reactions. It presents chemical equations as a way to account for and conserve atoms and to show how new substances form. It poses many questions that extend students' thinking to similar situations in the world around them.

Cluster 4 explores the energy changes that take place between reactants and products and uses separate energy equations to express these changes. It then focuses on reactions that require a "booster" to get started, either in terms of energy or chemical substances that remain after the reaction (catalysts).

Throughout the entire unit, students conduct their own research of a chemical substance. They apply the concepts learned in each cluster to their specific substance as they learn its chemical name, physical properties, history, uses, chemical composition, disposal method, and energy requirements. At the conclusion of the unit, students make presentations using formats they have chosen.

Unit Outline



Working in Groups

The activities in this unit are written to be done in small, collaborative groups, where students have distinct responsibilities for various tasks in the activities. We suggest that you assign students to groups—rather than letting students choose their own groups—to ensure diversity of thinking and action-orientations within the group. Be observant of how groups operate together, and restructure them if anyone is dominating a group or anyone is allowing others to do their work.

Many questions are also developed for discussion in students' small groups. These discussions are ones where students debate with each other in a collaborative effort to find solutions to problems. Students should still be responsible for writing individual answers to questions, so that those who do not contribute strongly or learn well from group discussions have opportunities to articulate their own ideas in writing.

Classroom Environment

Even though different teachers have different personalities and different approaches to helping students learn, what is common in classrooms where students are really making sense of science is student *activity*—students working, students thinking, students explaining. "Hands-on, minds-on" means that *doing* and *thinking* are linked together in developing scientific literacy.

Classrooms where students really make sense of science and learn to use its key ideas and habits of mind in their daily lives have a culture where students are continually trying things out, discussing their ideas, debating solutions to problems, being critical as well as open-minded, listening and thinking. Whether they are learning how to explain why something works, or how to describe a natural system in detail and show the connections of its parts, or how to use information to make predictions, or how to design and build a tool or a system, students have to be allowed to try out their ideas and explain their reasoning.

And teachers have to value students' thinking, both for the insight it provides to further a student's development and because it is the product of the student's honest efforts to grapple with the important questions being raised in the class. In this environment of working, thinking, and listening to others, students learn that their ideas are important and valued and that science is not authoritarian, dogmatic, and esoteric.

Supporting Young Women and Minority Students in Science

Unfortunately, there are far more white males in scientific and engineering enterprises than women and members of minority groups, including African Americans, Hispanics, and American Indians. We say "unfortunately" because the contributions of women and minority persons to the scientific and engineering enterprises has historically been strong, even though they have been underrepresented in their numbers.

Clearly science and technology are fields that many persons can make strong contributions to and that all persons should have the opportunity to choose. Many of our educational practices have pushed women and minority students away from science, though.

These materials, coupled with the best intentions of Michigan's teachers, provide support and encouragement for all students to take more science and mathematics courses and consider scientific and technical fields. They do this by integrating culturally-relevant science materials that reflect the perspectives, experiences, events and interests of different ethnic groups relative to their roles in the scientific enterprise into these teaching units. These culturally-relevant materials emphasize the impact that all groups, including women, have had on science and technology, and the significant consequences and implications for scientific improvement and achievement.

We do this for several reasons. Integrated culturally-relevant examples promote student pride in their ethnic, cultural, and gender heritage, as well as provide an understanding and appreciation of how their culture influences the nature and structure of science. Also, all students need multicultural science education, even if they live in entirely white communities, in order to appreciate the full spectrum of ethnic diversity that exists in our society, in preparation for the day when they will most likely work along side someone of a different physical appearance and cultural background.

State Objectives for This Unit

Specific objectives for this unit, from New Directions for Science Education in Michigan: Essential Goals and Objectives are listed below, along with specific unit learning outcomes derived from each objective.

The Constructing Scientific Knowledge and Reflecting on Scientific Knowledge objectives are integral parts of each New Directions unit. Each Constructing and Reflecting objective is woven throughout each unit, tied closely together with Using Scientific Knowledge objectives.

CONSTRUCTING SCIENTIFIC KNOWLEDGE

OBJECTIVES—8-10	RELATED CONCEPTS, TERMS AND TOOLS	REAL-WORLD CONTEXTS
13) Develop questions or problems for investigation that can be answered empirically.	Understanding the need to build on existing knowledge and to ask questions that can be investigated.	Appropriate scientific contexts: See Using Scientific Knowledge.

- Pose questions about weight changes in physical and chemical systems.

OBJECTIVES—8-10	RELATED CONCEPTS, TERMS AND TOOLS	REAL-WORLD CONTEXTS
14) Suggest empirical tests of hypotheses.	Hypothesis, prediction, test, conclusion.	Appropriate scientific contexts: See Using Scientific Knowledge.
15) Design and conduct scientific investigations.	Types of scientific knowledge: hypothesis, theory, observation, conclusion, law, date, generalization. Aspects of field research: observations, samples. Aspects of experimental research: variable, experimental group, control group, prediction, conclusion.	Appropriate scientific contexts: See Using Scientific Knowledge.

- Predict whether weight changes during several physical and chemical reactions and design experiments to test these predictions.

OBJECTIVES—8-10	RELATED CONCEPTS, TERMS AND TOOLS	REAL-WORLD CONTEXTS
19) Gather and synthesize information from books and other sources of information.	Scientific periodicals, reference books, trade books.	Libraries, technical reference books.

- Use various reference materials to find information on the chemical composition use, production, disposal, and energy involvement of a common substance.

REFLECTING ON SCIENTIFIC KNOWLEDGE

OBJECTIVES—8-10	RELATED CONCEPTS, TERMS AND TOOLS	REAL-WORLD CONTEXTS
11) Justify plans or explanations on a theoretical or empirical basis.	Aspects of logical argument, including evidence, fact, opinion, assumptions, claims, conclusions, observations.	Appropriate scientific contexts: See Using Scientific Knowledge.

- Use chemical formulas of reactants to justify possible products of a reaction.
- Justify weight gain and loss by accounting for invisible reactants and products.

OBJECTIVES—8-10	RELATED CONCEPTS, TERMS AND TOOLS	REAL-WORLD CONTEXTS
10) Recognize the contributions made in science by cultures and individuals of diverse backgrounds.	Cultural diversity, response to local conditions.	Diets of other cultures.

- Recognize the significance of specific resources in the historical development of other cultures.
- Appreciate the ingenuity of other cultures in using resources.

USING SCIENTIFIC KNOWLEDGE

OBJECTIVES—5-7	RELATED CONCEPTS, TERMS AND TOOLS	REAL-WORLD CONTEXTS
5) Describe common chemical changes in terms of properties of reactants and products.	Common chemical changes: burning paper, rusting iron, formation of sugars during photosynthesis.	Chemical changes: burning, photosynthesis, digestion, corrosion.

- Contrast the characteristics of reactants and products in everyday chemical reactions including burning, rusting, decomposition of water, and reacting vinegar with baking soda.

OBJECTIVES—5-7	RELATED CONCEPTS, TERMS AND TOOLS	REAL-WORLD CONTEXTS
11) Describe matter as consisting of extremely small particles (atoms) that bond together to form molecules.	Molecule, particle, matter, bond, atom.	Common substances such as those listed above.

- Explain what atoms are and how they form all the different kinds of matter.
- Explain the difference between solids, liquids, and gases using models and pictures of molecules.
- Use marshmallows and toothpicks to build models of simple molecules.
- Interpret chemical formulas in terms of the kinds and number of atoms.
- Describe the molecular structure of various reactants and products.

OBJECTIVES—8-10	RELATED CONCEPTS, TERMS AND TOOLS	REAL-WORLD CONTEXTS
13) Explain chemical changes in terms of arrangement of atoms and molecules.	Description of chemical change at molecular level, see Matter and Energy objective 12. Description of chemical change, see objective 5 above Atom, molecule, bond, reactant, product, conservation of matter.	Examples of chemical change: See objectives 5 and 6 above.

- Explain the difference between reactant and product molecules in terms of molecular structure.
- Build models of reactants and use these models to show how molecules come apart and rearrange as the products form.
- Explain chemical changes as molecular rearrangements.
- Write equations to represent chemical reactions.

OBJECTIVES—8-10	RELATED CONCEPTS, TERMS AND TOOLS	REAL-WORLD CONTEXTS
9) Explain how mass is conserved in physical and chemical changes.	Law of conservation of mass.	Common physical and chemical changes above. See objectives 1, 4, 5, 6 above.

- Observe and predict how weight changes as steel wool is compacted, an ice cube melts, sugar is dissolved in water, or water boils.
- Observe and predict how the mass of the system changes as vinegar and baking soda or Alka-seltzer and water react in an open and a closed system.
- Observe and predict how the mass of steel wool changes as it rusts or burns.
- Explain how mass is conserved in systems where substances such as gasoline seem to disappear when burned in a car, by accounting for the invisible gas.
- Account for the apparent increase in mass in systems where things seem to appear out of nothingness, such as in the burning of steel wool.
- Explain the Law of Conservation of Mass by accounting for atoms in chemical equations.

OBJECTIVES—8-10	RELATED CONCEPTS, TERMS AND TOOLS	REAL-WORLD CONTEXTS
12) Describe how common materials are made and disposed of or recycled.	Descriptions of physical and chemical changes. Manufacturing: refining, mining, waste disposal.	Manufacturing processes: steel mills, auto assembly lines, paper making. Recycling: glass, aluminum, paper, plastic, water treatment.

- Explain how copper and other metals are obtained from their ores.
- Explain what happens to copper and other metals when disposed of in various ways.
- Explain why recycling and conserving resources is important in terms of the needs of future generations.
- Research a common substance and find out how we get it and how we get rid of it at the end of its useful life.

OBJECTIVES—8-10	RELATED CONCEPTS, TERMS AND TOOLS	REAL-WORLD CONTEXTS
15) Describe energy changes associated with physical and chemical changes.	Physical change, chemical change, potential energy, kinetic energy.	Physical changes: dehydrated foods, solid air fresheners, recycling glass. Chemical changes: some hot and cold packs, burning fuels, corrosion

- Observe and explain energy changes associated with chemical reactions involving heat, cold, light, and electrical energy.
- Make hand warmers and explain the energy changes that occur.
- Explain various kinds of energy involved in chemical reactions.

Cluster 1

Describing Chemical Reactions

Cluster 1—Lesson 1

A. Many questions are posed in this unit simply to stimulate class discussion. Questions marked with numbers are ones for which students should write answers. We recommend that students use a notebook or a "science log" for writing answers to questions, so they can refer back to their earlier ideas when appropriate. They can also use the journal for recording observations and data from lab activities.

B. The KEY QUESTIONS in this unit are the "objectives" for each cluster or lesson. When they are first presented in the cluster or lesson, they are for stimulating discussion, activating students' prior knowledge, and giving an idea of what's ahead. Don't ask for or give definitive answers at this time—they will be developed during the cluster. But do ask students to voice their present ideas. This will give you some insight into their thinking, and perhaps stimulate some initial debate and questions that will carry through the cluster.

C. This lesson is designed to get students to explore their thinking about changes in matter and to allow teachers to become familiar with their students' thinking. This is not the time to correct errors in their perceptions of changes in matter. No explanations of the reactions are expected in this lesson. Students do, however, observe and describe the reactions as they are demonstrated, and they share their descriptions with other students.

Lesson 1: MIXING IT UP

Each morning we begin our day by mixing things. It may be our favorite cereal and milk, toast with butter, or cream and coffee. It doesn't end there. As the day continues, we use a wide array of mixed substances such as foods, hair sprays, liquid soaps, fertilizers for plants, gasoline and oil for the lawn mower, glue, detergents for washing clothes, and the flour, eggs, sugar, and baking powder for making cakes. The list continues until bedtime when you decide to mix a glass of hot milk and chocolate to help you go to sleep.

Mixing substances together is something we do (or have done for us) all the time. Asking questions about these mixtures will help us to look more closely at what is happening when things are mixed.

(A) Can you think of any things you mixed before coming to class today, or any mixtures you used today? How many combinations can you think of?

(B) **KEY QUESTION**

What happens when some ordinary household substances are mixed?

(C) **TRY THIS**

In this activity you will mix a variety of commonly used household substances and observe and think about what happens. You will work in groups assigned by your teacher.

YOU WILL NEED

One kit (containing a few commonly found household substances) per group.

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LESSON STATEMENT: Students combine some common, everyday household substances and observe and describe what happens. Some of the substances undergo chemical reactions, while others just mix. Students select their most interesting combination, demonstrate it for the class and share their observations with others in the class.

PURPOSE: To provide students with opportunities to explore, observe and describe some reactions involving common substances without providing scientific explanations.

APPROX. TIME: 1 1/2 class periods.

DO, OBSERVE, AND RECORD:

A. Prepare a data chart similar to the one below on which to record your observations. Use your paper the long way and use the full width of the sheet of paper in order to provide sufficient room for your descriptions. Each student should have a separate chart.

B. Work as a team. Examine your kit of materials and make a list of all possible combinations of two substances in your journal. Then make a list of all possible combinations of three substances.

STARTING SUBSTANCES			DESCRIPTION OF WHAT HAPPENED	DESCRIPTION OF ENDING SUBSTANCES
	COMMON NAME	DESCRIPTION		
SUBSTANCE #1				
SUBSTANCE #2				
SUBSTANCE #3				

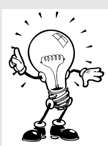
C. Mix each combination and check it off as you do it. Make a note of anything interesting that happens when you mix the substances.

D

D. For your most interesting combination (choose only one), record on your data chart in the appropriate columns:

- The common name and a description of each substance you started with.
- What you observed happening when you mixed your substances.
- A description of each substance you ended with. If you think you know the names of any of these substances, write them also.

Since people see things differently, it is important that your observations and ideas are shared, explained and validated by others. You will now have the opportunity to share your demonstration with the entire class as well as observe and describe reactions they will perform.



SAFETY!

Handle all chemicals with care, even ones that are found around the house. Avoid spills and contact with your skin. Never taste any substance unless told to do so by your teacher.

D. Teachers should talk with the lab groups about the descriptions they are writing. If they are having difficulty, ask them questions about color, odor, state (liquid or solid), etc. You don't need to go into too much detail since students will get more practice and much more direction for writing good descriptions in the next lesson. The purpose here is to get the students started thinking about changes in matter and to help teachers become aware of students' thinking.

E. One way to handle the group discussions of each demonstration is to have the performing group write their descriptions on the blackboard or on an overhead transparency and have the class critique it or add to it. Alternately, the class could come up with a description and compare it to the descriptions of the performing group.

F. Ask students in the class whether they have anything to add to the performing group's description. Write any new descriptions on the blackboard. Then ask the class whether there are any parts of the description that they wish to challenge or to be clarified.

G. QUESTIONS 1 & 2. These questions are for students to speculate about and to explore their own thinking about changes in matter. Do not correct or give them answers at this point. They will construct their own solutions as the cluster progresses.

(E) E. Prepare to repeat this experiment for the entire class. Use the following guidelines as you prepare for the demonstration:

- Try to involve each member of your group in the presentation.
- Allow the class to observe and examine the starting materials and write short descriptions of each one.
- Allow the class to observe and examine the ending substances and write short descriptions of each one.
- Compare your descriptions with those of your classmates.

(F) F. After each demonstration you should:

- Add the new reaction to your data chart. Use the same one you used earlier. Be sure to number each new reaction. Write a description of the starting and ending substances and what you observed happening when the substances were combined.
- Share your descriptions with the class and compare your observations and descriptions with those of the other students.
- Revise your data chart to show any new information gained from the class discussion.

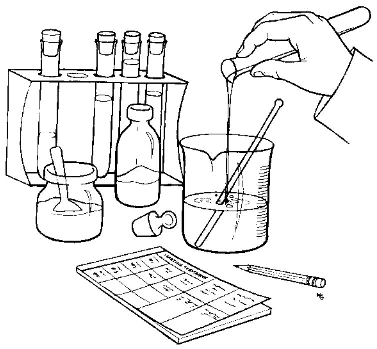
(G)

THINK AND WRITE

Use the descriptions you have written to answer the following questions. You may want to discuss these questions in your group before you write answers in your journal.

1. Do you think any of the demonstrations DID NOT produce new substances? How can you tell?
2. Do you think any of the demonstrations DID produce new substances? How can you tell?

If you found it difficult to answer these questions, you are not alone. Scientists often have difficulty with these questions because sometimes, when two substances are mixed, they just move in and around each other, like mixing tea and lemon juice, or sugar and salt. At other times, when two substances are combined, a chemical reaction takes place where new substances are made that didn't exist before the mixing took place. So how can you tell which of these two things is happening? The first step in figuring this out is making good observations and writing good descriptions of what you see. In the next lesson you will get more practice at this.



Cluster 1—Lesson 2

A. During the class discussion, have students tell why good descriptions are important. Help them understand that writing good descriptions is not easy and obvious but requires patience and very careful observations. It is one of the most important and more difficult activities of a good scientist.

B. The class generates a list of terms that can be used to describe substances, and students should be encouraged to use these words and phrases as they describe the reactants and products of the reactions. Good descriptive terms that should be included are for solids—crystals, powder (fine or coarse), metallic, brittle, shiny, dull; for liquids—clear, cloudy, colored, transparent, opaque, milky, chalky; for gases—fizzing, foaming, bubbling (vigorously or slightly), color or invisible, odor or no odor.

C. In this lesson, students observe and write descriptions of beginning and ending substances without any attempt to explain what is happening. This lesson should lay the groundwork for recognizing chemical change as the formation of new substances that have properties different from what existed previously, rather than just seeing the changes that involve gases, liquids or solids which can be either physical or chemical changes.

Lesson 2: IS IT A NEW SUBSTANCE?

Now that you have observed and described a variety of common household substances that were mixed, you are ready to try describing some other reactions that occur around you everyday and see if new substances are formed.

KEY QUESTION

What happens when baking soda and vinegar are mixed, when water decomposes and when things burn or rust? What kind of observations and evidence indicate whether or not new substances are or are not being formed?

(A) In this activity you will perform four reactions that involve solids, liquids, and gases. You will observe and describe each reaction and try to decide if new substances are formed. To know this, you must be able to describe accurately and completely both the beginning and the ending substances.

(B) In order to help you write good descriptions, the class should brainstorm to make a list of terms that can be used to describe substances. Be sure to include words that describe solids, liquids and gases. Your teacher may appoint a student to write the list on the blackboard or on an overhead projector so that you can refer to the lists often as you make your observations and write your descriptions. For each description you write, you should use at least three descriptive terms. Of course, you may use more than three. You may use terms you think up yourself or you may refer to the list for help.

(C)

TRY THIS

Prepare a data chart similar to the one you prepared in Lesson 1. Use your paper the long way and use the full width of the sheet of paper in order to provide sufficient room for your descriptions. Each student should have a separate chart. You should save your charts so you can refer to them again in Cluster 3.

LESSON STATEMENT: Using good and accurate descriptive terms from a list generated before the activities, students perform, observe and describe four chemical reactions. They use these descriptions to predict whether or not a new substance formed and give reasons for their thinking.

PURPOSE: To write good and accurate descriptions of four reactions and use these descriptions to find evidence for the formation of new substances.

APPROX. TIME: 1 class period.

REACTION 1
RUSTING IRON

YOU WILL NEED

- A small wad of steel wool
- 100 ml beaker
- 25-30 ml of vinegar
- paper towel

DO, OBSERVE, AND RECORD:

A. Write the common name for each starting substance in the appropriate space on your data chart.

B. Observe the small wad of steel wool and write as complete a description as you can in the appropriate space on your data chart. Remember, you should use a minimum of three descriptive words to describe the steel wool. Refer to the list on the board if necessary.

C. Place the steel wool in a beaker. Pour enough vinegar over the steel wool to cover it. Swirl the steel wool and vinegar making sure that the vinegar has come in contact with all the steel wool. The vinegar will remove an oily protective coating from the steel wool and leave the thin strands of steel wool.

D. Remove the steel wool from the beaker and blot it very dry with paper towels.

E. Loosen the strands by pulling them apart. Observe the steel wool for a few minutes. Then, put it aside and continue with the next reaction, but observe the steel wool every 5 to 10 minutes while you continue with the following activities.

F. Record your final observations of what happened on your data sheet.

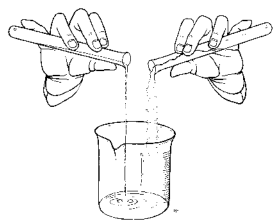
G. In the appropriate space, write the common name of the ending substance if you recognize it. Then describe the substance as completely as you can. Remember to use at least three descriptive words.

H. Was anything needed for this reaction besides steel wool? If you think it was, you may want to add it to your data chart under beginning substances and write a description of it.

I. Share your observations and descriptions with the other members of your group and change or add to your descriptions if you wish.

REACTION 2

BAKING SODA & VINEGAR



YOU WILL NEED

- small vials or test tube containing about 1 tsp. of baking soda
- test tube full of vinegar (about 25 ml)
- 100 ml beaker

DO, OBSERVE, AND RECORD:

A. Fill in the common name of each starting substance.

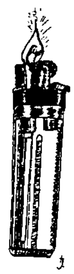
B. Observe each of these substances very carefully and write descriptions of each in the proper place on your data chart. Use at lease three descriptive words for each substance. Refer to the lists on the board if necessary.

C. Combine the baking soda and vinegar in a beaker and observe the reaction.

D. Record your observations of what happened in the appropriate space on your data chart. Be as complete as possible. Use at least three good, descriptive words.

E. If you think you can identify any ending substances, write good descriptions of them on your data chart. Use at least three descriptive words.

F. Discuss and compare your observations with those of other members of your group and make any changes or additions you want on your data sheet.



REACTION 3

BUTANE LIGHTER

YOU WILL NEED

- a clear plastic butane lighter
- balance

DO, OBSERVE, AND RECORD:

A. Record the common name of the starting substance that is inside the butane lighter in the appropriate space. Does the kind of lighter help you figure out what the starting substance is?

B. Are there any other starting substances? (Hint: Can a fire burn without air? What is in air that a fire needs? Is this a starting substance?)

C. Observe the fuel in the lighter and write a complete description (prior to lighting it) in the proper place on your data chart.

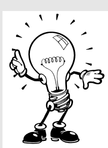
D. Write a description of the other starting substance.

E. Ignite the lighter and observe the flame.

F. Weigh the lighter. Then light it and let it burn for a few minutes. While it is burning, write a description of what you observe to be happening while the butane burns. Weigh it again and write a note about whether the lighter lost or gained weight or stayed the same.

G. If you can identify any ending substances, write complete descriptions of them in the appropriate spaces on your data sheet.

H. Share all of your observations and descriptions with your group. Make any changes or additions you want on your data sheet.

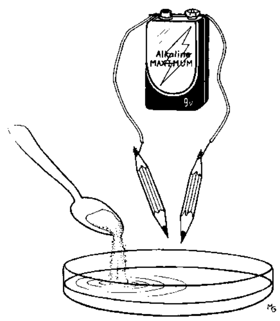


SAFETY!

If you have long hair, you should tie it back to avoid flames.

REACTION 4

DECOMPOSITION OF WATER



YOU WILL NEED

- 9 volt battery
- 2–12” pieces of telephone wire or wire with alligator clips on each end
- 1 petri dish
- 2–pencils sharpened at each end with 1/4” to 1/2” of pencil lead exposed at each end
- water
- 2 or 3 pinches of table salt

DO, OBSERVE, AND RECORD:

A. Write the name of the starting substance in the appropriate space on your data sheet.

B. Observe this substance and write as complete a description of it as you can. Be sure to use at least three descriptive words.

C. Attach one end of the wire to the pencil lead (not the wood) at one end of a pencil.

D. Similarly, attach one end of the other wire to the pencil lead at one end of the other pencil.

E. Fill the petri dish about half full with water. Be sure there is enough water to cover the bottom of the dish. Add about three pinches of salt to the water and stir it with your finger. (The salt just dissolves in the water but does not react. The salt is necessary for the reaction to occur. All the salt is still left after this reaction and it didn’t change in any way. It just helps the water conduct electricity better.)

F. Connect the other ends of each of the two wires to one of the two terminals of the 9-volt battery.

G. Place the tips of both pencil leads into the water of the petri dish. The leads should not touch each other.

H. Observe each substance being formed and write complete descriptions of these substances in the appropriate spaces on your data sheet. Be sure to use at least three good, descriptive words for each. Refer to the board for help if you need it.

I. Share all of your observations and descriptions with your group. Make any changes or additions you want on your data sheet.

(D) Now, you might be wondering if any of the ending substances were actually new substances, or if they were just some form of the old substance? How can you tell? Try to figure it out!

(E)

THINK AND WRITE

1. Review the description of the beginning and ending substances in the first reaction. Is there any evidence for a change? There aren't any hard and fast rules for finding new substances, but some things to look for might be a color change, a new smell, a change in taste **(CAUTION: DON'T TASTE ANYTHING IN THIS UNIT)**, the formation of a gas or a new solid or heat. Often, you must use several or all of these to help you decide. Look for any evidence for a change in the substances. Circle all the evidence you can find Then write a statement about this reaction that starts with "I think a new substance did (or did not) form because…"
2. Repeat question 1 for each of the other 3 reactions.
3. If you think that new substances were formed in any of the reactions, how could this be explained? Where would the new substances come from?

D. Each of the reactions in this lesson is a chemical change. Students describe the reactants and products as a preparation for recognizing chemical changes later. Be sure to focus on these descriptions and do not try to get students to name and identify any of the reactants or products (although some will spontaneously mention some products like rust), since this causes them to lose the focus of the lesson. Many students will describe the substances being formed simply as "bubbles." They will not think about what is inside the bubbles. You may want to ask them this question: "What do you think is inside the bubbles?" Many will say water or, maybe, electricity. Just get them to speculate now and write down what they think. Don't try to teach them yet that oxygen is in the bubbles at one electrode and hydrogen is in bubbles at the other.

E. Be sure to emphasize the "could have been formed" in all of these answers since visual evidence is very unreliable. Do not attempt to explain chemical reactions here or give explanations. Each of these reactions will be done again, and further explanations will be given as the unit develops.

1. Reaction #1: The color change is evidence that a new substance could have been formed. It is also flaky and brittle rather than in strands. This is evidence that a new substance could have been formed.

In this lesson, students are looking for evidence for new substances. Do not talk about chemical change yet although that is occurring. Avoid using the traditional approach to teaching students about when a chemical change has taken place, that is, labeling certain types of evidence as a clear indication of a chemical change (such as a gas produced, a new color, etc.). Any of these changes can also be the result of a physical change (gas is produced during boiling; a dark color solution becomes lighter colored when water is added). Nevertheless, students should begin to look for this kind of evidence, and add it to other things they may learn as indicators that chemical changes have occurred.

2. Reaction #2: The formation of bubbles and the fizzing is an indication that gases were formed. This is evidence that a new substance could have been formed.

Reaction #3: The butane is disappearing as is evidenced by the weight change. But what is happening to it? Although there were gases produced, these are invisible, and most students will not have them in their descriptions. Some students may think that the butane was vaporizing and turning to a gas.

Reaction #4: Again, gases were formed and released as bubbles formed at each electrode; this change is evidence that a new substance could have been formed. They did not test the properties of these gases though, so they cannot be sure. Many students have no clues about what the bubbles are or what is in them. They may think that air was inside the bubbles or, perhaps, that electricity was inside the bubbles, and the water just sort of went off the end of the wire. Some may think that water vapor was inside the bubbles.

3. Answers will vary. Let students speculate! Do not attempt to explain this here. Explanations will come later. This is just an opportunity for students to make use of their prior knowledge and for you to see what they think.

As you probably just found out, it is sometimes very difficult, if not impossible, to tell if new substances were formed. And if new substances did form, where did they come from? Was anything lost or gained in the process? In Cluster 2, you'll investigate how the weight of the starting substances compares to the weight of the ending substances and in Cluster 3 you'll find out where new substances come from.

REMEMBER TO SAVE ALL YOUR DATA CHARTS FOR REFERENCE IN CLUSTER 3.

Cluster 1—Lesson 3

Lesson 3: RESEARCHING A COMMON SUBSTANCE

(A) Every day we come into contact with substances that affect our personal lives. Most of us take them for granted, or know little about them other than their common name. One example is cholesterol; another is plastic. Other examples include aspirin, glass, nylon, gasoline, Tylenol, whiskey, beer, baking soda, fertilizer, baking powder, marijuana, sugar, cigarettes, and cornstarch. The list is a long one, but most people have limited knowledge about the items on it. If we examined these common substances, we would discover that a better understanding of them would improve our health, assist in cleaning up our environment, and upgrade our standard of living.

(B) In this lesson, you will begin research of a common everyday substance that is of interest to you. You will begin by identifying its common and chemical names and by describing its appearance and any other physical properties. Later on in the unit, you'll continue your investigation and find out much more new information about your substance.

RESEARCH QUESTION

What substance are you going to research? What other names does it have? What are its physical properties?

(C) TRY THIS

1. Your teacher will provide you with a list of substances. Select a substance of interest to you.
2. Using the sources of information provided by your teacher (or any at your own disposal), research your substance to determine the following:
   a. the chemical name, and any other name it goes by.
   b. a complete description of the substance.

A. You should decide if you want students to do this research individually or in groups. Probably a group of 2 or 3 will work best. Students will return to this same research as the last lesson in each cluster of this unit, each time extending their research on the substance by investigating the properties or principles learned in that cluster. At the end of the unit, students will choose a method of presentation by which to communicate their findings to some group, not necessarily their class.

B. It is not the purpose here simply to have students research a substance and find out everything they can and prepare a report. The investigation should concentrate on and be limited to those concepts and ideas learned about in each cluster. The questions are intended to be used only as a guide. Because there are so many different substances, they are also necessarily somewhat general in nature. The teacher will need to realize that, for some substances, a great deal of information is available and easy to obtain, while for other substances, even a minimum amount of information is not readily available. You will need to give direction and guidance to students in this regard. For some substances, some questions may not apply, or the answers may be too complex or involved for the students. They should be encouraged to get as much information as they can.

C. Because of the limited knowledge of students, the chemical formulas for the research substances need to be relatively simple. An attempt is also made to suggest some substances

LESSON STATEMENT: Students apply the concepts learned in this cluster as they begin research on an everyday substance. This research, continued throughout the cluster, will culminate in a presentation at the end of the unit.

PURPOSE: To use the chemical concepts learned in this cluster to investigate the chemical names and a description of the physical properties of a common substance.

APPROX. TIME: 1 class period.

that have strong and definite cultural implications, in the hopes that these connections will become evident in the student research. Following is a list of suggested possible substances: gasoline, plastic milk jug, post-1983 penny, dime, nickel, quarter, pop can, nylon, polypropylene, amethyst, diamond, ruby, garnet, turquoise*, emerald*, 18K gold, sterling silver, henna*, indigo*, alizarin*, bauxite, ambergris*, amber*, bronze, iron, rubber, rayon, methane, saran wrap, ethylene, acetylene, kerosene*, styrene, freon, ethanol, cresol, DDT*, cocaine, morphine, alizarin*, juglone, lawsone, cinnamon, quinine, oil of almond, jasmine, vanilla, camphor, cochineal, curare, brass, tobacco, sucrose, aspirin*, glass, marijuana*, Tylenol*, beer*, whiskey*, cholesterol*, etc. Feel free to add your own. Let us know which ones work best.

* Indicates substances that are either more complex in nature or may be several different substances. If you use these, you will probably want to assign them to more capable students.

That's all you need to find right now. In future lessons, you will continue your research with the following questions which are related to future clusters:

- What it is used for, present and past.
- Any special importance to various cultures or ethnic groups.
- The history of its discovery and development.
- How it is produced and disposed of.
- How energy and "boosters" are involved in its production and disposal.

For each reference book or other source of information you use, include this information about your sources:

- Title of source
- Author
- Copyright date
- Publishing company
- Pages on which the information is found

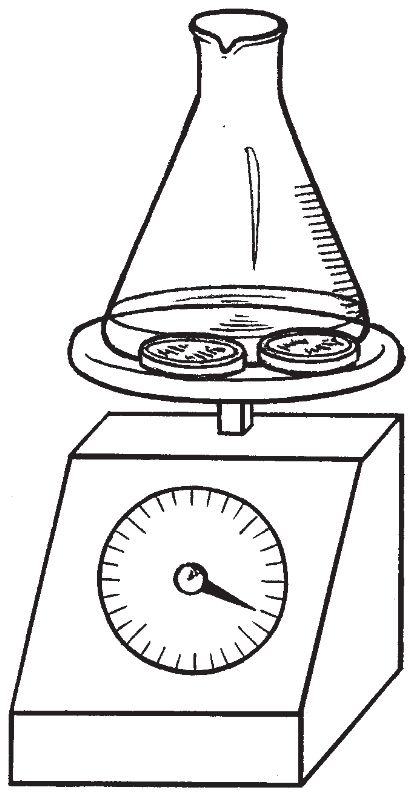
Record these findings in your notebook or science journal. You may prefer to keep your research notes on 5 x 8 cards with references at the top. Scientists often do this in order to help organize their information. Then, when they are preparing their report, they can shuffle the cards and put them in the order they want to use them when they write their report.

Scientists attempt to keep clear and concise records of their work and findings because they realize the importance of checking, verifying, and understanding what has happened over a period of time. It is important that you keep clear and concise records of the subject you are investigating. You will continue to investigate this same substance throughout the entire unit. In fact, by the end of the unit, you will be an expert on your substance, and you will prepare a presentation about your substance to share with others in your class or your school. More about this later in this unit!

Chemistry That Applies—Michigan Dept. of Education **14**

Cluster 2

Weight Changes in Chemical Reactions



Cluster 2—Lesson 4

A. This lesson is designed to start students thinking about weight gain or loss in reactions involving several kinds of physical changes, and to allow teachers to become aware of student thinking along with any misconceptions they have. Most of this should be a review of what students already know. However, many students still think that weight is lost when steel wool is compacted or when ice melts or sugar dissolves. Many students confuse density with weight so they think that compacted steel wool weighs more. Try not to get into any detailed discussion of density as this is a difficult and confusing concept to most students and is not relevant to the understanding of the Law of the Conservation of Matter which is what we are preparing for here.

B. This is NOT THE TIME TO TRY TO CHANGE OR INFLUENCE STUDENTS' THINKING. They must be allowed to become aware of how they think in order to discover discrepancies in their thinking and then construct new knowledge which will lead to conceptual change. The rest of this cluster is designed to do that. If this process is not allowed to occur, students will revert to their former way of thinking the minute they walk out the door.

Lesson 4: DOES THE WEIGHT CHANGE?

Hardly a minute goes by that we don't witness changes, both physical and chemical, in the world around us. The snow that fell on the ground this morning has melted into puddles of slush. Trash picked up at the curb is compacted by the garbage truck into a much smaller volume. Soda pop is cooled down by ice, meat cooked on the stove turns from red to brown, medicines change the condition of our bodies, cars rust, hair turns grey. The list is endless.

(A) In Cluster 1, you observed many changes and wrote detailed descriptions of the starting and the ending substances. In some of these changes, only the size, shape, the space it occupied or temperature of the material changed while the material itself stayed the same. But in other changes you observed, the material seemed to lose its character, and something with entirely new properties appeared. All of the changes that produced new substances with new properties involved chemical reactions. Other changes —where only the size, shape, space it occupied or temperature, changed—are lumped into the category of physical changes.

(B) Which of the changes above are ones where the material itself stays the same? Ice melting into snow? Which others? What other changes can you list where the size, shape or temperature of the material changes, but not the substance itself?

Which of the changes above are ones where the material itself actually changes into a new substance? Can you name other changes like this?

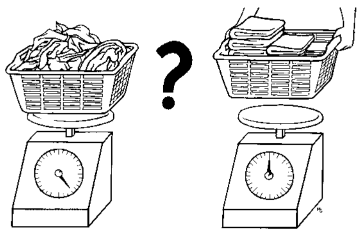
Chemical changes are not easy to understand simply by asking whether the material changes into a new substance. That is not always easy to tell. To get a deeper understanding of chemical reactions and the making of new substances, you are going to consider another question—how the weight of materials changes as they change in all these different ways.

LESSON STATEMENT: Students will observe physical changes in matter and make predictions about weight changes involved. They will discuss and debate their predictions in groups and then share their predictions with the class.

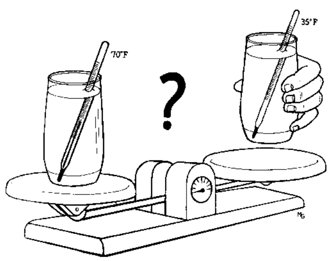
PURPOSE: Students will observe reactions involving physical changes such as crumpling, melting, dissolving and boiling; they will explore and discuss their thinking about the weight changes that occur.

APPROX. TIME: 1 class period.

What do you think?

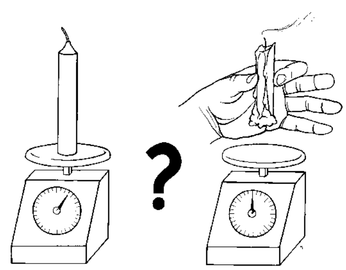


- Would a basket of mixed-up, rumpled clothes weigh more, less, or the same after they are folded? Why?



- Would a glass of water at 70°F weigh more, less or the same after it is cooled to 35°F? Why?

- Would a car weigh more, less, or the same if painted a new color? Why?



- Would a candle weigh more, less, or the same after burning for awhile? Why?

KEY QUESTION

Are there types of changes where you wouldn't expect the weight to change, and other types of changes where the weight may change?

C. Each of these demonstrations should be prepared before class starts. Direct students to watch carefully what you are doing. It is a good idea to say what you are doing also as you perform the demonstration. At the conclusion of each demonstration, have students write their prediction and explanation before doing the next one.

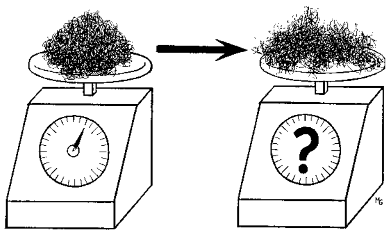
In this lesson, we will look at changes that scientists call physical changes—where only the size, shape, volume or temperature change, but not the material itself—and make predictions about how weight may change. For example, if you were standing on a bridge and took a quarter out of your pocket and threw it off the bridge, would your weight change? If you were standing outside in the rain, and your clothes changed from dry to soaking wet, would your weight (with the clothes on) change?

Making predictions and then writing the reasons behind your predictions is a very important aspect of doing science. Without reasons, predictions are really only wild guesses, but when reasons are given, scientists can share their thinking with others and devise experiments to test their predictions. If their predictions turn out to be correct, then scientists have faith in their reasons and believe them to be true. In the following activities, you will be practicing science as you explore how weight changes.

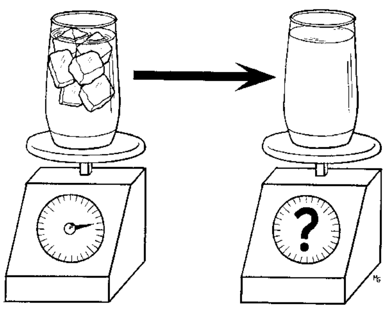
Ⓒ TRY THIS

Your teacher will perform four demonstrations. Pay close attention to what is happening and then predict whether you believe the weight increased, decreased or stayed the same. Then give reasons for your predictions. Use a chart similar to the one below.

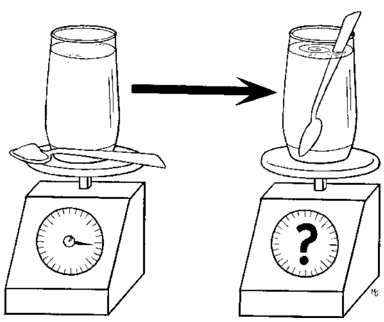
DEMO #	PREDICTION	EXPLANATION
1		
2		
3		
4		



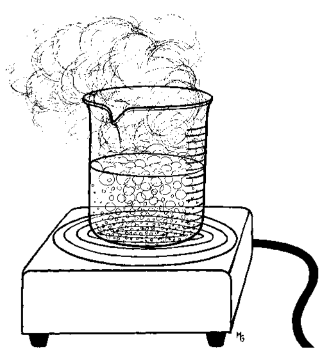
DEMONSTRATION 1: Which weights more, a tightly wadded ball of steel wool or the same steel wool stretched and pulled apart?



DEMONSTRATION 2: How does the weight of a glass of water with an ice cube in it change as the ice cube melts and eventually disappears?



DEMONSTRATION 3: Observe a teaspoon with sugar and a glass of warm water. Then stir the sugar into the glass of warm water until it has all dissolved. How does the initial weight of the teaspoon of sugar and the glass of water compare to the weight of the dissolved sugar and water?



DEMONSTRATION 4: How would the weight change if you boiled a beaker of water for 10 minutes?

D. After making their predictions and discussing them as a class, allow students to write new thoughts or change their predictions if they have been convinced otherwise.

E. Have the class discuss how they could verify their predictions. If time permits, you may want to begin the next lesson by having students write their plans for performing the experiments.

THINK AND WRITE

After all the demonstrations:

- Share and debate your predictions in your team.
- Make any changes you want in your own predictions or reasons. Your predictions don't have to be the same as those of the other team members.
- (D) Share the predictions and reasoning of the team with the entire class. You may do this by selecting one spokesman for each team or by having all members of the team share. Make sure you tell the class if not everyone agrees on any of your predictions or reasons.
- Get a class tally for each of the predictions. Find out how many students think the weight would increase, how many think it would decrease and how many think it would stay the same.
- (E) Revise or rewrite your predictions or reasons any time you feel that a different prediction or reason makes more sense to you. Don't be persuaded by others' predictions just because "they always get A's" or anything like that, though. That's not what science is about.

Look at the class tally. Are there disagreements among students in your class? How could these disagreements be settled? How could you test your predictions, and prove or disprove them? You'll do this in the next lesson.

Cluster 2—Lesson 5

Lesson 5: GATHERING EVIDENCE ABOUT WEIGHT FROM EXPERIMENTS

How can we test the predictions you made in the last lesson?

Did someone say "By actually weighing the materials?" Sure. In this lesson, you will perform the same activities that your teacher demonstrated. You will use a balance or scale to actually weigh the substances and then compare these results to your predictions.

KEY QUESTION

How do your predictions compare to the actual changes in weights of the substances?

TRY THIS

You should work in groups. Here's how you might go about conducting these experiments:

- Begin by planning, as a group, how to conduct each experiment. Write out your plan in steps.
- Think about each measurement you need to make and provide a clearly identified place on your data sheet for it.
- Think carefully about what might happen during your experiment that might make your measurements inaccurate, and plan ways to correct for these possible inaccuracies.
- (A) Conduct the experiment, making measurements that are as accurate as possible. Record your measurements in the spaces you provided on your data sheet.

Here are the experiments again:

EXPERIMENT 1: Which weighs more, a tightly wadded ball of steel wool or the same steel wool stretched and pulled apart?

A. You may want to have students show you their experimental plan before you let them check out the materials. Be sure that they include all the materials in both the before and the after weight.

LESSON STATEMENT: Each group will design and perform experiments that will verify or disprove their predictions from the last lesson. They compare the results to their predictions and they draw pictures that will help explain the results.

PURPOSE: To allow students to observe changes in weight as substances undergo physical changes, and to explain these changes in terms of changes in the molecules.

APPROX. TIME: 1 class period.

EXPERIMENT 2: How does the weight of a glass of water with an ice cube in it change as the ice cube melts and eventually disappears?

EXPERIMENT 3: How does the weight of a teaspoon of sugar and a glass of warm water before they are mixed compare to the weight after stirring the sugar into the warm water until it has all dissolved?

EXPERIMENT 4: How does the weight change if you boil a beaker of water for 5 minutes?

After you have collected all the needed data, your group should prepare to present your findings to the class. Be sure to include the following points in your presentation:

(B)
- Whether your results helped to prove or disprove your predictions.
- If your group still believes in the reasons you gave for your prediction.

After all the experiments have been done and reported to the class, try as a class to answer to following question:

(C)
- What must happen during any change for the weight of the materials to increase or decrease?

If you're having trouble coming to a good answer to this question, think about these questions:

(D)
- In which of the experiments did the weight decrease significantly?

(E)
- What was different about that experiment from the others where there was no weight change?

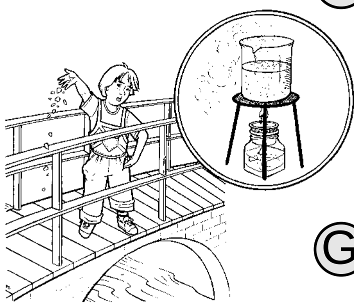
B. If students predicted that the weights would decrease, they should have some lively discussions as they try to construct explanations that account for their observations. Through the class discussion, students should construct a molecular picture of what is going on that would cause the observed results. Students find it very difficult to change their thinking from their original misconceptions. Allow plenty of discussion time while they construct new ideas.

C. • Something must be gained or lost—like putting quarters into your pocket or tossing them out.

D. • The weight of the boiled water decreased.

E. • Some of the water actually left the beaker and went into the air.

F



Here's how scientists would explain this. The last experiment—the one with boiling water—was different from the rest because as the water boiled, steam, which is a form of water, left the beaker. As the steam left the beaker, there was less water in the beaker, so it weighed less. It's like standing on a bridge, taking something heavy out of your pocket, and throwing it over the side. You now weigh less than before. As water boils, water molecules are going into the air, thus leaving fewer water molecules behind. Therefore it weighs less than it did before boiling.

G

THINK AND WRITE

Now try to answer the following questions in your journal:

1. What are all substances made up of? Use as much detail as you can.
2. What must happen to the substances involved in order for the weight of the materials to increase? to decrease?
3. Using this same sort of logic, how could you explain why a newly painted car would weigh more?
4. a. Did the steel wool change weight? Why or why not? Use molecules in your explanation. Then draw a picture that shows what is happening to the molecules.
   b. Did the water and ice cube change weight? Why or why not? Use molecules in your explanation. Then draw a picture that shows what is happening to the molecules.
   c. Did the sugar and water change weight? Why or why not? Use molecules in your explanation. Then draw a picture that shows what is happening to the molecules.
   d. Did the boiling water change weight? Why or why not? Use molecules in your explanation. Then draw a picture that shows what is happening to the molecules in your experiment. Include bubbles in your picture and show what's in them.

F. Ask students what they know about steam. See if they know what is inside the bubbles. Many think that the bubbles contain air but they have no explanation for how the air got there. Some think there is nothing in the bubbles. Others simply have no idea of what is in them.

G. When the water heats up, bubbles form in the water. Each bubble contains some molecules of water. As the water gets hotter, the bubbles rise to the top, break and the water molecules fly off into the air.

1. All substances are made of molecules. Students have probably heard of molecules before so take a few minutes to see how their thinking about molecules relates to these substances. If students are not comfortable with the concept of molecules, take some time to discuss the concept. It is sufficient here if students understand that all substances are made up of particles and that these particles are called molecules. The concept of atoms and molecules are developed much more in Cluster 3 so there is no need to go into any detail here—especially, do NOT discuss atomic structure or formulas.

2. Some of the substance must be added to or taken away from the system—like throwing quarters out of your pocket or putting some quarters into your pocket.

3. The paint adds weight to the car.

4. a. No. The number of molecules stayed the same whether the steel wool was stretched or compacted. Nothing left the system when compacting the steel wool. Picture should depict molecules spread out and far apart, possibly lined up in strands. The compacted picture should show the molecules much closer together possibly still in strands. Be sure students show the same number of molecules for each in their pictures.

4. b. No. The number of molecules did not change as the ice melted and changed to water. They simply went into a new arrangement. The water and ice cube picture should show water molecules as random and disordered while the ice cube molecules are neat and orderly floating in the water. When melted, all the molecules should show the same randomness and disorder. Be sure that the number of molecules stays the same in the ice cube

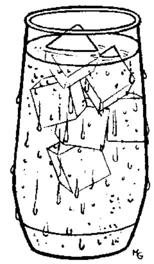
before and after melting. An important point to emphasize is that the ice and water molecules are identical. Be sure that students don't represent water molecules differently than ice molecules such as squares and circles. They should either be all square or all circles. Do not get into atomic structure here.

4. c. No. The number of molecules stays the same. When the sugar dissolves, the molecules separate and spread throughout the water molecules. The sugar should show a pile of ordered molecules as crystals of sugar (possibly square to show that they are different from water) and the water molecules (possibly round) should be random, disordered molecules in the glass. After dissolving, the sugar molecules (possibly square) should be equally dispersed into the water (round) molecules in the glass. None are lost in the process. Be sure that student drawings show no change in the number of molecules.

4. d. Yes. Bubbles filled with water molecules rise to the surface and burst, releasing some water molecules to the air. In the boiling water, as the water boils some of the molecules are leaving the beaker, spreading out and going into the air as water vapor. Since there are fewer molecules in the beaker, the water now weighs less.

5. a. All four reactions are physical changes.

5. b. Observing the changes reveals no new properties. Steel wool is still steel wool. Melted ice cubes and dissolved sugar taste the same. If you condense steam from boiling water on a spoon or lid of a pot, it is still water. Therefore, these are probably physical changes. Help students understand that observation alone is frequently not enough to tell if a change is physical or chemical.



5. a. Are these changes physical or chemical changes?

   b. How do your observations help you figure this out? Can you be sure?

   c. How do molecules help you figure this out? Why is this a problem?

6. Try these problems:

   a. Predict what would happen to the weight of a cold glass of water on a humid summer day? Explain your prediction.

   b. Predict what would happen to the weight of a car that gets very rusty over several years. Explain your prediction.

7. Can you think of any other examples of a change where weight would stay the same?

8. Can you think of any other examples of change where weight would increase or decrease?

We will use these ideas about weight change to understand more about that other kind of reaction, chemical reactions. The next lesson will give you more insight into chemical reactions as you make predictions about weight changes in some chemical reactions.

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5. c. At the molecular level, the molecules are still the same kind of molecule. But since you can't see individual molecules, this is not a practical way to detect physical changes. You need sophisticated instrumentation to figure out whether the molecules have changed or not.

6. a. It becomes very moist on the outside of the glass as it picks up water vapor from the air. It has added more matter so it will weigh more. Students have difficulty with this question. Some think that the water seeps through the glass. That doesn't make much sense to them, but they do not have a better explanation.

6. b. There are several plausible answers for this—the car gets lighter because metal rusts and falls off; the car gets heavier because the iron combines with oxygen from the air and forms a heavier molecule; there is no change in weight since rust is just the same iron discolored. Accept any reasonable explanation. Do not give answers here as this reaction is explored in lessons that follow.

7. Examples are chocolate melting, water freezing, bending metal, etc.

8. Answers will vary.

Cluster 2—Lesson 6

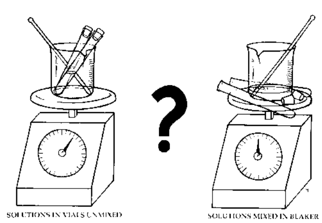
Lesson 6: DOES THE WEIGHT CHANGE IN CHEMICAL REACTIONS?

Chemical reactions are a little more mysterious than physical changes (some would say a lot more mysterious). When you mixed baking soda and vinegar together, what kind of change was that? Was it a change in shape, size or temperature? Not really. It was a change that produced bubbles, among other things. Where did the bubbles come from? They contained a new substance that was formed during the reaction which was different from the baking soda and vinegar that you started with. In this lesson you will look at an interesting chemical reaction and ask the same questions about weight as in the last lesson.

KEY QUESTION

How can you predict if the weight of a substance will change during a chemical reaction?

Unlike physical changes where the substances and the molecules that make them up do not change, chemical changes actually produce new substances with new molecules. The important question for this unit is when is a change a chemical reaction that produces new substances, and when is it a physical change?



In this lesson, you will examine two liquids before and after they are mixed together, to determine if new substances are formed. You will also check the weight of the liquids before and after to find out what happens to the weight.

LESSON STATEMENT: Students will observe and make predictions about whether the weight changes in a chemical reaction. Then they will perform an experiment to test their hypothesis.

PURPOSE: To allow students to examine two solutions and then observe the reaction when the substances are combined. They predict whether a weight change occurs. Then they perform the experiment to test their predictions, and finally, they explain their results.

APPROX. TIME: 1 class period.

TRY
THIS

YOU WILL NEED

- 2 stoppered test tubes containing solutions to be combined
- 100 ml beaker and stirring rod
- balance

A. Obtain two stoppered test tubes that contain each of the solutions to be mixed. Examine the properties of each of the solutions and write them in your journal. Save your solutions for later use.

(A) B. Your teacher will combine solutions of the two substances together and stir for several minutes. Watch carefully and write any observations in your journal.

C. Your teacher will give each group a small portion of the product to examine. Examine the properties and record your observations in your journal. Compare these properties to those you observed before the reaction. Record whether you think a new substance was formed, and why you think so.

(B) D. Make a prediction. Did the weight increase, decrease or remain the same during this reaction? Write your prediction in your journal. Then write all the reasons why you think this.

How can you verify your predictions for this reaction?

E. Before you begin, plan out the experiment carefully, by following these steps for conducting the experiment.

- Plan, as a group, how to conduct your experiment. Write out your plan in steps.
- Think about each measurement you need to make and provide a clearly identified place on your data sheet for it.
- Think carefully about what might happen during your experiment that might make your measurements inaccurate, and plan ways to correct for those possible inaccuracies.

A. Students are allowed to observe the reaction and make predictions about weight change. They design an experiment to test their hypothesis and use their findings to prove or disprove their predictions. Through group discussions, students construct the explanation that no matter entered or left the system. Therefore, the weight did not change.

B. A common misconception is that the weight increases because a solid formed, and solids weigh more that liquids. Many students will be surprised to find that there is no change and will find it hard to accept this fact even after they have done the experiment. In the discussion, they should give reasons why they think what they do, and they should become aware of any discrepancies in their thinking.

- Check your plan with your teacher before starting.

F. Conduct the experiment, making measurements that are as accurate as possible. Record your measurements in your journal.

G. Discuss as a group whether your results help prove or disprove your predictions. Also discuss whether there were any substances that left the reaction or that were added to the reaction.

THINK AND WRITE

After the experiment, answer the following questions:

1. a. How were the ending substances different from the starting substances?

   b. Does this indicate that the change was a physical change or a chemical change? Explain your reasoning.

2. a. Did the weight change during this experiment? If so, how?

   b. How can you explain these results? Think about whether any substances entered or left the beaker during the reaction.

You'll continue your investigation of whether the weight changes during chemical changes in the next lesson.

1. a. The starting substances are transparent or semi-transparent liquids. The ending substance is a white, chunky solid.

   b. This is a probably a chemical change. The properties of the products are different than the properties of the reactants and indicate that a new substance was formed. If some students suggest that this change is "like freezing" because liquid has turned to solid, ask them if they had to cool the two liquids to make the change happen as you do when freezing something. Also, ask if the solid is colder that the liquids. This is not a change of state (physical change) since the solid is not just a frozen form of either of the two liquids.

2. a. There was no change in weight.

   b. No new substances were added to or taken from the system.

Cluster 2—Lesson 7

A. This lesson allows students to explore their own thinking about weight gain or loss in reactions involving gases as products. It also allows teachers to become aware of their students' thinking about gases and of any misconceptions they have. Because the gases produced in these activities are invisible, many students are not even aware that they are being formed and given off. Most students do not know what bubbles are and they certainly do not think of them as pockets of gases that were formed as the reaction occurred. Many students think the bubbles contain air. Another common misconception is that these gases have no weight and are not matter, so they take no account of them in their predictions. Students are frequently very surprised when the cork pops off the vinegar and baking soda reaction. Some students think something is being formed and given off but may think it is energy.

B. This is NOT THE TIME TO TRY TO CHANGE OR INFLUENCE STUDENTS' THINKING. During the rest of this cluster, students will discover their misconceptions and discrepancies and construct new knowledge so that conceptual change can occur. If students are not allowed to go through this process, they will probably revert to their former way of thinking the minute they walk out the door.

Lesson 7: WHAT'S INSIDE THE BUBBLES? INVISIBLE PRODUCTS

(A) You just finished comparing the weight of the reactants (starting substances) to the weight of the products (ending substances) in a reaction that could happen in a closed and sealed jar; very interesting chemical reaction. Now you will compare the weights of the reactants and products of two other reactions that get a little trickier.

KEY QUESTION

What does it mean when bubbles are formed in a reaction? What happens to the weight in a reaction if bubbles are formed?

(B) You have observed both of the following reactions (vinegar with baking soda and Alka-Seltzer with water) many times before, but have you ever taken the time to observe what is really happening? Have you ever thought about or wondered what's in the bubbles? And what happens to the weight after the reaction compared to the weight before the reaction? Let's see how good your powers of observation are!

TRY THIS

YOU WILL NEED

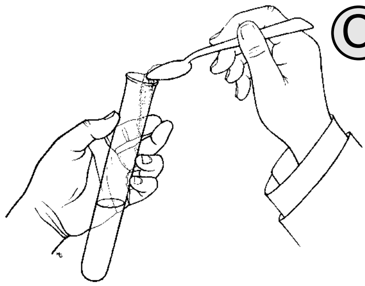
- test tube about 1/3 filled with vinegar fitted with a stopper
- about 1/2 teaspoon of baking soda
- 250 ml Erlenmeyer flask and balloon that fits over the neck of the flask
- Alka-Seltzer tablets

LESSON STATEMENT: Students will observe two chemical changes where gases are produced in the reactions. They make predictions about weight changes as reactants form products and give reasons for their predictions.

PURPOSE: To provide opportunities for students to observe chemical reactions that form bubbles of invisible gases as products of the reactions; to think about whether any weight changes occurred.

APPROX. TIME: 1 class period.

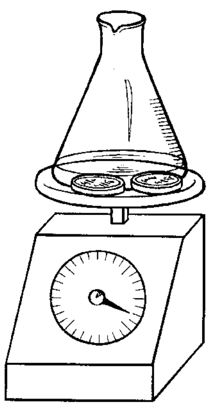
C



ACTIVITY 1

Obtain the largest test tube you can find. Fill it about 1/3 full of vinegar and then place about 1/2 teaspoon of baking soda in it. Observe the reaction. Then make a prediction. Did the weight of the test tube, vinegar and baking soda before the reaction weigh more, less or the same as the test tube and its contents after the reaction? Write the reasons why you think this in your journal.

ACTIVITY 2



Obtain a 250 ml Erlenmeyer flask and put a small amount of water in it—enough to fill it about 1/2 inch. Add an Alka-Seltzer tablet to it. Observe the reaction. Make your prediction. Did the weight of the flask, water and Alka-Seltzer before the reaction weigh more, less or the same as the flask and its contents after the reaction? Write the reasons why you think this in your journal. Share your predictions and reasoning for each of the above reactions with the other members of your group. Try to understand what the other students in your group think about each reaction. If there are differences in the predictions or reasons in your group, discuss and debate these differences and try to come to a consensus. If you want to change anything you wrote in your journal, write these changes after you have finished the discussion.

Now continue with the next two similar activities.

D

ACTIVITY 3

Repeat the procedure in Activity 1 above, except this time put a stopper on the test tube very securely. Observe the reaction. Does this change what you thought in Activity 1 above? Make a new prediction for Activity 1 if you want to and write the reasons for your new prediction in your journal.

C. ACTIVITIES 1 & 2: Even though it is recommended that students try to come to a consensus in the group, it is not necessary. Allow students to hold their own beliefs if they have not been convinced otherwise, and they could not bring the group to their way of thinking. You will probably find groups where, even though the students have a correct prediction, they cannot give a reason for the prediction (This is really just a guess.), or the reasons they have are not correct. This will all come together at the end of the next lesson when the focus is on constructing new knowledge.

D. ACTIVITIES 3 & 4: Probably the cork will pop off the test tube with some force so be sure that it points toward the ceiling or wall, not toward themselves or another student. Hopefully, the popping of the cork will help the students realize that the bubbles that form have something in them that creates a force, and maybe it is matter and has weight. But, once again, remember—no help from the teacher. Let the students figure it out in their discussions.

ACTIVITY 4

Repeat the procedure from Activity 2 above, but, immediately after dropping the Alka-seltzer into the flask, fit a deflated balloon securely over the flask. Observe the reaction. Make a new prediction for Activity 2 if you want to and write your reasons for this prediction in your journal.

In your group, discuss any changes you made in your predictions and your reasons. Try to reach a consensus, if possible. After the group discussions, one member from each group should present your group's prediction and reasons to the entire class. At the end of the presentations, discuss any differences among the groups. In your journal, make any changes or additions you want and then get ready to see how your predictions compare to real data.

Verifying your predictions for these experiments is not very easy, but there is a very clever way to do it. We'll save that for the next lesson. But first, try answering the KEY QUESTIONS from the beginning of this lesson. Discuss them in your group before you write your answers. Here are the questions again.

E

THINK AND WRITE

1. Were there any invisible substances formed in these reactions? Why do you think this?
2. Is anything inside of bubbles? If so, what do you think it is?
3. Where did the bubbles in this reaction come from?

F

SPECULATE ABOUT THESE

- Are air and other gases substances? How could you find out?
- Do they have weight? How could you find out?

In the next lesson, you will find out if you are correct.

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E. These questions are posed simply so that students will think about them and write their ideas. Student answers will vary Do not correct or explain answers at this point. Answers will develop during the next two lessons. Answers are given below for teacher information only.

1. Yes, there are gases inside the bubbles. Evidence for the formation of the gases is the cork popping off the test tube and the balloon filling with something.

2. Answers vary.

3. Some students may just say "I don't know." That's OK. Do not discuss or answer this question at this time. However, some students might recognize that the invisible gases are new molecules.

F. These are speculation questions. Students do not yet have the evidence they need to answer the questions. They should answer it based on the knowledge they have so far and then pose ways they could test their predictions.

Cluster 2—Lesson 8

Lesson 8: DO GASES HAVE WEIGHT?

The last lesson asked some interesting questions but didn't offer any definite answers to the big questions. What are the big questions?

KEY QUESTION

Do gases have weight? How can you find out? How does the weight of the starting substances compare to the weight of the ending substances when gases are formed and given off in a reaction?

Ⓐ By the end of the last lesson, you probably decided that all the little bubbles that formed in the two reactions contained some kind of invisible gases. As the bubbles broke, the gases escaped to the surrounding air.

If you knew for sure whether these gases have weight, then you would know how to make your predictions. How could you design an experiment that would test this out?

TRY THIS

The most sensitive method by which to compare two weights is a balance. You'll use a meter stick suspended from the middle with weights hung at both ends. The weights for this experiment are 2-liter soda bottles with a small amount of water in the bottom used to dissolve Alka-Seltzer tablets. The bottles are hung from the ends of the meter stick by strings or wires. Coat hangers, bent to fit around the neck of the bottle at one end and bent into a hook on the other end to hang over the meter stick, work quite well. They should be taped in place so they do not move during the experiment. Two Alka-Seltzer tablets, are broken in half, tied together and suspended above the water inside one of the bottles with a string and tape.

A. Have the class, as a whole or in small groups, try to design an experiment to test these predictions. Students should come to the idea, or you should introduce it when appropriate, that the reaction must be done in a way that can capture the gases and weigh the products, and then release the gases and weigh the products again. This demonstration is very powerful in helping students understand that gases have weight. Allow them to watch the demonstration and come to their own conclusions. As always, they will first predict what will happen to the weight and then check their predictions against experimental evidence. Do not give clues when students are making their predictions. Let them see for themselves!

LESSON STATEMENT: Students will observe a chemical reaction, which forms a gas as a product, in an open and a closed system. They will see changes in weight between the systems when the gas is trapped inside the bottle and when it is allowed to escape.

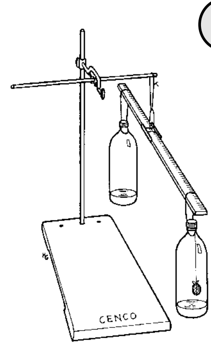
PURPOSE: To provide visual, experimental evidence that gases have weight and to help students begin to construct a conceptual understanding of the Law of the Conservation of Matter.

APPROX. TIME: 1 class period.

B. In the open system, as the gas is given off, that bottle becomes lighter and that end of the meter stick goes up. If necessary, you can use a large piece of paper behind the meter stick and mark the beginning and ending positions. However, the movement should be obvious if the bottles are balanced at points about 20 cm from the pivot point. Be sure the students understand that the lighter side rises. Use the analogy of a teeter-totter if necessary. In the closed system, the weight stays the same until the trapped gas is released at which time the bottle becomes lighter.

C. Be sure to stop at the appropriate places while students make predictions and write reasons for the next part of the demonstration. A reminder—DO NOT HELP STUDENTS WITH THEIR PREDICTIONS OR REASONS AND DO NOT TELL THEM WHAT THE BALANCE IS GOING TO DO. LET THEM DISCOVER IT FOR THEMSELVES.

D. After students have completed their predictions, repeat the demonstration. This time make a closed system by screwing the caps on very securely so that gases do not escape. Also, make sure that the caps are the ones that came on that particular bottle so that gases are not "sneaking" out and causing contradictory results.



(B)

A. This demonstration is done first as an "open system"—that is, the cap is left off the bottles. The Alka-Seltzer is fizzing in a open bottle. Write your prediction about weight change—increase, decrease, or remain the same—for this reaction. Also, be sure to write a reason for your prediction.

B. Your teacher will prepare the apparatus for a class demonstration. When all is ready, balance the set-up by moving the meter stick slightly to the left or right on the balance until all is level. When all is balanced and the reaction is to begin, tip the bottle slightly so that the Alka-Seltzer is dropped into the water. You may need a student assistant to support the other bottle as you tip it. Observe and notice any change in the position of the bottles as the reaction proceeds. Any change in weight will show up as the meter stick tipping to one end, just like a see-saw tips to the heavier end.

(C)

(D)

C. Does the experiment support your prediction? Any new thoughts about what happened to weight? Share your ideas with your group.

Now you teacher will repeat the demonstration as a "closed system." When there's a top on a jar, so that nothing can get in or out, it is called a "closed system." The Alka-Seltzer will be fizzing in a closed jar.

D. Write your prediction about weight change—increase, decrease, or remain the same—for this demonstration and the reason for your prediction.

Are you ready for this one?

E. Prepare the apparatus as described above, but this time screw the caps on the bottles very securely. When all is balanced, tip the bottle with the Alka-Seltzer to start the reaction. Observe the reaction and watch the meter sticks as the reaction proceeds.

F. What do you think will happen to the weight when the caps are released? Write your prediction and the reason for your prediction.

G. Now, open, but do not remove, the cap of the bottle with the Alka-Seltzer. Watch what happens?

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THINK AND WRITE

1. a. Does the experiment support your prediction for the open system reaction?

   b. Does the experiment support your prediction for the closed system reaction?

2. a. Try to explain what happened to cause the weight change in the open system.

   b. Try to explain what happened which prevented a change in weight in the closed system.

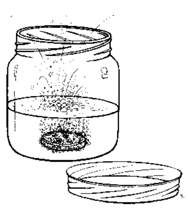
   c. Try to explain what happened when the bottle cap was opened.

3. What did you learn? Do gases have weight or not? What evidence do you have?

4. a. The reactants are ALL the substances you started with including any invisible gases, and the products are ALL the substance that were formed, including any invisible gases. Are they different in an open system than they are in a closed system?

   b. And now the big question, the one you've been trying to answer all along: How does the weight of the products compare to the weight of the reactants?

(E) Share your ideas with the class. Compare your thoughts with the thinking of the rest of the class.



Here's how scientists think about this reaction. When Alka-Seltzer reacted with water, it produced a gas which formed under the water. When trapped under water, the gas gets inside little, empty spaces or small pockets that we see as bubbles. The bubbles rise to the top of the water and break. The gas inside the bubbles flies off into the jar. If the jar does not have a cap on it (open system), then the gas leaves the jar and goes off into the air.

Would this result in a loss of weight? Is the reaction "throwing off" any quarters? You don't see anything leave the container, do you? But the evidence from your experiment is a weight loss. So something must be leaving, and whatever it is must have weight. It's the gas

1. a & b. Answers vary.

2. a. The cap was not on the bottle so the gases, which do have weight, escaped, and the system weighed less at the end than at the beginning.

   b. The cap was on the bottle so the gases, which do have weight, were trapped inside the bottle, and the system weighed the same at the end as it did at the beginning.

   c. When the cap was opened, the gases, which do have weight, escaped into the air, and the system weighed less than it did at the beginning.

3. Gases do have weight. The weight did not change when the gases were trapped inside the bottle, but when the gases were let out, the system got lighter.

4. a. No, since all substances are included whether they escaped or not, the reactants and the products always weigh the same.

   b. The weight of the products is equal to the weight of the reactants.

E. The class discussion should focus on the differences in weight when the gases are included and when they are not. Students should come to realize that often the products of a reaction are gases which are invisible. This leads many people to believe that matter is lost. The weight of the system after the reaction without the gases is actually less than the weight of the reactants, but the actual weight of the products is the same as the weight of the reactants.

from the bubbles. They leave the container and take weight away with them. So gases must have weight!

Having trouble believing that gases have weight? So do lots of other people. Many people believe that nothing is inside bubbles, and that gases have no weight because they can't be seen or touched. They think that part of the substance just disappeared during the reaction.

Here's another way to think about this: Are the gases produced in this reaction matter or energy? If they are matter, then they are made of molecules. If they are composed of molecules, then they have weight. In fact, they are molecules of carbon dioxide gas. When gases leave a container, it is really molecules leaving the container, taking their weight away with them.

So what happened when the top was left on the bottles (closed system)? Could the gas inside the bubbles float off into the air? No. This time, the gases escaped from the bubbles and got into the air inside the bottle. But with the cap on the bottle, the gases could not get out of the bottle, so no weight left the container. Nothing could leave the closed system. The weight did not change. But when the cap was released (open system), the gases flew out into the air.

And what happened to the weight? It decreased because gases, which are matter and have weight, left the bottle. It's like throwing quarters out of your pocket.

Now go back to the four reactions you did in the previous lesson and review your predictions. Discuss each prediction and reason in your group. Remember that a correct prediction depends on whether you think any matter is leaving the container.

5. For each of the four reactions, use the new information you just learned to decide whether the weight would increase, decrease, or remain the same. Give a reason for your answer.

So where does all of this bring us now? These experiments all demonstrate one of the most fundamental laws of nature—the Law of the Conservation of Matter. It states that: Matter can neither be lost nor gained. It can only be changed from one form to another.

5. Students should have no difficulty now predicting what should happen in the four reactions from the last lesson. In the first two, when bubbles formed and gases escaped, the weight of the system would be less because something (gas molecules) was let out of the system. But in the last two reactions, where you used a stopper or a balloon, the weight would be the same because now the gas molecules are trapped inside the system.

6. Write a paragraph in your journal telling how this law can explain the result of the demonstration you observed today.
7. For all reactions involving physical or chemical changes, how does the weight of the products formed compare to the weight of the reactants you started with? Remember that the reactants are ALL the substances you started with including any invisible gases and the products are ALL the substances that were formed, including any invisible gases. Write the answer in your journal.
8. A newspaper headline recently read: "Young chemist discovers substance that continually loses weight." Use your scientific knowledge to write a letter to the newspaper editor refuting the article.

In the next lesson you will explore another variation on this law.

6. Important points to include are:

• In every case, the weight of the products formed was exactly equal to the weight of the reactants.

• The system weighed less in the first two reactions because the gas which formed was leaving the bottle and going into the air. It was not included in the weight. It is like throwing quarters out of your pockets. You weight less, but no matter was lost. It was just being put into a different place. So it is with the gas particles. When they leave the bottle, the bottle weighs less because the gas particles are just being put into a different place.

7. The weight of the products is always exactly equal to the weight of the reactants. Just in case a student asks—in a nuclear reaction like an A-bomb, an H-bomb, or the reaction of the sun, small amounts of matter are changed into very large amounts of energy. Don't bring this up at this time unless students ask about it. Then it is best to acknowledge this fact but don't dwell on it or discuss it.

8. As part of their letter, students should include the following points: nothing ever disintegrates since matter is always conserved. Probably invisible gases are formed constantly and escape into the air. The weight of the system is, therefore, slowly but continuously decreasing.

Cluster 2—Lesson 9

A. KEY QUESTION: If situations where gases are produced in chemical reactions are somewhat mysterious to students, then these reactions where invisible gases are being used as reactants are even more mysterious. Since oxygen is invisible and there is an almost limitless supply of oxygen available, it is seldom obvious that oxygen from the air is being used, For the same reasons, it may be difficult for students to interpret the evidence presented in these activities and students may need help in understanding this evidence.

This is the time to gather students' thoughts. Do not expect or provide answers at this point.

B. As the oxygen is used by the steel wool while it reacts, the balloon will be sucked into the flask. It may pop as it is pulled in—probably while students are discussing this question. This should lead right into the next question and activity during which students should begin to construct an explanation.

Students need to understand that if there is air in the funnel, nothing else can get in. Also, when the air leaves the funnel, the water rushes in and fills it instantly. Conversely, if the water rushes in, it is because the air left the container leaving a big empty space behind for the water. Nature just doesn't leave empty spaces. Other substances rush to fill the void.

Lesson 9: RUSTING METAL AND THE DEFLATING BALLOON

You learned in the last two lessons that chemical reactions sometimes produce invisible gases. The gases often make bubbles if they are produced inside a liquid. When the bubbles pop, the gases fly off into the atmosphere.

(A)

KEY QUESTION

Can invisible substances like oxygen and other gases be involved in chemical reactions in any other way (not just as products)?

TRY THIS

Here is an activity to start you thinking about these questions.

YOU WILL NEED

- steel wool
- beaker with vinegar for cleaning the steel wool
- paper towel
- 250 ml Erlenmeyer flask and balloon to attach securely to the top

(B)

A. Obtain a piece of steel wool that will form a ball about the size of a ping-pong ball. Dip it in vinegar very briefly just to clean off the protective coating. Dry it very thoroughly by pressing it between several layers of paper towel.

B. Pull the strands apart to loosen them and then drop the steel wool into a clean, 250 ml Erlenmeyer flask.

C. Squeeze all the air out of a balloon and then stretch this deflated balloon over the top of the Erlenmeyer flask.

LESSON STATEMENT: Students will observe a chemical change that uses oxygen, and as it does, a balloon over the neck of the flask is sucked into the flask. Students figure out why this happened as they raise and lower a funnel into a beaker of water and make observations on what happens to the air in the funnel.
PURPOSE: To provide evidence for students that gases from the air can be involved in chemical reactions; to make observations that verify the fact that two things (air and water) cannot occupy the same space at the same time.
APPROX. TIME: 1 class period.

D. Observe for a few minutes and then set it aside while you discuss the following question.

- What are some very important properties of gases in addition to the fact that they are usually invisible? Refer back to the last lesson if you need help on this answer.

E. Now observe the reaction again.

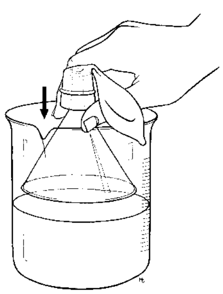
- What happened to the balloon in this experiment?
- What is this evidence for?

TRY THIS

If you are having trouble with this last question, the next activity will help you.

YOU WILL NEED

- funnel
- a balloon that will attach securely to the small end of the funnel—if necessary, fit a rubber stopper over the stem of the funnel to attach the balloon
- beaker



A. Obtain a funnel and a beaker half filled with water, such that the large end of the funnel will fit into it. Lower the funnel gradually into the beaker all the way to the bottom. Does water enter the funnel? Why or why not?

B. Now repeat the process, but this time hold your finger over the small end of the funnel and immerse it into the beaker of water. Lower it gradually all the way to the bottom. Does water enter the funnel? Why or why not? Now, with the funnel at the bottom of the beaker, remove your finger and observe what happens. Try this several more times by placing your finger over the end of the funnel when it is only partly immersed and see what happens.

C. Place a balloon tightly over the small end of the funnel by first squeezing all the air out of the balloon and then pulling it over the end of the funnel. Be careful not to rip the balloon. You may need to insert the funnel through a rubber stopper so that the balloon can fit securely. Your teacher will do this for you or tell you how to do it. Place the large end of the funnel in the water. Lower it gradually. What happens?

D. Squeeze the balloon slowly but firmly and see what happens. What is causing this to happen?

THINK AND WRITE

1. What invisible substance was in the funnel when you first placed it in the water?
2. a. When you placed your finger over the end of the funnel and pushed it into the water, no water entered the funnel. How would you explain this?

   b. How would you explain what happened when you removed your finger from the funnel and water rushed in?
3. a. Why did the balloon inflate?

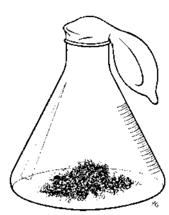
   b. How can you explain your observations when you squeezed on the balloon?

This is a demonstration about air. It can push on water. Water can push on it. If you get some pop in a straw and blow on the straw, the pop flies across the room. The air in your mouth pushed on the air in the straw, which pushed on the pop.

Air is a substance. You can't see it, but is pushes on things.

4. If you put a straw into a plastic bag filled with air, and started to suck the air out, what would happen to the plastic bag? Why?

Now look at your steel wool experiment.



5. How can you explain why the balloon was sucked into the flask when the steel wool rusted.

Did the air in the flask just disappear? Did it leak out? What happened to it?

Could it have been used in some way when the steel wool rusted?

This is the big question for the next lesson.

SAVE YOUR FLASK WITH THE STEEL WOOL REACTION FOR THE NEXT LESSON.

1. Air.

2. a. No water could enter the funnel because it was filled with air. There was no way for the air to get out, and the air kept the water out.

   b. The air could be pushed out by the water, allowing the water to rush into the funnel.

3. a. The air was pushed out of the funnel and filled the balloon.

   b. The air was forced back into the funnel, pushing the water out.

4. It would deflate.

5. The only way that the balloon can be "sucked" into the flask is if the air inside either leaves the other end (which it doesn't) or the air is used up in some way. The rusting must use up the air somehow.

Lesson 10: DOES RUSTING NEED AIR?

What happened to make the balloon get sucked into the beaker?

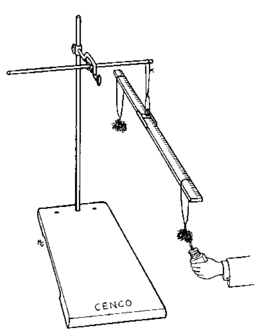
Here is an activity that will help you figure out what happens with air and rusting. You will start by making a prediction.

A TRY THIS

A. Observe the flask with the steel wool reaction you saved from the last lesson. Make a prediction about what happened to the weight of the steel wool—increase, decrease or remain the same. Write your prediction and the reasons why you think this in your journal.

Once again, verifying your prediction is very tricky because—if there were any gases involved in the reaction—the weight of gases is very small. A very sensitive balance made with a big meter stick, similar to the one used earlier, will work again to test your prediction, but the procedure for reacting the steel wool must be changed slightly to make the steel wool react more, and therefore have a bigger change in weight that can be measured.

This time the steel wool will be burned intensely with a Bunsen burner to cause a reaction that is very similar to rusting, only faster and more intense. More about that after you observe the reaction.



B. Your teacher will once again prepare a demonstration using a meter stick balance similar to the one used in Lesson 8. Set up the balance as before and wrap the ends of the meter stick with aluminum foil to prevent them from burning. Obtain 2 large pieces of steel wool, enough so that when compacted and rolled into a ball, they are about the size of a ping-pong ball. Attach each of them to a piece of wire. Once again, a piece of a coat hanger works well with a loop at one end to hold the steel wool and a hook at the other end to hang over the meter stick. Suspend

A. Many students will probably predict a weight loss, since now they think they have this invisible gas phenomena all figured out from the previous lessons. Also, they may be thinking about the burning rather than rusting of steel wool. In this case, a common misconception is that when things burn, they "burn up," that is, they disappear.

LESSON STATEMENT: Students make predictions, give reasons and then observe a chemical reaction that uses oxygen from the air to form a product that weighs more than the reactants.
PURPOSE: To provide evidence that when gases are used as reactants, there is an increase in the weight of the products; to help students construct an explanation for these observations.
APPROX. TIME: 1 class period.

B. FOR GROUP DISCUSSION:

The steel wool reacted with something to gain weight and that something was probably oxygen from the air. The product weights more than the steel wool but it weighs the same as the steel wool and the oxygen together. It is like putting quarters into your pocket. Your new weight is the weight of you and the quarters together. In this case, the oxygen is comparable to the quarters. So the gases do not disappear—they change into a different substance which is no longer a gas. The product is black and powdery. It is iron oxide and is very similar to rust which is also iron oxide. Do not discuss formulas at this time.

1. The steel wool is very black. This looks different from normal rust.

2. The weight increased. This is surprising to most students, since they usually believe that things get lighter when they burn (e.g., wood ashes weigh less than the original wood).

3. Since its weight increased, something must have been added to it, like when you add stones to your pocket and your weight increases.

4. Either the “flame” or the gas from the Bunsen burner was involved in the reaction, or something from the air.

5. The best guess would be that oxygen from the air is used in this reaction. In fact, this is the case. Oxygen is “added” in some way to the steel wool, making it heavier. A complete explanation of this reaction is constructed in Lesson 3.

the steel wool about 10 to 15 cm from the ends of the meter stick. The steel wool should be suspended at least 8 to 10 inches below the meter stick. This will help prevent the stick from burning because of the heat from the Bunsen burner. Tape the hangers to the meter stick so they do not move during the experiment. Balance the set-up by moving the meter stick slightly to the left or right on the balance until all is level.

C. Make a prediction about how the weight might change if the steel wool is heated with a very hot Bunsen burner.

(B) D. When all is balanced, heat the steel wool very intensely for five or six minutes with the Bunsen burner. Be sure to use the hottest part of the flame—the tip of the inner cone. When the steel wool begins to glow, remove the Bunsen burner. Observe what happens. Allow the product to cool and examine it. Has it changed?

THINK AND WRITE

1. Write a description of the product in your journal.
2. What happened to the weight after the steel wool was burned? Did this surprise you? Did you expect something else?

In your group, discuss the answers to the following questions. Be prepared to share your answers with the entire class.

3. Using the analogy of throwing stones out of your pocket to lose weight or picking up stones and adding them to your pocket to gain weight, write about whether the steel wool had something added to it or something taken away from it during the chemical reaction.
4. What, besides the steel wool, do you think might be involved in the reaction?
5. Remember, this reaction is similar to that of the rusting of steel wool. The same reactants are needed, and very similar products are formed. Can you now explain what happened with the steel wool rusting under the balloon?

How would scientists explain the steel wool rusting and burning reactions? You may remember that steel wool is a form of iron. When steel wool burns, a chemical reaction occurs that is very similar to the chemical reaction of rusting. Just like a candle or a match or a piece of paper needs oxygen from the air to burn, steel wool needs oxygen from the air to rust or to burn. Candles, matches and paper wouldn't burn on the moon, and neither would steel wool rust or burn on the moon. In both cases, steel wool combines with oxygen from the air to form new substances, both of which are called iron oxide. The reddish, flaky rust is actually a new substance and the jet black, powdery substance left after burning the steel wool is also a new substance. These two new substances are very similar to each other.

6. What do you think happened to the weight of steel wool when it rusted? Explain your answer using the data you collected in the experiment with the balloon: the observation that the balloon was sucked in to the beaker (what does this mean about the air around the steel wool?).
7. Why might your little brother think that matter was created in this experiment?

Ⓒ TRY THIS

Here is the final activity of this cluster. You'll use all the new information you learned in this cluster as you predict and write your explanations of what is happening.

YOU WILL NEED

- butane lighter
- aluminum pie tin
- clay or florist's adhesive
- rubber band
- 400 ml beaker

A. Remember the butane lighter? Observe it as you light it and allow it to burn for a minute or two.

6. The weight of the steel wool in the beaker probably increased, since air seems to disappear from the beaker. The air must have attached itself in some way to the steel, making it heavier.

7. If the steel wool gets heavier, without adding anything *that is visible* to it, it might seem that new matter was created.

C. In this activity, students will try to use all the information about invisible reactants and products and their effect on weight. Usually students are somewhat puzzled about the butane reaction because invisible gases are involved both as reactants and as products. Many times, even though students see the fog collect on the inside of the beaker, they have no idea what this is or where it came from because they do not know what fog is. They may just think it is smoke but butane really burns with a clean flame if it gets enough oxygen. They may know that carbon dioxide is produced when substances burn.

Allow students to observe the reaction and try to fit the pieces of the puzzle together without help from the teacher. They should answer the questions and then compare their explanations with the scientific explanation given later.

8. By now, students should be able to figure out the answers to most of these questions. If they are not sure, encourage them to speculate on the answer. They will revise and add to their explanations after they read the scientific explanation given later.

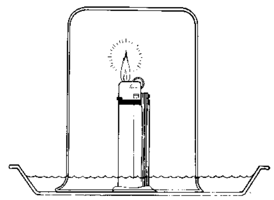
a. Yes; from the evidence that water rushed into the beaker as the butane burned, one can conclude that air was used somehow in the reaction. It is similar to the balloon being sucked into the flask when steel wool rusted.

b. Water vapor and carbon dioxide. Let students make their best guess. Do not tell them the answer at this point.

c. The weight would decrease as the butane burned and formed the products.

d. The weight of the products would be greater that the weight of the butane that burned because oxygen was also involved in the reaction.

e. The weight would not change since the total weight of the products (carbon dioxide and water vapor) is exactly the same as the total weight of the reactants (butane and oxygen). No molecules were gained and no molecules were lost. Since there are three invisible gases involved here, some students might have difficulty explaining where the weight went in the products. They should explain whatever they can.



B. Place a rubber band around the butane lighter in such a way that it can hold the fluid release open, but don't open the release yet.

C. Secure the butane lighter to the bottom of an aluminum pie tin using a piece of clay or florist's adhesive.

D. Fill the pan at least half full with water.

E. Secure the rubber band in such a way that the fluid release is open and then quickly light the lighter.

F. Place a beaker over the lighter and immerse it in the water, making sure that the lip of the beaker stays entirely under water.

G. Observe what happens to the water and to the flame. You may need to repeat this several times to really see what is happening.

H. IMPORTANT: Release the rubber band from the lighter immediately.

8. a. Was any invisible gas involved in this reaction? What evidence do you have?

b. What do you think the products were in this reaction? (Hint: What collected on the inside of the beaker? What else forms when fuel burns?)

c. Suppose you placed a lighter on a balance and let it burn for five minutes. Predict what would happen to the weight of the lighter. Explain why you think this.

d. Suppose you could collect just the products that form in this reaction. How would the weight of these products compare to the weight of the butane that burned? Explain why you think this.

e. Predict what would happen to the weight of the system if you placed a lighter inside a closed jar and then placed the jar and burning lighter on a balance? Explain why you think this.

Here is how scientists would explain this reaction. Read the explanation and compare it to your explanations. Does the butane just "burn up"? No! It can't just disappear. Nothing disappears. It changes, though, into new substances. When butane burns, it combines with the oxygen in the air, and forms two new substances, water and carbon dioxide. The lighter gets lighter. Carbon dioxide is a gas. It floats off into the air. The water formed is hot so it is a gas (water vapor) and it, too, floats off into the air. If the gas hits the cool beaker, it forms a mist of tiny liquid droplets on the side of the beaker. Frequently, you can't see any products in this reaction because both products are gases and they go off into the air.

But in the closed system—when the gases are trapped inside a closed jar—the weight would not change, since the butane and oxygen gas were used to make two new substances, carbon dioxide and water vapor.

9. Review your answers to the last question and use any new information to revise or add to these answers.
10. Do you think this reaction is a physical change or a chemical change? What evidence do you have?
11. Why might your little sister think that the butane just burned up and disappeared in this reaction?
12. Write a paragraph in your journal that explains how the Law of Conservation of Matter applies to this reaction.

In the next cluster, you will see how atoms and molecules can help you understand even more about the Law of Conservation of Matter.

9. Answers vary.

10. It is probably a chemical change since new substances were produced. The properties of the products (invisible gas and water vapor) are totally different from the properties of the reactants (a clear liquid and an invisible gas from the air).

11. Because both products are gases that often are invisible to the naked eye.

12. Points to include are:

- even through the system appears to weigh less, that is only true if you don't account for ALL of the reactants
- when the invisible gases of the reactants are accounted for, the products weigh the same as the reactants
- matter is conserved in all chemical reactions

Cluster 2—Lesson 11

Lesson 11: RESEARCH CONTINUED!

You may recall from cluster one that you selected a substance to research. You determined its common name and chemical make-up and started making notes in your journal or on separate cards in preparation for a scientific presentation at the end of the unit. Since that time, you have learned a great deal more about chemical substances and reactions, so you are now in a position to continue the investigation of your chemical substance.

WHAT YOU'VE ALREADY LEARNED ABOUT YOUR SUBSTANCE:

- the chemical name and any other name it goes by;
- a description of the substance.

HERE'S WHAT YOU SHOULD INVESTIGATE NOW:

A. What is this substance used for. Describe all the uses you can find from anywhere in the world.

B. Is this substance of any particular importance to any special culture or ethnic group. If yes, describe how and why.

C. Did the substance have any different uses in the past? If yes, describe them.

D. Give a history of its discovery and development. What person(s) was (were) involved?

HERE'S WHAT YOU'LL LEARN ABOUT IN LATER CLUSTERS:

- how it is produced and disposed of;
- how energy is involved in its production and disposal.

Chemistry That Applies—Michigan Dept. of Education 44

LESSON STATEMENT: Students will apply what they have learned in this cluster as they continue the research they began in Cluster 1.
PURPOSE: To provide opportunities for students to extend their knowledge to a new situation—the investigation of their assigned research substance.
APPROX. TIME: 1 class period.

(A) As in Cluster 1, you should include this information for each reference book or other source of information you use,

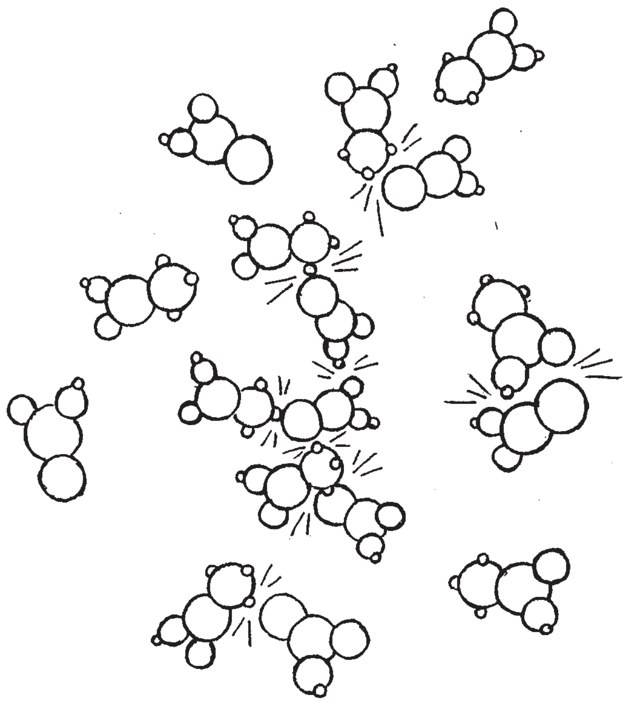
- Title of source
- Author
- Copyright date
- Publishing company
- Pages on which the information is found

Record these findings in your notebook or science journal or on 5 x 8 cards as you did earlier. You may be able to use some of your former references again for this new information. In such cases, you may use a new card or you can add new information to the card you used earlier.

A. You will need to guide students both in finding resources and in helping them find answers to the questions for their particular substance if it becomes too difficult for them. Not every substance will have an abundance of information available for every question. Students will need guidance to insure that they have tapped available resources and to help, in those cases, when the information is limited.

Some substances have been included in the suggested list and some questions have been placed in the research sections in an effort to get at the cultural implications of the substances. Frequently, certain substances played significant roles in the history and development of various groups or cultures and there is a rich history associated with them. Hopefully, students will be able to tap into some of this in their research.

Molecules and Atoms



Vinegar

Cluster 3—Lesson 12

Lesson 12: WHAT MAKES ONE SUBSTANCE DIFFERENT FROM ANOTHER?

In Cluster 1, you observed reactions of some common, everyday substances. You made careful observations and wrote descriptions of the starting substances. That part was fairly easy. But when you described the ending substances and examined them to see if these substances were different from the original ones, it wasn't always easy to tell.

One reason for this is that many substances look alike. For example, vinegar and water look alike. They are both clear liquids. If you pour them, they both run out of the container about the same, that is, neither of them runs out of the container like syrup or oil would. Another reason it's hard to identify substances is that most people are familiar with only a few common substances out of millions of possibilities.

KEY QUESTION

What makes substances different even though sometimes they may look alike?

Think about this last question for a minute. What are some differences between vinegar and water? What are some differences between baking soda and sugar? Between hydrogen gas and oxygen gas?

? ? ? ? ? ?

The basic difference between substances, one that chemists have figured out over the last several centuries, is that *different substances are made up of different kinds of molecules.*

Chemistry That Applies—Michigan Dept. of Education 48

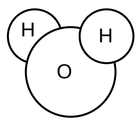
LESSON STATEMENT: Students begin the process of constructing an explanation for chemical changes by building models of the three phases of matter and considering how molecules are unaffected in changes of state. Then they use letters and words as a basis for understanding that molecules are built from atoms. They develop a model of their own and compare it to real molecules.
PURPOSE: To introduce the concepts of molecules and atoms; to explore the question of how there can be so many different substances.
APPROX. TIME: 2 class periods.

A

THINK AND WRITE

1. Write what you remember about **molecules** in your journal.

Chemists have come to understand that common substances in our environment—really all substances, common or not—when they are magnified millions of times, are composed of different kinds of molecules. Water, for example, has its own kind of molecule, which we often refer to as H_2O.



a water molecule

Sugar has its own kind of molecule.

Vinegar is made up of its own special kind of molecule.

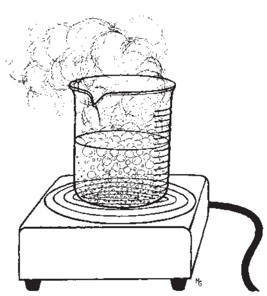
Oxygen is made up of still another kind of molecule.

Carbon dioxide is composed of molecules different from oxygen.

So are aluminum, and iron, and copper, gold and many, many, many other solids, liquids and gases.

Take a chunk of ice. Magnify it millions of times, and you would see water molecules joined together into sort of a cage-like structure, jiggling a little, but staying in the same place. Solids are made of molecules that are close together in neat, orderly, regular arrangements.

When ice gets warmer, it becomes liquid water. The molecules jiggle faster as the ice gets warmer, until they break free from the forces that hold them together as solids. As a liquid, the molecules are moving freely within the container, sliding around past each other. *But nothing about the individual molecules has changed.* They are still H_2O.



When water is heated, it boils and becomes water vapor. The molecules are given increased speed by the heat, and fly off the surface of the water, into the air. As gaseous water vapor, molecules are very far apart. But they are still H_2O molecules.

Whether a substance is in the solid, liquid or gaseous phase has only to do with how the molecules are

A. 1. This question is intended not only to get students to think about what they know, but also to help teachers become familiar with students' thinking on this subject and become aware of any misconceptions. Some students will know more about molecules than others. One typical misconception is the idea that molecules are in substances, rather than making up the substance—e.g., that there are molecules inside an ice cube, perhaps between the water, or that the molecules in liquid water are similar to germs, floating around in the water. Underlying this misconception is the general notion that substances are continuous, not made up of discrete particles—that water is a continuous liquid, or that solid aluminum is a continuous substance, not actually composed of discrete, individual particles.

If possible, show models of solids, liquids and gases. The solid should be a rather rigid, orderly arrangement of molecules. Be careful that the models you use represent molecules, not atoms which students haven't learned about yet. Since the models should represent entire molecules, marbles or styrofoam balls work well. Marbles or styrofoam balls moving freely in a dish make a good model for a liquid. Blowing ping-pong balls around in space with a hair dryer is a good model for molecules of gaseous substances.

2. Students pictures should show the arrangement and distance between molecules—that the spacing in solids is close and very orderly. The spacing in liquids is very close and in gases the molecules are very far apart. Only distance and arrangement (orderliness or randomness) are changing. In this question, students are drawing molecules as a single particle and atomic representation is not expected. Students should use different symbols, such as circles and squares, or different color circles, or size for different kinds of molecules.

In preparation for understanding the difference between chemical and physical changes, it is important that students recognize that the molecules stay intact during physical changes.

The molecules don't change in any way during melting, freezing, etc.

If students draw pictures of ice cubes that contain molecules, rather than being made up of molecules, you might ask them to describe what the other stuff in the ice cube is.

3. a. You would heat it, for example, bring an ice cube to room temperature or put it in the sun. You could heat water on the stove.
b. You would cool it, for example, gases in the air change to liquid on the outside of a glass of cold pop. Lakes freeze in the winter time.
c. Yes, but in the case of a metal, you would have to get it very, very hot.

4. Fruits dry out when the water in them evaporates. See the fruit is still there, just less water. Think about grapes to raisins. The molecules of water in the fruit leave it by flying off into the air.

5. Can't be a change of state, since you add heat to make it seem more solid (adding heat usually melts things). It must be some other kind of change. (It's actually a chemical change, where the heat affects the proteins in the egg.)

arranged and how they move. If you heat a solid, it changes to a liquid and, if you heat it more, the liquid changes to a gas. The opposite is also true. If you cool a gas, it changes to a liquid and, if you cool it more, the liquid becomes a solid. The molecules themselves are the same in all three forms. They have simply gone into different arrangements because of the increased speed (when heated) or decreased speed (when cooled.) And because the molecules are still the same, **no new substances are formed.**

2. Draw a picture of what you think pure ice, water and water vapor would look like if magnified millions of times.
3. a. How could you get a solid to change to a liquid or a liquid to a gas? Give an example of each.
   b. How could you get a gas to change to a liquid or a liquid to a solid? Give an example of each.
   c. Would your methods work for butter? for chocolate? for a metal such as aluminum? Explain.
4. All the food we eat (fruits, vegetables, milk, juice, meat, bread, etc.) contains large amounts of water. If fresh fruits or vegetables are left around for a while, they begin to wither and dry out. What kind of change is this? Use molecules to explain why you think this.
5. When an egg white is cooked, it goes from sort of a liquid to some sort of a solid. Is this a change of state or some other kind of change? (This is really a tough one, so here's a hint. If water changes from liquid water to solid ice, do you heat it or cool it? When the egg white changes from liquid to solid, do you heat it or cool it?)

DIFFERENT KINDS OF MOLECULES

A gold ring can be melted into liquid gold, and then poured into a mold to make a new ring. Its gold molecules never change in this process. But if you poured water into the ring mold, and froze it, would it come out as gold metal? Why not?

? ? ? ? ? ?

Every pure substance has its own special kind of molecule, different from the molecules of all other substances.

(B) How might a vinegar molecule be *different* from a water molecule? How might a salt molecule be *different* from a sugar molecule? Brainstorm answers to these questions, and write them on the board. Then work through the following questions. They help explain how there can be so many different kinds of molecules in the world.

6. a. Think of all the letters of the alphabet. How many letters are there?
   b. What can you *build* out of letters?
   c. How many words can you build from the 26 letters of the alphabet?
   d. Where could you find a complete list of all these words?
   e. Are new words ever added to these lists?

LETTERS MAKE WORDS

ESNESNON EKAM OSLA SRETTEL

7. a. Do all combinations of letters make words?
   b. Does it make a difference what order the letters are in?
   c. Does it make a difference if you add or take letters away?
   d. Think of an example that will illustrate each of these last 3 questions.

(C) So how do letters and words help us understand molecules? Well, it's like nature has a construction set too, only nature's set is made up of 92 different kinds of pieces called **atoms.**

B. Let students speculate about the differences between water and vinegar, salt and pepper. Some students may suggest (rightly) that molecules are built from various types of atoms, and that water molecules have different atoms than vinegar molecules. Some students may also suggest (and this is naive thinking) that vinegar molecules smell like vinegar does, or attribute some other macroscopic property of vinegar or water to their molecules.

6. a. 26
   b. Words
   c. Billions, trillions...
   d. An unabridged dictionary or the Oxford English Dictionary (OED) would be the best source for finding a complete list.
   e. Yes, just recently it was announced that several new words had gone into the OED—words like nerd.

7. a. No
   b. Yes, "also" makes sense in English, but "osla" doesn't. The phrase above is "Letters also make nonsense" spelled backwards.
   c. Yes. "To" is a different word from "Tom" or "Today."
   d. (Given above.)

C. It is important when using models to point out that no model or analogy is perfect. Therefore, be sure to always talk both about similarities and about differences. This lesson should lead students to formulate an explanation for the structure of matter, so don't give them explanations before they have arrived at their own. Also, don't provide additional information about the structure of atoms and molecules. Keep it simple at this point.

D. Some students may know that there are about 109 elements. We refer here to the 92 NATURALLY OCCURRING ones. The elements beyond number 92 on the periodic chart are made in laboratories.

A copy of the periodic table of elements can be found in any chemistry book. We encourage teachers NOT to have students memorize anything from the periodic table.

ATOMS

D Nature uses atoms as pieces to build hundreds of thousands of different substances—much like the 26 letters of the alphabet are used to build hundreds of thousands of different words. Many of these atoms are familiar to you. Others have very strange names. The chart lists the most common atoms.

The most common chemical "building blocks"	Its chemical symbol and normal state	
Oxygen	O	gas
Hydrogen	H	gas
Nitrogen	N	gas
Chlorine	Cl	gas
Fluorine	F	gas
Carbon	C	solid
Silicon	Si	solid
Sulfer	S	solid
Iron	Fe	metal
Aluminum	Al	metal
Zinc	Zn	metal
Mercury	Hg	metal
Silver	Ag	metal
Gold	Au	metal
Tin	Sn	metal
Sodium	Na	metal
Lead	Pb	metal
Nickel	Ni	metal
Platinum	Pt	metal
Calcium	Ca	metal
Chromium	Cr	metal
Copper	Cu	metal
Iodine	I	solid
Arsenic	As	solid

Think about how letters make words and use this information to answer the following questions.

8. How can all the different materials of the earth be made from only about 20 building blocks?
9. Where do you think you could find a complete list of all the different kinds of molecules?
10. Do all combinations of atoms make real molecules?
11. Does it make a difference what order the atoms are in when they form molecules?
12. Would it make a difference if you add atoms to a molecule or take them away?

(E) Like with words, where not all combinations of letters make a real word, not all combinations of atoms make real molecules. When atoms join together to form molecules, they must fit together, much like particular legs fit on certain chairs. Not all legs fit on all chairs; you must get the right leg to fit a given chair. In the same way, you must have the right atoms to fit together to make a certain molecule.

You may have noticed that we are using a lot of models to talk about atoms and molecules. Why? Because atoms and molecules are so small that we cannot see them even under the most powerful microscope. So scientists use things we can see to help them understand how the things that we cannot see work. No model is ever perfect, so when using models it is important to think about how the model is similar to and how it is different from what it represents. Now it's your turn to be a scientist and think of a good model for atoms and molecules.

8. These building blocks (atoms) are put together with different numbers of pieces that are arranged differently. There are many, many possibilities, producing all the different substances on the earth.

9. There must be some reference that has it. Actually, it is put out by the International Union of Pure and Applied Chemistry.

10. Probably not. Students are expected to use the analogy of letters and words from above to answer these questions. But since it was a model, the use of the word "probably" is to be encouraged.

11. Probably it does.

12. Probably it would.

E. You may want to mention that because molecules are too small for visible light to bounce off them, even ordinary light microscopes can't resolve molecules or atoms. Something with a shorter wavelength than visible light has to be used; electron microscopes, using beams of electrons, can take an image of molecules which can then be displayed on a monitor.

13-14. These two questions should help students formulate the “big picture” that everything is made of molecules. And since molecules are made of atoms, everything is made of atoms. Some students will hesitate a long time trying to think of something. Give them plenty of time as they try to conceptualize the particle model of matter.

15. Try to get students to realize that the lists could be identical or they could be very different since everything is made of molecules and all molecules are composed of atoms. Every answer is a correct answer except empty space (truly EMPTY space as in outer space, not the atmosphere which is composed of gases).

16. This is an application question that ought to get students to think of the entire universe as being made of particles—the particle model of the universe. At the molecular level, they would see individual particles of the wood vibrating in place.

TRY THIS

A. Consider bricks as a model for how atoms make molecules. List three things that can be built from bricks.

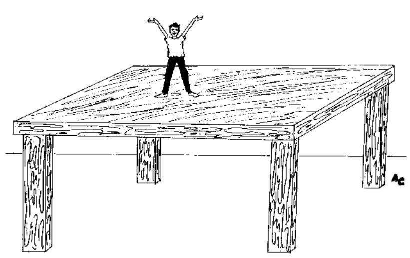
B. Use the chart below to think about ways that objects made from bricks are like molecules, and ways that they are different.

Bricks	Molecules
A house is made out of smaller pieces called bricks.	Molecules are made out of smaller pieces called ATOMS.
Bricks can be used to make many different objects, including HOUSES, WALKS, ETC.	Atoms can be used to make many different molecules, including WATER, SALT, NYLON
A house is made of only one kind of building block (the brick.)	Most molecules are made of: a) only one kind of atom, or ✓ b) different kinds of atoms.
If someone adds bricks to the house (to build an addition) it is not the same house as it was before.	If somehow one or more atoms is added to a molecule, it is: a) just a larger molecule of the same substance, or ✓ b) a totally new and different molecule making a new substance.

13. Write a list of at least ten things in your classroom that are made of molecules.

14. Write a list of at least ten things in your classroom that are made of atoms.

15. What’s the difference in these two lists? What’s the similarity? Explain.



16. a. Pretend you are standing on your desk and somehow you are shrunk so small that you were the size of molecules. Draw a picture of what you think you would see as you looked around your desk top.

b. Present your drawing to your group and explain it. Allow each other group member to ask questions to clarify what you say, and let them comment on your drawing.

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Did your drawing include molecules? What kind of molecules were they? Were they all the same kind?

Did your drawing indicate that the molecules were built up of atoms? If yes, how many atoms did you have for each molecule—the same number for each, or different?

17. Is there anything between the molecules in your drawing? What?
18. Is sand made of molecules? Is each sand grain a molecules? Why do you think what you said?
19. Is clay made of molecules? Why do you say that?
20. a. Is soup made of molecules?

    b. How could you explain how soup is made of molecules? Fill in the blanks below, putting the following parts in their right order:

    a. broth, vegetables, rice, maybe meat

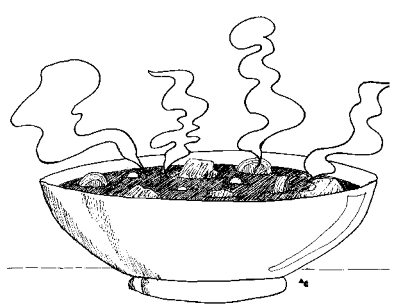
    b. proteins, and proteins are molecules

    c. cell parts, like a nucleus, mitochondria, cytoplasm

    d. animal and plant cells

Soup is made of

1. __________ … which are made of:
2. __________ … which are made of:
3. __________ … which are made of:
4. __________ … and molecules are made of:
5. __________



In the next several lessons, you will build models of the substances involved in some of the reactions you have done.

17. There is nothing between the molecules that make up substances, but students might suggest that there is, especially if they hold the naive view that materials are "continous"—with no breaks in them. They might suggest that "glue" is between the molecules, or "wood fibers" etc. Eventually students should come to believe that all substances are made of molecules, each molecules held to the others close to it. Molecules are the tiniest pieces of substance, therefore nothing could be smaller to be between them.

18. Yes, as is everything. But each grain is made of billions of molecules.

19. Some students may be confused by clay, because it seems so hard to believe that it could be made of discrete, individual particles. Of course, it is.

20. 1. a
    2. d
    3. c
    4. b

Cluster 3—Lesson 13

A. KEY QUESTION: We've been preparing for this "big idea" for a long time now. Allow students to speculate about answers. This will help you understand their current thinking so you can guide better them through these difficult concepts.

The four reactions that form the backbone of this entire unit are used again in this cluster as a basis for understanding how new substances are formed. Since each reaction has already been done by the students, it will be done here as a teacher demonstration. The purpose of observing the reaction again is to help students make the connection between the actual reactants and products observed in the reaction and the words and symbols they will be using. This is an extremely difficult conceptualization for most students. You need to use every possible visual aid in your presentation. By now, students should be aware that gases can be part of the system of the reactants and/or the products and they should be looking for signs that gases are involved.

In this cluster, the teacher should work with the students, step-by-step through the entire first (and possibly second) reaction. For each successive reaction, the teacher role should diminish gradually and students should begin to work in groups independent of the teacher as much as possible. By the end of the cluster, students should be able to work through the process on their own. Do not expect students to balance dozens of equations. That is not the purpose. Rather, a conceptual understanding of the principles and laws involved, along with the association of the real world context, is much more important.

Lesson 13: ATOMS IN EQUALS ATOMS OUT: Decomposing Water

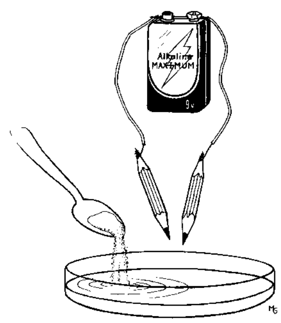
In Cluster 1, you observed some chemical reactions of common substances and wrote descriptions of what you observed. Then in Cluster 2, you learned one of the most basic laws of nature, the Law of Conservation of Matter. Take a few moments to think about what this law means and share your ideas with the class.

In the first lesson of this cluster, you learned how atoms combine to form molecules. Now you will see how atoms and molecules can explain both the formation of new substances and the Law of Conservation of Matter.

Ⓐ

KEY QUESTION

How can atoms and molecules be used to explain the formation of new substances? How can they be used to explain the Law of Conservation of Matter?



In an earlier lesson, you used a battery to make bubbles appear under water. The water level went down as the bubbles were formed.

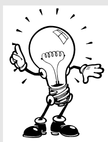
How can atoms and molecules be used to explain the formation of bubbles from water?

LESSON STATEMENT: Students will make models of the molecules involved in the decomposition of water; they will take the water molecule apart and use the atoms to build hydrogen and oxygen molecules. They will draw pictures of the reactant and product molecules, write formulas showing how the atoms have recombined, and consider why mass is conserved in chemical reactions based on the idea that no atoms are created or destroyed, only rearranged to form new molecules.

PURPOSE: To begin to construct a picture of how new substances are formed by observing the decomposition of water reaction and building models to demonstrate how reactants form products; to write balanced equations based on these models; and to consider why mass is conserved in chemical reactions.

APPROX. TIME: 1 class period.

TRY THIS



SAFETY!

If your model kits contain gumdrops, marshmallows, and toothpicks, do not place any of them in your mouths. Upon completion of this project discard these materials as instructed by your teacher.

YOU WILL NEED

Marshmallows or gumdrops and toothpicks for model building.

Use a data chart like the one below:

A. Write the common name of the reactant (the starting substance) on your data chart in the appropriate space.

B. You probably know the chemical formula for water. Write it on your chart.

The formula for any substance is the shorthand way that chemists use to show the kind and number of atoms that are needed to make a molecule of that substance. Can you figure out what the formula for water means? The H stands for hydrogen, and there are 2 atoms of hydrogen in a molecule of water. The O stands for oxygen, and since there are no numbers beside it, there is only 1 atom of oxygen in the water molecule.

	REACTANTS	PRODUCTS
COMMON NAMES	WATER	
FORMULA		
PICTURE OF MODEL		
PICTURES OF MODELS FOR THE REACTION		
ACCOUNTING FOR ATOMS	Number of oxygen atoms: Number of hydrogen atoms:	Number of oxygen atoms: Number of hydrogen atoms:
BALANCED EQUATION		

The gases produced as water decomposes look exactly the same and students need to be convinced that there are two different substances being formed. If you have a Hoffman apparatus with platinum, stainless steel or nichrome electrodes, you will be able to set up this experiment in advance and generate enough oxygen and hydrogen gas to test them with a burning splint. Other electrodes do not work well, since although it is easy to make and collect the hydrogen gas, the reaction at the anode tends to be with other ions rather than with water to produce oxygen gas. If you do collect the gases, you can test them with a burning splint to show that they are different gases. The evidence that oxygen gas has been produced is that a glowing or burning splint bursts into flame or burns very brightly when brought to the mouth of the upright test tube. The evidence that hydrogen gas has been produced is a "bark" or a pop when a burning splint is brought to the mouth of the test tube. You will need to explain these two tests to the students. If you do not have the materials to generate the gases, you can use a few drops of bromthymol blue indicator in the water, which will produce different colors at each of the electrodes.
This ought, at least, to convince the students that the gases being produced are different. You can use the same set-up used in Cluster 1, a petri dish and pencil lead (graphite) as the electrodes, salt and water with bromthymol blue indicator. Bromthymol blue will turn yellow where the oxygen is being produced and blue where the hydrogen is being produced. An overhead projector or microcam can be used and will project the color quite well.

	REACTANTS	PRODUCTS	
COMMON NAMES	WATER	HYDROGEN	OXYGEN
FORMULA	H_2O	H_2	O_2
PICTURE OF MODEL			
PICTURES OF MODELS FOR REACTION			
ACCOUNTING OF ATOMS	H 4, O 2, Atoms Total 6	H 4, O 2, Atoms Total 6	
BALANCED EQUATION	$2\ H_2O$ ➜	$2\ H_2 + O_2$	

B. Since bonding is not taught in this unit, space-filling models such as the marshmallows or gumdrops, rather than ball and stick models which represent double, single or triple bonds, work best. You need to decide what colors represent each kind of atom depending on what model kits you have. It is best to be consistent in the color representations so that students begin to think about different kinds of atoms as being different. The toothpicks should be broken into halves or thirds and the model built so that the marshmallows or gumdrops are touching and the toothpicks are pushed all the way in. This eliminates any need to discuss bonding of any type which is beyond the scope of the unit. Students should always check their models with the teacher to be sure they are correct.

C. Students should realize very quickly that it is not enough to know the formula which tells what pieces are required and how many of each piece, but they also need to know how these pieces are connected. In water, for example, the 2 hydrogens are both connected to the oxygen, not to each other. Some students may have connected the two hydrogens to each other and the oxygen to the outside of the two hydrogens.

Now think about the products that were formed. What could they be? They were bubbles, of course, but what was in the bubbles? Since the water level went down, we might assume that the water changed into the bubbles. We know, though, that the water wasn't boiling, because it never got hot. So the bubbles couldn't have been water vapor. What else could they be?

Here's a hint. Look at the types of atoms that make up a water molecule. Since water molecules are made up of only hydrogen and oxygen atoms, the substances formed inside the bubbles can only contain hydrogen and oxygen. Would it be possible to have carbon dioxide (CO_2) as a product of this reaction? Why?

So what substances are inside the bubbles? Did someone say "Maybe there's oxygen gas inside some of the bubbles, and hydrogen gas in the other bubbles?" Yes! **The water molecule is coming apart and making hydrogen and oxygen molecules. Hydrogen gas is in the bubbles coming off one of the pencil leads, and oxygen gas is in the bubbles coming off the other lead.**

You can prove this by collecting the gases and conducting tests on them. The tests are easy. Hydrogen explodes with a loud pop when a burning piece of wood is placed in it. Oxygen makes a slightly burning (glowing) piece of wood burn very brightly. You need to collect these gases separately before you can test them.

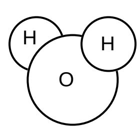
C. Write the common name of the ending substances (the products.) In this case, they are oxygen gas and hydrogen gas.

B

D. Obtain a model-building kit and find the necessary pieces to build a water molecule. Your teacher will tell you which colors represent which kinds of atoms. Try making a model of a water molecule. You need two hydrogen atoms (the same color) and one oxygen atom (a different color).

C

Do all the models in the class look exactly alike? Why not?



H_2O—a water molecule

Chemists have found that both hydrogens attach on opposite sides of the oxygen, not to each other, like in the picture on the left. If your model has the two hydrogens attached to each other, change it.

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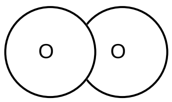
Model-building is an extremely important tool that enables students to develop their understanding of the structure of matter. The transformation of students' thinking about matter from continuous to the particle model is usually very gradual. As students make models of various molecules, the way they talk about matter as being made up of molecules and of molecules as being made up of atoms will indicate changes in their thinking that often do not occur without model-building. Changing students' view of the world around them is not a concept that is taught in a day or a week. Only very slowly over time will you see the correct scientific picture evolve and take shape. Don't omit any of the model-building lessons if you expect this transformation in your students.

D **Make two water molecules.**

Draw a picture of your model of the water molecule on your data chart. Label each atom or color it to show what kind they are.

E

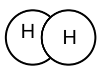
E. Now build models of the ending substances. Start with oxygen. Are you wondering what the formula is? Chemists found—a long time ago—that two oxygen atoms join together to make an oxygen molecule, so what would the formula be?



O_2—an oxygen molecule

Write the formula in the proper space. Then make the model. Remember to use the same color that you used above for oxygen. Draw a picture of your model of the water molecule on your data chart. Label each atom or color it to show what kind they are. Remember to use the same color that you used above for oxygen.

F. Now try making a model of a hydrogen molecule. Like oxygen, two atoms of hydrogen join together to make a hydrogen molecule.



H_2—a hydrogen molecule

Write the formula in the proper space.

Draw a picture of your model of the water molecule on your data chart. Label each atom or color it to show what kind they are. Remember to use the same color that you used above for hydrogen.

Now that you know the formula and can make a model of each reactant and each product, you are ready to figure out how new substances form.

Recall from the last lesson what makes one substance different from another: Each substance is made up of its own kind of molecule, made of different kinds of atoms. Water is a collection of water molecules, each molecule made from 2 hydrogen and 1 oxygen atoms. Vinegar is a collection of vinegar molecules, each molecule made from 2 carbon atoms, 4 hydrogen atoms, and 2 oxygen atoms. Sugar is made of sugar molecules, each molecule made from 6 carbon atoms, 12 hydrogen atoms, and 6 oxygen atoms.

D. Students will need two water molecules later (in step G) from which to make hydrogen and oxygen molecules.

E. Most model-building is done by making models of the reactants and models of the products. This method often does not get the point across of where these product molecules come from, so in step G we have students take apart the water molecules and use those atoms to build the oxygen and hydrogen molecules.

F. Be sure to collect all unused "atoms" so they cannot pick up these pieces to make the products. If they balance the equation by using multiples of the expected equation (doubling or tripling the quantities), don't have them change it since the equation is balanced and the concept is equally well demonstrated.

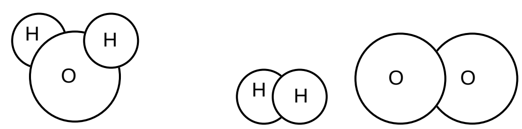
What happens when an electric current runs through water, and the water decomposes into hydrogen gas and oxygen gas? The atoms of the water molecules come apart and then form into new molecules. **No new atoms of any kind are added.** Its like taking a Lego building apart and using all the pieces to make two smaller objects, like a plane and a tree.

Let's try doing this with your models.

(F) G. Take a molecule of water apart and USE THESE SAME ATOMS to make the products, in this case, oxygen and hydrogen molecules.

starting substance "reactant" — ending substances "products"

H_2O — H_2 — O_2



What happens? You can make the hydrogen molecule (H_2), but you cannot make the oxygen molecule (O_2), because you have only one oxygen atom. Where can the other oxygen atom come from to make an oxygen molecule?

In the real chemical reaction you watched, with many bubbles being formed, there were billions and billions of molecules. Billions of water molecules were coming apart at the same time. And all the other water molecules coming apart also have an oxygen atom. So two oxygen atoms from different water molecules find each other and join together to form an oxygen molecule.

H. Try doing that with your models now. Take a second molecule of water apart and make another hydrogen molecule. Use this single oxygen atoms to join the oxygen atom from the first water molecule. Together they form an oxygen molecule.

G

I. How many water molecules did you use in all? Draw exactly that many water molecules in the space on your data sheet labeled PICTURES OF MODELS FOR THE REACTION. Color your models using the same color code as above.

How many hydrogen molecules were formed? Draw exactly that many hydrogen molecules in the appropriate space on your data sheet. Color your models using the same color code as above.

How many oxygen molecules were formed? Draw exactly that many oxygen molecules in the appropriate space on your data sheet. Color your models using the same color code as above.

Are you beginning to see how atoms rearrange themselves to make new substances?

CONSERVATION OF MATTER

Now let's see how atoms and molecules can be used to explain conservation of matter. Remember that conservation of matter in chemical reactions means that the beginning weight of all of the reactants is exactly the same as the ending weight of all of the products. Can you speculate about why this might be?

? ? ? ? ?

J. How many atoms of oxygen are there in the molecules of the reactant—the starting substance? How many atoms of hydrogen are there in the molecules of the reactant? Record this information on your data sheet under ACCOUNTING FOR ATOMS.

How many oxygen atoms are there in the product molecules—the ending substances? How many hydrogen atoms are there in the product molecules ? Record this information on your data sheet in the appropriate space.

H

WHAT DO YOU NOTICE ABOUT THE NUMBERS OF **ATOMS** IN THE STARTING SUBSTANCES AND THE ENDING SUBSTANCES? They are the same! The atoms don't disappear or appear out of nowhere… they just rearrange themselves into new molecules.

And if each atom has a certain weight (which it does), then how does the weight of the reactant compare with the weight of the products?

G. When the models are completed, students will draw pictures of the 3-D models that represent the balanced equation. Since the drawings are two-dimensional and the models, like real molecules, are 3-dimensional, the models will look somewhat different from the pictures. It is a good idea to bring this to the students' attention since students often have great difficulty seeing this connection. Be sure they use the same color coding for different kinds of atoms throughout their entire data sheet.

H. Students will begin to construct new knowledge as they see that not only must the kinds of atoms in the reactants and products be the same, but the number of each kind of atom must also be the same. They should also begin to see that the Law of the Conservation of Matter is true because atoms are conserved.

I. Students should write the balanced equation by thinking about their models and looking at the pictures of the models that they drew. If they write the correct formula first and then "how many," they should not have trouble figuring out where the numbers go. Don't use abstract ideas to explain equations.

QUESTIONS:

The following questions should be used for discussion in small groups. Students should use this opportunity to work out any discrepancies in their thinking as well as "fine tune" their thinking. After group discussions, students should be given time to write their answers on the back of their data sheet.

1. Boiling: The gas given off is water vapor, which has the same molecules as water. No atoms are rearranged to form new molecules in boiling.

2. a. Any substance that contains only hydrogen and/or oxygen atoms are possible products. There are no chlorine atoms available and no carbon atoms available.

b. Yes, these molecules only involve atoms that are available in water. Students may need some help in understanding that the individual products formed do not need to use every different atom from the reactants.

3. The subscripts tell how many atoms are in a molecule. They are like the "recipe" for making a molecule. The coefficient tells how many "whole" molecules are involved. If students have trouble with this, have them go back and look at the pictures of the models they drew.

This is the Law of Conservation of Matter, or the Law of Conservation of Mass. No weight is lost or gained in chemical reactions. No mass is lost or gained. No matter is lost or gained. Why? Because no ***atoms*** are lost or gained during chemical reactions.

CHEMICAL EQUATIONS

Chemists use a shorthand to write about this reaction. They show the starting substances on one side of an equation, and the ending substances on the other side, to show how their weights are equal. They use an arrow instead of an equal sign, to show that the left side reactants change into the right side products. The formula for this reaction is

$$2\ H_2O \rightarrow 2\ H_2 + O_2$$

The 2 in front of the H_2O means that two molecules of water were used in the reaction. The 2 in front of the H_2 means that two molecules of hydrogen gas were formed. No number in front of the O_2 means that one molecules of oxygen gas was formed.

K. Write the formula for this reaction on your chart.

THINK AND WRITE

1. When water boils a gas leaves its surface, and the level of the water goes down. When water is chemically decomposed, like in this experiment, it forms gas and the level of the water also goes down. What's the difference between boiling and decomposing water? Talk about the different gases that are formed in your explanation.
2. a. Could chlorine gas, Cl_2 be a product in this reaction? What about carbon dioxide, CO_2? Explain why you think this.

   b. Do you think it would be possible for ozone, O_3 to form as a product in this reaction? What about hydrogen peroxide, H_2O_2? Explain why you think this.
3. Find a partner and explain the difference between the two number 2's in 2 H_2O. Use your models to help you. Then write your explanation.

4. After doing the same experiment with water that you just completed, and doing it until all the water was gone, the teacher asked what happened to the water. Jamie responded quickly with “Oh, that’s easy. It just decomposed into nothing.” You are now an expert on this. How would you help Jamie understand what happened?

4. The gases inside the bubbles go into the air when the bubbles pop, adding new substances and new weight to the atmosphere. The water is gone, but new substances (hydrogen and oxygen gases) have appeared to take its place. (Of course, the hydrogen and oxygen can react in other ways to form new products. Actually, hydrogen gas is so light that it floats out of the atmosphere and into space. Oxygen, when breathed in by animals and absorbed by plants, is used to chemically react with glucose to give organisms the energy they need for life processes. The products of this reaction—cellular respiration—are carbon dioxide and water. Yes, the oxygen atoms have recombined to form water again!)

Cluster 3—Lesson 14

This is the second of the four reactions that form the backbone of this entire unit. Since this reaction has been done earlier by the students, it is done here as a teacher demonstration. The purpose of observing the reaction again is to help students make the connection between the actual reactants and products observed in the reaction and the words and symbols they will be using. Be sure to use the reaction with the balloon sucked into the flask for the demonstration so students remember to include the invisible gas as a reactant.

In this lesson, the teacher should continue to work step-by-step through each part with the students. As students catch on, they will start going a little faster. Don't let them omit the model-building steps. Usually, students who do this have trouble later when the formulas and equations get a little more involved. As they build their models, have them hold them up for you to see and give a nod of approval.

For building the molecular models, students need two iron atoms and three oxygen atoms. Provide students with only enough parts to make one model of each molecule. They should take these apart before beginning making models for the reaction. Space-filling models with marshmallows or gumdrops work best since bonding is not taught in this unit. Again, you need to decide what colors represent each kind of atom depending on what model kits you have. Students should, if possible, use the same color for oxygen that was used in the last lesson. They should decide what color will be used for iron.

Lesson 14: ATOMS IN EQUALS ATOMS OUT: Rusting

Let's repeat the whole process now with a different chemical reaction: rusting. Take a minute or two to remember what a fresh piece of steel wool and a piece that has reacted (perhaps the one with the balloon on top) look like.

TRY THIS

YOU WILL NEED

Marshmallows or gumdrops and toothpicks for model building.

A. Draw a new data chart in your journal.

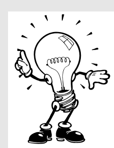
THE REACTANTS

B. Write the common names of the reactants in the proper place on your data sheet. One is steel wool, which is just threads of steel. What's the other reactant? (Can you remember how you knew that it was used in this reaction?)

C. The steel in steel wool (or in cars, bikes, etc.) is made by adding small amounts of carbon or other metals to iron. Probably "iron wool" would be a better name since it is mostly iron and it's the iron in steel wool that reacts. The chemical formula for iron is Fe (from the Latin word for iron: ferrum). The molecule is made from just one atom. **Write the formula** in the appropriate space on your data chart.

Write the formula for an oxygen molecule in the reactants column also. If you don't remember it, look in the last lesson.

D. **Make a model of the iron molecule.** You need only one atom. **Draw a picture of it** and label or color it to



SAFETY!

If your model kits contain gumdrops, marshmallows, and toothpicks, do not place any of them in your mouths. Upon completion of this project discard these materials as instructed by your teacher.

LESSON STATEMENT: Students will build molecular models of the substances involved in the rusting of steel wool; they will use the reactants, iron and oxygen molecules, to build models of the product, iron oxide (rust) molecules. They will draw pictures of the reactant and product molecules, write formulas showing how the atoms have recombined, and consider why mass is conserved in chemical reactions based on the idea that no atoms are created or destroyed, only rearranged to form new molecules.

PURPOSE: To continue to develop an understanding of how new substances are formed by modelling the formation of rust molecules from rust molecules and oxygen molecules.

APPROX. TIME: 1 class period.

show that it is different from the other atoms you have worked with.

Make several molecules of iron, in case you need them later.

Make a model of the oxygen molecule and draw a picture of it on your chart.

Make several molecules of oxygen, to take apart and use to make rust molecules. Return ALL unused pieces to the model kit.

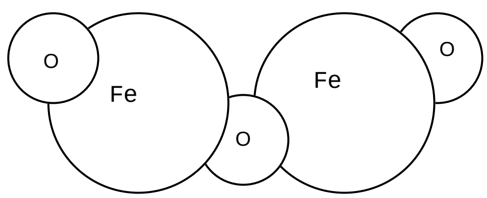
THE PRODUCTS

What is the formula for rust? Steel wool needs oxygen from the air in order to rust. So what kind of atoms can be present in rust?

? ? ? ?

If you said that rust can be made only from iron and oxygen atoms because only those two kinds of atoms are present in the reactants, you are correct. Chemists have found that the formula for rust is Fe_2O_3. **Write the formula** in the products column.

E. Make a model of rust. It looks like this:



Draw a picture of it on your chart. Use the same labels or color codes you used above.

MODELING THE CHEMICAL REACTION

F. Use your models to show how the rust forms from the steel wool and the oxygen: Take an oxygen molecule apart, grab an iron molecule (yes, it's just one atom) and start building a molecule of rust. Is one molecule of oxygen and one molecule of iron enough? No. So take a second molecule of oxygen apart. How many iron molecules do you need?

Is anything left over? Once again, an oxygen atom is left over. Remember, in chemical reactions, reactant molecules never break into atoms that are left over in

Remember to break the toothpicks into halves or thirds and build the models so that the marshmallows or gumdrops are touching and the toothpicks are pushed all the way in.

	REACTANTS			PRODUCTS		
COMMON NAMES	IRON	OXYGEN		IRON OXIDE (RUST)		
FORMULA	Fe	O_2		Fe_2O_3		
PICTURE OF MODEL						
PICTURES OF MODELS FOR REACTION						
ACCOUNTING OF ATOMS	Fe 4	O 6	Atoms Total 10	Fe 4	O 6	Atoms Total 10
BALANCED EQUATION	$4Fe + 3 O_2$		➜	$2 Fe_2O_3$		

A. It is important that students do not have left-over molecular models when they show how the reaction works.

Stress the idea that billions of molecules are reacting, not just the one or two that we write in an equation. Remind them that they'll start with a more realistic number but real reactions work in a similar manner.

the reaction. This is a very, very important characteristic of chemical reactions. So what happens? Yes: Two molecules of rust are formed. Make another molecule of rust, using the left over oxygen atom, and any more oxygen molecules and iron molecules you need. (Remember, the steel wool contains billions of molecules and so does the oxygen in the air. There are plenty of iron and oxygen molecules available to react. Now can you see why you started with several models of each reactant molecule?)

(A) Put all the unused reactant molecules back in the kit. They did not react in your model.

G. Count how many iron molecules and oxygen molecules you used and how many rust molecules you formed and draw them on your data chart, in the row marked "Pictures of models for the reaction." Color or label your models using the same color codes or labels you used above.

CONSERVATION OF MATTER and THE CHEMICAL EQUATION

Would the weight of the iron and oxygen used equal the weight of the rust formed? Remember the experiment with the balance? If you put the flask with the rusting iron and balloon on a scale and watched the weight as the steel wool rusted, would it stay the same?

What do you think, and why?

? ? ? ?

You can use what you know about atoms and molecules to prove that the weight (or mass) stays the same. Here's how:

H. On the next line of your chart, labeled ACCOUNTING FOR ATOMS IN REACTANTS AND PRODUCTS, **decide what kinds of atoms are present in the reactants and the number of each kind. Do the same for the product.** Record this information on your chart.

Are there the same number of oxygen atoms in the starting substances as in the ending substances?

Are there the same number of iron atoms in the starting substances as in the ending substances?

Can you use this discovery to answer the question about weight changes?

(B) I. To write a balanced equation for this reaction, write the correct formula under each kind of molecule. Then show how many molecules of each kind were involved in the reaction, by putting a number in front of the formula for the molecule (for example, 2 Fe).

The balanced equation should look like this, with numbers in front of each molecule:

$$\_\_ Fe + \_\_ O_2 \rightarrow \_\_ Fe_2O_3$$

THINK AND WRITE

1. You have a friend who doesn't know the first thing about chemistry. He thinks that rust just starts somehow and then "eats" away at cars or pipes—sort of like termites eat wood—and this makes holes in the car or the pipe. You must explain to him what is really going on. Tell him what the reactants are and where they come from. Explain what product is formed and how this happens.
2. Is rust just the same thing as iron, only brown? Explain.
3. A friend of yours says that she left a shovel outside during the winter and it got rusty. She says that if you scrape off the rust with a steel brush, the shovel will be as good as new. To test her knowledge of chemical reactions, you ask her if it will weigh the same after the rust is scraped off as when she bought it. She says she's not sure, but it seems like it should—after all, rust just grows on the shovel like moss on a tree or mold on stale bread.

   Do you agree? Explain. Use atoms and molecules in your explanation, too, if you can.
4. Some cars and trucks get so rusty that holes start to form in the metal. How can this happen?

B. Students should write the balanced equation by thinking about their models and looking at the pictures of the models that they drew. If they are having difficulty, remind them to write the correct formula first and then "how many."

QUESTIONS:

1. Students should explain that the iron in the car body combines with oxygen from the air to form the rust. The rust is a reddish-brown color, and is flaky—significantly different in color and texture from the original iron (this is why this unit stresses student observation and description of products early on). The rust can fall away from the car.

2. No. It's a new substance. This can be seen by its properties—it is quite different from iron.

3. Since rust is a combination of some of the iron from the shovel with oxygen from the air, if the rust is scraped away the shovel loses some of its original iron and therefore wieghs less.

4. Rust starts when iron is exposed to the oxygen in the air and reacts with it. The iron has not disappeared, but is present in a new form in the rust that formed. It has chemically combined with the oxygen to form iron oxide which is rust. Since the iron is actually involved in the reaction (it is reacting to form a new substance), there will eventually be a hole in the original substance.

5. The experiment might place a car on a truck scale, inside a closed large plastic bag with air inside and perhaps a pan of salt water, and observe for 10 years as it slowly rusts. The weight should stay the same, although the bag might collapse as some of the oxygen is removed from the air.

6. We grease tools, paint cars, spray a protective silicone coating on jewelry or statues. This protects iron from rusting by preventing the iron from coming in contact with oxygen from the air which it needs to react. However, any little nick or scratch in the finish is enough for the reaction to get started.

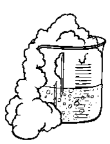
5. Design an experiment that shows that weight is conserved when a car rusts. Use a car that stays in the same place for 10 years, getting rustier and rustier.
6. Give some examples of how we protect things made of iron and keep them from rusting. Then explain how the protection works.

You are now ready to explore what happens when vinegar and baking soda are combined and that great bubbling reaction begins!

Lesson 15: ATOMS IN EQUALS ATOMS OUT: Baking Soda & Vinegar

Now, what about the baking soda and vinegar reaction? These molecules get a little more complicated, but you are getting to be an expert at this, so you should not have difficulty.

Your teacher will perform this reaction. Observe it carefully. It is easy to tell that a reaction is occurring (because of the bubbles) but it is not so easy to tell what the products are. What do you think is in the bubbles? Can you see anything else that might have been formed? You'll be able to figure out what all the products are as you proceed with model-building.



TRY THIS

YOU WILL NEED

Marshmallows or gumdrops and toothpicks for model building.

A. Use a chart to help study this reaction, as you did with the decomposition of water and with rusting of iron.

THE REACTANTS

B. **Write the common names of the reactants** in the proper place on your data sheet.

C. Chemists have discovered that the chemical formula for baking soda is $NaHCO_3$. Each of the oxygens are joined to the single carbon atom. The hydrogen and sodium (Na is from the Latin name for sodium, natrium) are each connected to different oxygens. **Write the formula** for baking soda on your chart, and **draw a picture** of the molecule. Label or color each atom appropriately using the same color code you used earlier.

By now, students are beginning to understand how chemical reactions work. Depending on your students, you may want to allow some students to work on their own while you help students who are having difficulty. Or you may want to pair a student who is having difficulty with another who seems to understand the process. Or you may find that you still need to work with the whole class. Don't let students omit the model-building steps. Again as they build their models, just have them hold them up for you to see and give a nod of approval.

For building the molecular models, students need two carbon atoms, four hydrogen atoms, three oxygen atoms and one sodium atom. Try to use the same color codes for oxygen, hydrogen, and carbon that were used earlier. Students can decide what color they will use for sodium.

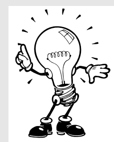
Both of these molecules are pretty big so students could get confused. Usually, by now they are taking it as a personal challenge to be able to build the molecule without directions from the teacher. Be sure they get teacher approval when finished.

Stress again the idea that billions of molecules are reacting, not just the one or two that we write in an equation. You might call their attention to all the bubbles being formed and that it took lots of molecules to make all these. Because of the probability for confusion, students will start with only one of each reactant molecule. That's all they need for the balanced equation.

LESSON STATEMENT: Students will build molecular models of the substances involved in the reaction of baking soda and vinegar; they will use the atoms from the reactants to build models of the products. As in the two previous lessons, they will draw pictures, write formulas, and consider why the weight of the reactants equals the weight of the products.
PURPOSE: To continue to develop an understanding of how new substances are formed by modelling the reaction.
APPROX. TIME: 1 class period.

Be sure students identify or color code all the different atoms in their pictures.

Once they have made the models, students will probably be able to finish the data sheet quite independently. If they have trouble when writing the balanced equation, refer them back to their models.



SAFETY!

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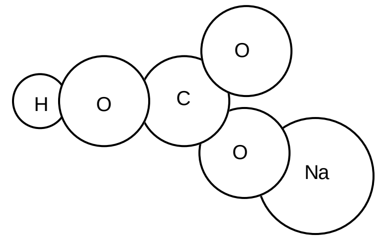
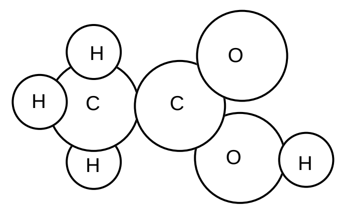


baking soda

D. Vinegar is made up of 2 carbon atoms, 2 oxygen atoms, and 4 hydrogens: CH_3COOH. It is written that way because that is pretty much how the atoms are arranged in the molecule. The two carbon atoms join to each other. Three hydrogen atoms join to one of the carbon atoms and are spaced equally around it. Two oxygens join to the other carbon atom. The other hydrogen atom joins to one of the oxygens. **Write the formula** for baking soda on your chart, **and draw a picture** of the molecule. Label or color each atom appropriately using the same color code you used earlier.



vinegar

E. Make models of the reactant molecules. Make **two** models of each, then replace all the unused atoms in your kit.

THE PRODUCTS

What are the products from this reaction? What is in the bubbles?

Look at the atoms that make up vinegar and baking soda: carbon, oxygen, hydrogen, and sodium. What substances can these atoms make that you are familiar with?

Carbon dioxide, CO_2?

Oxygen, O_2?

Water?

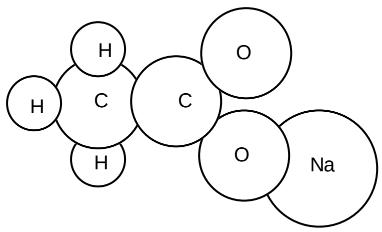
Hydrogen gas?

Butane?

Salt—sodium chloride, NaCl?

Something had to be in the bubbles. It could be any of the gases listed above. (Which substances are gases?)

(A) Actually, three substances are formed in this reaction. Chemists have analyzed what's left over after the reaction, by doing tests on the products. They have found carbon dioxide in the bubbles, water in the liquid, and another substance called sodium acetate. Its formula is CH_3COONa.



sodium acetate

F. **Record the appropriate information about the products** in your chart.

G. **Draw pictures of each molecule** in your chart.

MODELING THE CHEMICAL REACTION

H. **Use your models to show how the products form from the vinegar and baking soda:**

First, look carefully at the pictures you have of the baking soda and sodium acetate molecules. Notice the cluster of atoms on the right side, the COONa? That cluster stays together during the reaction, as part of the baking soda molecule becomes part of the sodium acetate molecule.

Second, look carefully at the pictures of the vinegar and sodium acetate molecules. Notice the cluster of atoms on the left side, the CH_3? That cluster stays together, as part of the vinegar molecule becomes the other part of the sodium acetate molecule.

Now take a baking soda molecule apart, leaving the COONa cluster of atoms together. Take a vinegar molecule apart, leaving the CH_3 cluster together. Then make one sodium acetate molecule out of the two clusters.

Look at what you have left, and try to build a carbon dioxide molecule and a water molecule.

A. Sodium acetate is a solid, indistinguishable from any baking soda that might be left over in the bottom of the beaker. The vinegar in the reaction already has lots of water mixed with it, so the water produced in the reaction just mixes with the vinegar's water.

	REACTANTS		PRODUCTS		
COMMON NAMES	BAKING SODA	VINEGAR	CARB. DIOX.	SODIUM ACETATE	WATER
FORMULA	$NaHCO_3$	CH_3COOH	CO_2	CH_3COONa	H_2O
PICTURE OF MODEL					
PICTURES OF MODELS FOR REACTION					
ACCOUNTING OF ATOMS	Na H C O Atoms Total 1 5 3 5 14		C O H Na Atoms Total 3 5 5 1 14		
BALANCED EQUATION	CH_3COOH + $NaHCO_3$ ➜		CO_2 + H_2O $NaCH_3COO$		

B. You may either ask students to verbally explain this to the class, or ask them first to write this explanation in their journals and then add to it after a class discussion. The connection we want them to make here is that if all of the atoms that made up the starting substances are present in the ending substances, then no weight was lost or gained, since it is the atoms themselves that make up the weight of any substance.

These questions should be used for discussion in small groups to allow students to express their ideas and find any discrepancies. After group discussions, students should write answers in their journals.

1. There is more baking soda in the beaker that has not yet reacted with vinegar.

2. Use BTB after trapping the gas in some way. BTB turns yellow when carbon dioxide is present.

3. No, since the bubbles produced from boiling water have water vapor in them, which is not a new substance—it is the same molecule as makes up liquid water. If no new molecules are produced, then no new substances are produced, and no chemical change has occurred.

4. Students answers may vary on these. Remember, they are going on visual descriptions now and may or may not know the formulas which are needed to be sure if a chemical change occurred. As long as their explanations make sense, they should be accepted as feasible answers. We are trying to get away from teachers always having the correct answers and jumping in whenever there is doubt.

1. Yes: Water, which is a transparent liquid, has very different properties from the invisible gases hydrogen and oxygen.

CONSERVATION OF MATTER and THE CHEMICAL EQUATION

I. Check the kinds of atoms and number of each kind in both reactants and products and fill in the ACCOUNTING FOR ATOMS IN THE REACTANTS AND PRODUCTS portion of your data sheet.

Are there as many atoms of carbon in the reactants as in the products?

Are there as many atoms of oxygen in the reactants as in the products?

Are there as many atoms of hydrogen in the reactants as in the products?

Are there as many atoms of sodium in the reactants as in the products?

B *Explain how this proves that if you trapped all the gas given off in this reaction, the weight of the original baking soda and vinegar would be the same as the weight of all the products after the reaction.*

J. To write a balanced equation for this reaction, write the correct formula under each kind of molecule. Then show how many molecules of each kind were involved in the reaction, by putting a number in front of the formula for the molecule (for example, 1 $NaHCO_3$).

The balanced equation should look like this, with numbers in front of each molecule:

__ $NaHCO_3$	+	__ CH_3COOH	➜	__ CH_3COONa	+	__ CO_2	+	__ H_2O
BAKING SODA	+	VINEGAR	PRODUCES	SODIUM ACETATE	+	CAR. DIOX.	+	WATER

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THINK AND WRITE

Discuss each question below in your group. Then write the answers on the back of your data sheet.

1. Sometimes when you do this reaction, after all the bubbles have popped (and the fizz settles down) you can add more vinegar and start the reaction going again. What does this tell you about the baking soda?
2. Design an experiment to show that carbon dioxide is actually what's inside the bubbles.
3. The change that you observe when baking soda and vinegar are mixed is a chemical reaction. The reaction produces bubbles with carbon dioxide in them. When water boils, bubbles are also produced. Is this a chemical reaction? Explain.
4. a. For each of the following changes, tell if you think new substances formed. Tell why you think as you do.
    1. Hydrogen and oxygen gas are ignited with a spark and explode to form water.
    2. Copper jewelry tarnishes (turns green after being exposed to air and water for a long time).
    3. An iron nail is magnetized by rubbing it against a magnet.
    4. Salt is stirred into water until it all dissolves.
    5. An egg is cooked, turning from a drippy liquid to a rubbery solid.

   b. Which of the above were you unsure of? What information would you need in order to make a correct decision?
5. Think about all the reactions you have done in this cluster, including the mixing you did in Lessons 1 and 2 of common household substances. Write a short paragraph telling what happens when new substances form. Be sure to tell both what you would observe with your eyes and what happens to the atoms and molecules which your eyes cannot see.

You are now ready to explore what happens when butane burns.

2. Yes, because of significant change in color and texture of the tarnish.

3. No, the nail is still the same and can be used as a nail in exactly the same way. Nothing new was seen forming.

4. No, the salt is still there as is evidenced by the taste. Also, the water could be evaporated and you would have salt and water. So they were just mixed together. Students often think that dissolving is a chemical change because the solid "changes into a liquid." They usually know that it did not melt but they do not know what is happening. Tell them to think about the properties of the substance, especially taste. Ask them what would happen if they evaporate the water?

5. Yes, the egg is different in color (the egg white) and taste. Most people don't eat raw eggs. This is confusing because we call both the cooked and the uncooked egg an egg so students often say "it is still an egg." Sometimes students say that it was liquidy and it went to solid as in a physical change but remind them that heat was added to cook the egg and when liquids change to solids (water to ice), the substances must be cooled.

4. b. Answers vary. You need to know the chemical formulas for the reactants and the products to see if they are the same or different.

5. Important points to include are:

- the properties that you can observe with your senses change, usually in an obvious way but sometimes in a less discernible way.
- the reactant molecules come apart and then go back together again in new arrangements.
- the total number of atoms in the reactants and in the products does not change.

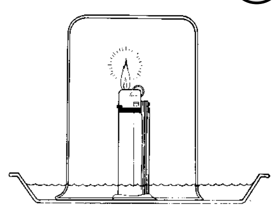
Cluster 3—Lesson 16

This is the last of the four reactions that form the backbone of this entire unit. Since this reaction has been done earlier by the students, it is done here as a teacher demonstration.

A. When burning the butane in the lighter, it is easy to see that the amount of the butane is decreasing, but observing the products is much more difficult since two invisible gases—carbon dioxide and water vapor—are formed. Students probably observed water vapor on the inside of the beaker when they did this experiment earlier but they did not have any evidence for the presence of carbon dioxide. You can test for the presence of carbon dioxide by turning the beaker over quickly, placing a small amount of bromthymol blue in the beaker and swirling it. The carbon dioxide will stay in the beaker since it is heavier than air. The bromthymol blue changes to yellow when carbon dioxide is present. Students have probably used this test before so they may remember the test. In any case, review with them how the test works.

By now, students are beginning to understand how chemical reactions work. Depending on your students, you may want to allow some students to work on their own while you help students who are having difficulty. Or you may want to pair students who are having difficulty with another who seems to understand the process. Or you may find that you still need to work with the whole class. Don't let them omit the model-building steps. Again as they build their models, have them hold them up for you to see and give a nod of approval.

Lesson 16: ATOMS IN EQUALS ATOMS OUT Burning Butane



A Recall the burning of butane from Cluster 2. Your teacher will demonstrate the reaction for you, to refresh your memory and to try to identify the products.

What did you learn about starting substances when the beaker was put over the lighter?

What product formed as little droplets on the inside of the beaker?

Turn the beaker upright and add a little dilute Bromthymol blue to the dish and swirl it around. What does this chemical test show you about one product formed when butane is burned?

	REACTANTS		PRODUCTS	
DESCRIPTION	Clear liquid	Invisible gas	Liquid droplets	Turns BTB yellow
COMMON NAME	Butane	???	??? (don't write here!)	???
FORMULA	C_4H_{10}	???	??? (don't write here!)	???
PICTURE OF MODEL	(write on chart in journal)			

LESSON STATEMENT: With less direction from the teacher than in the previous three lessons, students make models of the burning butane reaction to explain what is happening.
PURPOSE: To help solidify students' understanding of how new substances are formed in chemical reactions and why mass is conserved.
APPROX. TIME: 1 class period.

TRY THIS

(B)

YOU WILL NEED

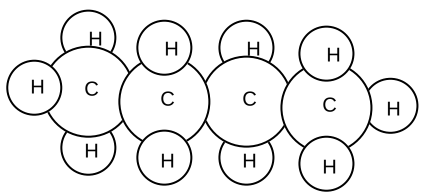
Marshmallows or gumdrops and toothpicks for model building.

A. Use a chart to help study this reaction, as you did with the decomposition of water and with rusting of iron.

B. Fill in whatever you can about the starting and ending substances.

C. Build models of the reactant molecules.

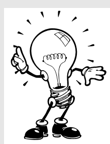
Chemists have analyzed butane as it burns, and found that its formula is C_4H_{10}—four carbon atoms and 10 hydrogens.



D. Draw pictures of the product molecules in your chart. Use the pictures as you do the next step.

E. Take apart the starting molecules and rearrange them to form the ending molecules. You'll need to start with two butane molecules and many molecules of oxygen.

F. As a special project, make a video, or draw a cartoon strip to show what happens when butane burns—how butane molecules come apart and recombine with oxygen atoms to make the ending substances. In the video or cartoon explain why a butane lighter gets lighter when it burns, but why the lighter under the beaker **doesn't** change its weight.



SAFETY!

If your model kits contain gumdrops, marshmallows, and toothpicks, do not place any of them in your mouths. Upon completion of this project discard these materials as instructed by your teacher.

(C)

B. For building the molecular models, students need four carbon atoms, ten hydrogen atoms and two oxygen atoms. Provide students with only enough parts to make one model of each molecule. They should take these apart before beginning making models for the reaction. Again, you need to decide what colors represent each kind of atom depending on what model kits you have. Students should, if possible, use the same color for oxygen and hydrogen that were used in the last two lessons. They should decide what color will be used for carbon.

Butane is the biggest molecule students have used and there are lots of different ways that the four carbon atoms and ten hydrogen atoms could be attached together so there is plenty of opportunity for confusion. Be sure they get teacher approval when finished.

It is important that students do not have left-over molecular models when they begin making models for the reaction.

C. Because butane is a large molecule and students may get confused, they will start with two butane molecules. Both of these react and students are told to show how TWO butane molecules come apart and form products. They get frustrated if they start with only one and then find they have to repeat the whole process with a second butane molecule in order to balance the equation. Do be sure to collect all unused "atoms" so they cannot pick up these pieces to make the products.

Be sure students identify or color code all the different atoms in their pictures.

Students will probably be able to finish the data sheet quite independently. If they have trouble when writing the balanced equation, refer them back to their models.

	REACTANTS		**PRODUCTS**	
COMMON NAMES	BUTANE	OXYGEN	CARB. DIOX.	WATER VAPOR
FORMULA	C_4H_{10}	O_2	CO_2	H_2O
PICTURE OF MODEL				
PICTURES OF MODELS FOR REACTION				
ACCOUNTING OF ATOMS	C 8, H 20, O 26, Atoms Total 54		C 8, O 16, O 10, H 20, Atoms Total 54	
BALANCED EQUATION	$2\ C_4H_{10} + 13\ O_2$ ➜		$8\ CO_2 + 10\ H_2O$	

QUESTIONS:

The following questions should be used for discussion in small groups as students refine their thinking. After group discussions, students should write the answers on the back of their data sheet.

1. 13

2. $2\ C_4H_{10} + 13\ O_2 \rightarrow 8\ CO_2 + 10\ H_2O$

3. You can't burn trash up and get rid of it. This violates the Law of the Conservation of Matter. When burning trash, the trash and the oxygen it needs to burn change into new forms, much of it being gases which are given off into the atmosphere, including carbon dioxide and water vapor. Other gases can be produced, depending on what is burned; some of those gases contribute to air pollution. (Butane does not release other gases, as can be seen from the chemical equation; it is therefore a "clean" fuel. See note below.) Students frequently have the misconception that when things burn up, they weigh less. They fail to realize that the total weight of all the ash and the gases formed is exactly equal to the weight of the trash before it burned.

4. a. The gasoline in cars reacts to form carbon dioxide and water vapor and a few other products which are also mostly gases. These are given off into the atmosphere. The total weight of these products is less than the weight of the gasoline alone but it is exactly equal to the weight of the gasoline and the oxygen in the air needed to burn the gasoline. Nothing disappears or is lost.

THINK AND WRITE

Discuss each question below in your group. Then write the answers on the back of your data sheet.

1. How many molecules of oxygen did you need to react with the two butane molecules?
2. Write the balanced equation for the reaction in the appropriate place on your data sheet.
3. Charlie has been hearing a lot recently about all the trash that we are making and the problem of getting rid of it. He just had a brainstorm! Just burn it all up and it will be gone! What do you think about his brainstorm? Will it work? How would you explain this problem to a friend. Write your explanation in your journal.
4. The gasoline in your car is a fuel very similar to butane. When it enters the engine, it combines with oxygen in the cylinders and a spark makes it explode!
   a. What products are formed when gasoline is burned? (Hint: The products are the same as the products you got when your burned butane.) Would these products weigh more, less, or the same as the gasoline your started with? Where do these products go? Tell why you think this.
   b. Explain why you eventually run out of gasoline: What happens to the gasoline?
5. Your friend doesn't believe that butane or gasoline needs an invisible reactant to make them burn. Design an experiment to prove the invisible reactant is needed.
6. Some homes use bottled gas for their stoves, or for heating water for the shower, or for drying clothes. Some houses in cities get their gas from a pipe connected to their house, just like water and electricity come into your house. Other people, often those who live out in the country, get their gas from a tank in their back yard.

In all of these cases, a pipe takes the gas from the tank into the house and then to the stove or water heater or furnace or dryer. When you turn on the stove, the gas

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A note about burning: Many substances burn (chemically react with air, releasing a great deal of heat), including gasoline, paper, wood, butane, coal, oil, natural gas, kerosene, charcoal, candle wax. These substances are all composed of carbon and hydrogen atoms, like butane; many also have oxygen atoms, nitrogen atoms, sulfur atoms. When each substance burns, it chemically changes into carbon dioxide and water; but in most cases (not butane) other substances are produced as well. Burning wood, paper and wax can produce smoke (small particles like dust) and comes out, and a small flame called a pilot light (or, in newer furnaces, an automatic, sparking electronic device) ignites the gas.

a. Every few months, a truck has to come to the houses in the country and fill up the tank. Why?

b. If you said that the gas is used up or burned up, what do you mean? Does it just disappear leaving nothing behind? Use the idea of molecules to answer these questions? For instance, are there molecules in the gas tank? Is there anything other than molecules in the tank? What happens to those molecules when the gas is burned?

7. Miguel knows that people drown in water because they don't have any oxygen to breathe. But now he also learned that water is made up of oxygen and hydrogen. How can it be that a person drowns because of lack of oxygen but water is made up of partly oxygen? Can you help Miguel with this dilemma?

8. Natalie's problem is similar to Miguel's. She knows that fire needs oxygen in order to burn. She also knows that water, which is made up partly of oxygen, is used to put fires out, not to help them burn. What is going on in this world of chemistry anyway? Help!

b. Cars eventually run out of gasoline because it is chemically changed into carbon dioxide, water vapor, and other products. It does not disappear!

5. One design of an experiment would be to put a butane lighter in a flask with a balloon on top and observe what happens to the balloon as the oxygen is used—the balloon will be sucked into the flask, just as with the rusting steel wool. Another design would put a butane lighter in a vacuum chamber where the air could be sucked out; the butane lighter would stop working as the oxygen decreased.

6. a. The tank has to be filled up because the propane is reacting and forming carbon dioxide and water (and releasing heat in the process). The carbon dioxide and water vapor float off and mix with the air. The amount of gas in the tank decreases as it reacts (burns).

b. Nothing ever disappears. So it means that although the gas was no longer there, the products formed from it are still around somewhere.

7. Even though water molecules have oxygen atoms as a part of their make-up, water as a substance is not oxygen. Oxygen, as a substance, has a molecule made of two oxygen atoms combined. Humans and other animals cannot separate the oxygen atoms from the water molecules and make oxygen molecules in their lungs: this requires a chemical process, similar to the decomposition of water activity done earlier. (There is, of course, oxygen as a substance dissolved in water. This is why fish can extract oxygen from water in their gills. Fish do not change water into oxygen.)

8. Water as a substance is not any kind of mixture of oxygen and hydrogen gases. It is its own substance, totally distinct from oxygen gas or hydrogen gas. Even though the water molecule is made from oxygen atoms, water as a substance has no characteristics of the substance oxygen.

The ideas used in these last two questions have to do with the distinction between elements and compounds, which is not discussed explicitly in this unit. Here's the distinction: There are 92 naturally occurring types of atoms in our world. These 92 can make their own substance (called elements), or they can combine with each other to make zillions of other substances (called compounds). Elements are therefore made of only one kind of atom, although sometimes the molecule of an element is made from more than one of the same kind of atom. For example, the element oxygen is made from two oxygen atoms. The element carbon, in some forms, is made from 8 carbon atoms. Some elemental substances, like iron and sulfur, are crystals, or long structures of connected atoms.

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ashes. Some of the products are hazardous, in different ways. The carbon monoxide produced when gasoline, kerosene, or charcoal burn can suffocate people who burn them in closed areas. The sulfur dioxide produced from burning coal or oil can change to sulfuric acid in the air, returning to the ecosystem as acid rain. Other air pollutants come from burning fossil fuels. While burning reactions are all similar at a basic level—producing carbon dioxide and water—each has its own additional products.

Cluster 3—Lesson 17

An optional reading assignment is in the Appendix. It answers the question of how chemists learn what the formulas are for various chemical substances.

Also, there is an excellent article from *Discover* magazine that relates rusting to photosynthesis. A copy is in the Appendix.

A. KEY QUESTION: Allow students to share their thoughts with a partner and then perhaps with the class. No answers are expected and should not be given at this time.

Lesson 17: WHERE DOES IT GO?

If new substances are really made from the atoms of old substances…

if atoms are never destroyed in chemical reactions, but only rearranged to make new materials…

could it be true that the atoms that make up my body may have once been part of a dinosaur?

Could it be possible that some atoms that are part of me could someday be part of a spaceship that travels to distant galaxies?

And would it be true that the materials we throw in landfills don't just rot into nothingness?

Ⓐ

KEY QUESTION

Where do the materials and substances we use go when we are finished with them and throw them away?

TRY THIS

YOU WILL NEED

- a small beaker about 3/4 full of a solution of copper chloride
- a piece of aluminum cut from an aluminum pie pan
- model kit

A. Draw a data chart in your journal.

B. Observe the solution of copper chloride. It was made by dissolving a crystal of copper chloride ($CuCl_2$) in water.

Observe the piece of aluminum. It is a thinly rolled piece of metal. Its molecule has only one atom: Al.

Write the names, descriptions and formulas on your data chart for the reactants.

LESSON STATEMENT: Students will perform an experiment involving various forms of copper to see how copper can exist in both its elemental form and in a compound that looks nothing like it. Students use this experiment to explore ideas about how the atoms that make up earths' resources and life forms cycle into each other over time.
PURPOSE: To extend students' understanding of chemical reactions in the context of the earth's resources and life forms. To draw on and build students' ideas about recycling, landfilling, and resource conservation.
APPROX. TIME: 1 class period.

Copper chloride is a mineral found in the earth. You'll see in a few minutes where it gets its name (at least part of its name!)

C. Place the piece of aluminum into the copper chloride solution. Observe for several minutes. How many changes can you find? **Discuss these changes in your group.**

D. **Write a description of any product you notice.** One of them is coating the aluminum pie pan. Can you identify it? (Hint: What kinds of atoms could be present in this product?)

(B)

E. Your class will figure out, with your teacher's help, what the products are. **Make models of the reactants and products,** and draw pictures on your chart.

F. **Write a balanced equation** for this reaction.

THINK AND WRITE

Discuss these questions in your group before writing answers.

1. Would every blue solution work like this to form copper? Why do you think this?
2. What do you think you would get if you tried this experiment again but started with a solution of iron chloride instead of copper chloride?
3. There are many chemical reactions that can be used to obtain various metals from the rocks (ores) of these metals. You have used only one of them. What is the essential chemical property of a rock or ore in order to obtain a certain metal from it?
4. Where do you think the copper in the electrical wiring in your home came from? Explain your thinking.
5. Have you ever seen an outdoor copper statue or monument, or perhaps nuggets of copper near a mine in the Upper Peninsula? Can you relate what it looked like to this activity? Explain.

B. Students should easily see the copper metal forming on the pie tin and they will notice that the blue solution is clear. However, they may fail to recognize that the clear solution is not just water: it contains aluminum chloride. The teacher will need to help construct the explanation. For building the molecular models, students need three copper atoms, six chlorine atoms and two aluminum atoms.

The equation is $3CuCl_2 + 2Al \rightarrow 2AlCl_3 + 3Cu$. For both chloride compounds, the chlorine atoms each attach to the metal atom (copper or aluminum).

Optional experiment: After completing the experiment given here, you can have the class do another experiment with a copper solution, that shows a very interesting reaction—a reaction that forms stalactites and stalagmites as in caves. It is printed in the appendix.

QUESTIONS:

1. The blue solution must contain copper in a different chemical form from copper metal. If it were not present in the solution, then no copper would form in the reaction with aluminum.

2. If you started with iron chloride, you would get iron metal, assuming that this reaction actually does work. You certainly wouldn't get copper.

3. Rocks and ores must contain the desired metal in a different chemical form in order to get a new chemical form, namely the metal, from it. Then one must know the correct chemical process in order to get the specific chemical reaction to occur.

	REACTANTS		PRODUCTS	
COMMON NAMES	COPPER CHLORIDE	ALUMINUM	ALUMINUM CHLORIDE	COPPER
FORMULA	$CuCl_2$	Al	$AlCl_3$	Cu
PICTURE OF MODEL				
PICTURES OF MODELS FOR REACTION				
ACCOUNTING OF ATOMS	Cu 3, Cl 6, Al 2	Atoms Total 11	Al 2, Cl 6, Cu 3	Atoms Total 11
BALANCED EQUATION	$3 CuCl_2 + 2 Al$	$\rightarrow$	$2 AlCl_3 + 3 Cu$	

4. From the earth, either from copper nuggets or from ore or various rock forms. Ores that contain copper, such as copper sulfate, are chemically changed to form copper metal. This is often done in solutions using electrolysis. The metal is then melted and formed into useful materials.

5. Copper nuggets or copper statues have the characteristic copper metal color. But they can also have a blue or blue-green tarnish on their surface, from being exposed to oxygen in the air and water. This is a new form of copper formed when the copper in the statue or monument reacted with oxygen and/or water vapor in the air to form a new substance.

6. When you throw away materials made of copper, the copper will eventually react with air, water and other substances in contact with it and go into a different chemical form that does not at all resemble copper metal. It may then be dissolved in water and carried away to rivers, lakes and oceans, where it becomes available again to form copper metal under the right conditions.

6. What happens to copper wires, pots, jewelry, etc. when you throw them away?

7. Almost everyday you hear that you should recycle such things as aluminum, copper, paper, etc. Do you think this is important? Use what you have learned in this unit to explain why you think this.

   As you thought about the Law of the Conservation of Matter, you wondered if it could possibly apply to this situation. What do you think?

8. Now what do you think about the KEY QUESTIONS for this lesson? Here they are again:

   Could it be true that the atoms that make up my body may have once been part of a dinosaur?

   Could it be possible that some atoms that are part of me could someday be part of a spaceship that travels to distant galaxies?

   And would it be true that the materials we throw in landfills don't just rot into nothingness?

   Explain your thinking about each question.

In this cluster, you have learned where new substances come from and how they form. As you continue your research in the next lesson, think about atoms and molecules, and how new substances are formed.

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7. The earth's supplies of ores that contain many of the metals we use everyday is getting very depleted. When there is no more ore from which to obtain various metals, the only way to get them is to recycle them. The same is true of paper which is made from trees. We are cutting down trees faster than the new ones can grow. When we run out of trees, either substitutes must be found for paper as we know it today, or paper must be made from recycled paper. When the materials we use are just buried in large dumps with all our other trash, it is doubtful that the useful substances could ever be sorted out and refined in order to use them again. Hence, we must "sort" our trash before it is thrown out and recycle the useful materials so they will be around for future generations.

8. Yes, the atoms that made up dinosaurs now make up some portions of plants, animals, or non-living substances on the earth. When a dinosaur died—like any living thing—the matter that made up its body was recycled into other materials, by the processes of decomposition and growth of new plant material. Some of the matter that made up some dinosaurs changed into the fossil fuels we use today. Some of the atoms that make up the minerals in our bodies—minerals like calcium, potassium, zinc, iron, etc.—will return to the soil when we decompose, and be picked up in plants, which will be eaten by animals, including humans, etc. But some will also be mined and possibly used in spaceships. The materials we throw into landfills do not just "rot into nothingness."

Cluster 3—Lesson 18

Lesson 18: MORE RESEARCH!

To end this cluster, you will use your new knowledge of chemistry to continue your research. Consult your resources and try to find answers to the following questions. Each of these are big questions and could require a lot of research and information. Do the best you can with the time allowed!

Here are the questions you have already researched.

- the chemical name, and any other name it goes by.
- a complete description of the substance.
- what it's used for, present and past.
- any special importance to various cultures or ethnic groups.
- the history of its discovery and development.

Here are the questions for this cluster:

1. What is the chemical composition of this substance? Find the chemical formula if you can.
2. How do we get more of this substance? Try to trace its origin all the way back to its source. This may require several steps. If you find any chemical processes involved in its production, be sure to include these in your report.
3. How is this substance disposed of at the end of its useful life? There may be more than one process or more than one step in the process. You may find some chemical reactions that occur. You should include all of these facts in your report.

At the end of cluster four, there will be one more question to answer for your research: How is energy involved in the production and disposal of your substance.

Students have already researched the names of their substance and a description of the physical properties. They have investigated its uses and any special significance to various cultures or ethnic groups. Now they will find the chemical composition of the substance and what natural or earth materials it comes from. They will find out how it is or how it ought to be gotten rid of at the end of its useful life. They will be able to give the consequences of various methods of disposal.

LESSON STATEMENT: Students continue investigating their substance, this time focusing on the questions of this cluster—the chemical composition of the substance, where the materials come from and where they go after we finish using them.

PURPOSE: To expand students' knowledge of their assigned research substance based on new knowledge gained .

APPROX. TIME: 1 class period.

Cluster 4

Energy and "Boosters"

Cluster 4—Lesson 19

As the final cluster in this unit, students will be introduced to two other aspects of chemical reactions, energy and boosters (catalysts). Energy is a very abstract and difficult concept for students to understand. A common misconception is that matter changes into heat and light energy, accounting for the decreased mass of a pile of ashes after a fire. The cluster begins by allowing students to explore their thinking about familiar reactions that release energy.

Lesson 19: WHERE DO THE HEAT AND LIGHT COME FROM?

In the first three clusters of this unit you studied chemical reactions. You learned

- how weight changes during the reactions,
- where any invisible reactants and products come from,
- what the chemical formulas for the substances are, and
- what a balanced equation tells you.

In this cluster you will study the **energy** involved in some of these reactions.

Some reactions—such as burning butane, paper, or wood—give off heat and light. But many other reactions—such as reacting vinegar with baking soda or decomposing water—release no heat or light at all. Where does that heat and light come from?

KEY QUESTION

Where does the heat and light come from when things burn?

Let's begin by doing a little brainstorming.

LESSON STATEMENT: Students will brainstorm to generate lists of reactions that release energy and ways that this energy is used. They will consider whether heat and light released from burning substances actually comes from the substances and carries away the substances' weight (a common misconception.)

PURPOSE: To engage students with the question about where energy comes from that is released during burning. Lesson 20 develops an answer to this question.

APPROX. TIME: 1 class period

THINK AND WRITE

Make a chart like the one below. Then, in your group, discuss and answer the following questions:

REACTIONS OR PROCESSES THAT GIVE OFF ENERGY	WAYS WE USE THE ENERGY

1. a. Think of all the reactions you performed in this unit that gave off heat and list them on your chart.

   b. Many reactions or processes that you see around you every day also give off energy. Add as many as you can think of to your list. You may not realize it, but you depend daily on these forms of energy for many activities.

2. a. Think now of all the ways you use this energy and add them to your chart.

   b. Often, common things use energy in hidden ways. For example, the aluminum can that your soda comes in required energy to dig ore from the earth, transport it to a refinery, and melt it to form the can. Think of hidden energy uses for the items on your chart and write them down.

Probably one of the first things you associate with energy-releasing reactions are fuels. See how many of the reactions or uses of energy that you've listed involve fuels.

3. Circle each reaction in the first column that involves a fuel.
4. Circle each use in the second column that requires a fuel.

1. a. Students should readily come up with the reaction of burning butane. Another reaction that released energy was the rusting and the burning of steel wool. Some students may have noticed that the flask got warm when the steel wool was placed in it to react. Also, once the steel wool started burning, it glowed and released heat. Many students will not think about these. Some students may have noticed that the reaction between aluminum and copper chloride got very warm.

   b. The most familiar reactions are those that involve burning such as striking a match, burning paper, wood, gasoline, alcohol or other things. But there are others. Compost piles and decaying vegetation get very warm, often hot—and cellular respiration in our bodies produces enough heat to account for our body temperature. Plaster and many other substances get warm when they set. Also, friction produces heat; the appliances that cook food and heat water produce excess heat; fireflies produce light, as do light sticks—in fact, all light bulbs produce light, by changing electrical energy into light and heat energy. While we are primarily concerned in this unit about chemical reactions that release energy, rather than conversions of energy from one form to another, students may not be making this distinction yet.

2. a. This energy is used for cooking, heating our homes, producing electricity at the power plant (and consequently all the things electricity is used for), powering automobiles, etc.

   b. Hidden energy is involved in producing fabrics, plastics and just about every other substance around you. It is used in the harvesting of food as well as in preparing and preserving it and transporting it to consumers.

3. Answers vary but most reactions on student lists will probably be fuels.

4. Most uses of energy on student lists will require fuels.

5. Good fuels are substances which, when burned, release a lot of heat energy.

6. Answers will vary. Most students will have questions about what energy is and where the heat energy comes from, how it formed, etc. Do not answer these questions at this time. They will be answered in the next lesson.

7. Some students will answer that the heat and light comes from the wood that is no longer there. Others will know that the wood (combining with oxygen) has turned into carbon dioxide and water vapor.

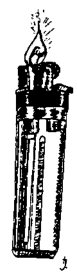
8. a. $2\ C_4H_{10} + 13\ O_2 \longrightarrow 8\ CO_2 + 10\ H_2O$

b. 8 carbon atoms, 26 oxygen atoms and 20 hydrogen atoms

c. The same number, 8 carbon atoms, 26 oxygen atoms and 20 hydrogen atoms.

5. Look at these two columns and try to decide what make a good fuel. List as many of these characteristics as you can.

6. If, as you brainstormed about and answered these questions, other questions came up about energy, write them in your journal.



A question you may have asked was, "Where does the heat and light come from when paper or butane or wood burns?" Does it come from the paper or the butane or the wood? Well, yes. But does the butane or paper turn into energy?

Here's another way to ask the same question: When a house burns to the ground and only a pile of burned wood and ashes is left, has the weight that's disappeared turned into heat and light?

7. Record in your journal what you think about this question at this point in the lesson.

❄ ❄ ❄ ❄

How can we find an answer to that question?

First, you already know that when something burns—whether it's butane, paper, or wood—carbon dioxide and water vapor are produced, that float off into the air. Also, when wood or paper burn, sometimes smoke is produced that floats off into the air. Smoke is tiny particles of dust.

But to many people, it doesn't seem possible that all of the weight that was in a house could float off into the air as gases or as smoke. They believe that the heat and light come from the weight of the wood or butane or paper. They believe that the weight of the wood or butane was changed into heat or light energy.

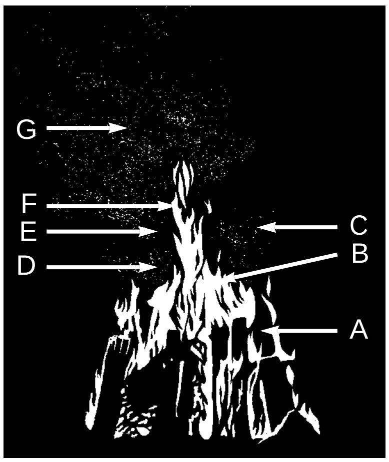
To think more deeply about this, think about the chemical equation for burning butane:

8. a. Write and balance the equation for burning butane. Refer to Cluster 3 if you need to.

b. How many oxygen, hydrogen, and carbon atoms are present in the starting substances before the reaction takes place?

c. How many oxygen, hydrogen, and carbon atoms are present in the ending substance after the reaction takes place?

9. Based on your answers to the above questions, what do you think:
   a. Were any atoms that make up butane or oxygen not accounted for in the molecules of the products?
   b. Was all of the weight of the original starting substances (the butane and the oxygen) accounted for by the products (carbon dioxide and water)?



   c. Could heat or light energy be composed of other atoms from the reaction that didn't make up the carbon dioxide or water?
   d. So would you say that heat or light energy has weight, or carries weight away from a fire? Explain.
   e. Using a table similar to the one below, label each "substance" with its corresponding letter from the drawing to the left. Then answer whether each is made of atoms and has weight.
   f. Does butane turn into heat or light?

	"SUBSTANCE"	LETTER FROM DRAWING	MADE OF ATOMS? (YES OR NO)	HAS WEIGHT? (YES OR NO)
REACTANTS	wood	C	Yes	Yes
	oxygen	B, E, or D	Yes	Yes
PRODUCTS	carbon dioxide	B, E, or D	Yes	Yes
	water	B, E, or D	Yes	Yes
	smoke	G	Yes	Yes
ENERGY	heat	*	No	No
	light	F	No	No

*Can't see heat, but could be anywhere around the flames

Explain your reasoning.

If butane does not turn into heat and light, then where does this energy come from? The next lesson will help you answer these questions.

9. a. No

b. Yes

c. No, because all the atoms were accounted for; no new matter was created, none was lost.

d. No, since all the weight comes from the atoms, and all the atoms of the reactants are accounted for in the products.

e. See chart for answers; oxygen, carbon dioxide and water vapor are all gases in the air and can therefore be either b, c, or d.

f. No, the atoms of the butane molecule come apart and rearrange with atoms from the oxygen molecules to form new substances, but none of the butane turns into heat and light. The heat and light must come from somewhere else.

Cluster 4—Lesson 20

For most students, the concept of energy is quite mysterious. Often, they will reiterate what they have been told, namely, that energy is not matter. But they will also say that when a substance burns, it went up as heat and light. This lesson is an effort to help students understand that energy is stored in substances in many different ways. It is only when it is released that you can observe it.

Typically, terms used to talk about energy are terms that are also used when talking about matter. For example, energy is stored and so is food. Energy is released and a bird can be released from a cage. Energy gets free as does a kite caught in a tree. Energy is given off but so is smoke from a fire. Energy is produced and so is fruit produced by a tree. Unfortunately, there do not seem to be any words that would make the distinction here between matter and energy. Some of the misconceptions students have could well be the result of the common terminology used to talk about matter and energy. Therefore, it is very important to stress and question students many times about their concept of energy, to help them distinguish it from matter.

Lesson 20: WHERE DOES FUEL GET ITS ENERGY?

Since energy is not matter, it is not given off during reactions in the same way that gases are produced and float away. Energy is not made up of molecules that leave the system. So the big question still remains:

Where does energy come from? (The same key question that we started this cluster with.)

The following familiar activity will start you thinking about this question.

TRY THIS

YOU WILL NEED

- rubber bands
- strong magnets
- matches
- paper
- forceps
- pan of water
- wooden splints
- butane lighter

A. Stretch and relax a rubber band without letting it go. What differences, if any, do you feel between its stretched and relaxed states?

B. Hold the rubber band without stretching it, then let it go. What happens?

C. Stretch the rubber band and release it towards a wall **(NOT TOWARDS ANY PERSON—YOU WOULDN'T WANT TO BE RESPONSIBLE FOR POKING SOMEONE'S EYE OUT!)** What happens now? What differences in reactions are there, if

LESSON STATEMENT: Students observe the energy stored in rubber bands and magnets and they consider conditions that vary this energy. They compare this stored energy to the chemical energy stored in substances such as matches, paper, wood and butane.

PURPOSE: To use the stored energy of magnets as a model for constructing new ideas about how chemical energy is stored and then released from fuels such as wood and butane.

APPROX. TIME: 1 class period.

any, between releasing it after stretching it a lot and just a little? Record your observations of what happened.

THINK AND WRITE

Discuss the answers to the following questions in your group. Then write the answers in your journal.

1. What difference did you feel in the rubber band when it was stretched compared to when it was relaxed?
2. What difference did you see between releasing the rubber band without stretching it compared to stretching it?
3. What difference did you see when releasing the rubber band stretched only a little compared to stretched a lot?
4. What did you do to the rubber band when you stretched it that accounts for its motion across the room?

If you find any of these questions hard to answer, you are not alone. Here's how scientists think about rubber bands flying across the room:

When you stretch a rubber band, you are giving it energy. When you let the rubber band go, that energy is responsible for it flying across the room and perhaps hurting someone or possibly moving something small if it hits it. You can't see the energy and—if the rubber band is held stretched apart by someone else or by some machine—you can't feel it **while it is stored in the rubber band.**

The idea of storing energy is very important in explaining where heat and light in fires come from. Stored energy is being set free when the rubber band flies across the room and hits something.

D. Take a few minutes to think of situations in which energy is set free. Since you know it was stored before it could get free, think about where it was stored. Make a chart and, in the first column, tell what form you see the energy take when it gets free.

1. When it was stretched, you could feel the tension in it. You felt no tension in it when it was relaxed.

2. When not stretched, the rubber band was limp. It just dropped to the floor. When stretched, it flew some distance, depending on how far it was stretched, and it could strike something and move it or possibly do some damage.

3. If you stretched it a little, it went only a short distance and probably did little if any damage. If you stretched it a lot, it went a lot farther and could possibly move something or do considerable damage.

4. When you stretched the rubber band, it got energy from you that was stored in the rubber band. (This answer is explored in more depth in the text that follows.)

A.

WHAT FORM DOES THE ENERGY TAKE?	WHAT SUBSTANCE STORED THE ENERGY?
Motion of rubber band	In the stretched rubber band
Human body moving, thinking, digesting food, circulating blood,...	Food
Light from flashlight	Flashlight battery
Moving car	Gasoline
Lights, radio and starting car	Car battery
Falling stone or other object	Higher position of the object
Heat and light	Substance on match head & wood from match
Heat and light	In the paper
Heat and light	In the wood
Heat and light	In the butane

B. You may want to do this as a teacher demonstration.

C. Be sure that all students feel the force of the magnets. There is no way to get anything out of this activity by just watching. Help students realize that the forces in magnets are not visible to the eye. They must be felt in order to know they are there. You may want to demonstrate that under certain circumstances, lines of force can be made visible. To do this, place the ends of the magnets about 2 inches apart. Cover with a piece of wax paper. Then spread a few iron filings very lightly over the wax paper. Do this with the poles of the magnets first attracting and then repelling.

Then, in the second column, tell what substance stored the energy. You may use the rubber band for your first entry. A sample chart with the first entry is shown below:

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WHAT FORM DOES THE ENERGY TAKE?	WHAT SUBSTANCE STORED THE ENERGY?
Motion of rubber band	In the stretched rubber band

Here are some familiar examples to see energy being freed. Try them to see if you can figure out where their energy was stored. Add each of them to your chart if they are not already there.

E. (In your head) hit a rock hard with a large sledge hammer. What energy did you observe? Where was it stored when the hammer was raised and ready to hit the rock?

F. Plug a light into a socket and turn it on. What energy do you observe? Where was it stored before the light was turned on?

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G. Light a match and observe it. What form of energy do you observe? Where was it stored?

H. Use forceps to hold a piece of paper with a pan of water under it. Then light the paper. **CAUTION: Tie back long hair to avoid flames.** Repeat once more with a wooden splint and with a butane lighter. In each case, decide what form of energy you see. Then try to decide where it was stored before it burned. Be sure to include each of these in your chart.

Since each of these substances gives off heat and light, you know that the energy was stored in them. But what does it mean to say that energy is stored in butane or in wood? That is the hard question.

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The energy was not stored as heat or light inside the substance, since the match, paper, wooden splint, and butane were neither hot nor glowing before they burned. So how was this energy stored? To help you answer this question, try the next part of this activity.

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I. You probably know that magnets attract each other if you hold their opposite ends together. Also, if you turn one magnet over, end over end, they repel each other. Try doing this now. Be sure that everyone in your group can feel both the attraction and the repulsion of the magnets.

(D) J. Place the magnets on the table or desk and hold them together so they repel each other while they are touching. Now let go. What happens? Everyone in your group should try this to feel the energy it takes to push them together. Record your results.

K. Repeat this process. This time move the magnets close but not touching—say 1 inch apart—and release. Record what happens.

L. Repeat this process several more times, with the magnets a little farther apart each time. Record what happens.

5. What difference did you observe as you placed the magnets farther and farther apart?

6. What can you conclude about the amount of energy stored in the magnets when they are pushed close together compared to when they are held not so close?

M. If more magnets are available, try holding four or six magnets together and then release them. What differs from when you held just two magnets together? Record your results.

N. Repeat the process several more times, again moving the magnets a little farther apart each time. Record the difference.

7. What difference didyou observe when you held four or six instead of just two magnets?

8. Did the magnets store energy? What evidence do you have of this?

9. Did the magnets lose any weight when they flew apart? What does this tell you about energy?

D. Students should record their observations in J, K, L, M and N.

5. They didn't move as far and were easier to hold.

6. There must be more energy stored in the magnets held close together.

7. More magnets produce a greater motion.

8. The magnets seemed to store energy, since when they were released, the magnets flew apart. The motion of the magnets is evidence that some energy was involved.

9. The magnets didn't lose any weight, as most students would guess. This means that the energy released did not come from some kind of conversion of matter into energy. Actually, in the case of magnets, the energy that is released is released as heat from friction on the table as the magnets move apart. In the case of the rubber bands, no energy is being released as they fly across the room—although their potential energy has been converted to energy of motion. The energy is given off when they hit something, again as heat from friction.

How are magnets like butane molecules?

Substances store energy very much like magnets do. Some molecules need less force to hold them together, and therefore store a small amount of energy. Other molecules need more force to hold them together, and therefore store a considerable amount of energy.

Butane molecules, paper molecules, and other fuels store a great deal of energy, which is released when they react with oxygen—when they burn.

Not all of the energy stored in butane molecules is released as heat and light, though. Some of it is needed to form the carbon dioxide and water molecules. In fact, when this chemical reaction takes place, some of the energy stored in the butane and oxygen molecules is used to form the carbon dioxide and water molecules, and what's left over is released as heat and light.

If we wrote this idea as an equation, it would look like this:

Energy in reactants	*equals* energy in products	*plus* energy given off
The energy stored in butane and oxygen	= the energy stored in carbon dioxide and water	+ the energy released as heat and light

How is this "equation" like the equations used to represent chemical reactions? In chemical equations, all of the atoms in the reactants (on the left side of the arrow) show up again in the products (on the right side of the arrow.) In this equation, all of the *energy* before the reaction begins shows up again after the reaction takes place. Some of it is in the new chemical substances, and some of it is given off.

10. Write an energy equation for burning paper.

11. Remember how chemical equations help explain conservation of mass? Since the atoms of the reactants is what has weight (or mass), and the atoms of the products are exactly the same, no weight (or mass) has been lost or gained. How does this "energy equation" show another kind of conservation?

10. Energy in the paper and the oxygen equals the energy stored in the carbon dioxide and water vapor (and possibly smoke and ashes) plus the energy given off as heat and light.

11. Since the energy before the reaction equals the energy after the reaction, no energy is lost or gained. This is an expression of the Law of Conservation of Energy. Energy is converted from one form to another, in this case, from chemical energy to heat and light, but it is never lost.

The next lesson is about the match that starts a fire. It gives a boost to get the burning reaction started, and the paper wouldn't burn without it.

But before we get to the next lesson, think about the house that burned down:

12. Write a short paragraph that explains what happens to the weight of all the wood in a house when it burns down. In your paragraph, talk about the heat and light energy given off, and whether the heat and light have any weight.

12. Students' paragraphs should include the ideas that any weight of the wood in the house is either in the pile of ashes, or floating in the air as smoke, water vapor, or carbon dioxide—as hard as this is to believe! The heat and light did not take away any weight or mass.

Cluster 4—Lesson 21

We are using the term "booster" to refer to anything that gets a chemical reaction started (it gives the reaction the boost it needs to make it happen). The term "activation energy" is not used in this unit, although this is essentially the set of concepts that we are dealing with.

A. The first set of questions in the lesson is intended to be used as discussion-starters. Allow and encourage students to speculate and present their ideas about each question. Answers will be constructed as the lesson proceeds. These questions also allow you to learn about students' thinking.

B. In explaining their thinking about why there isn't as much energy given off by a match as by a fire, students might suggest that a fire burns a lot longer, burns much hotter, and gives off more light.

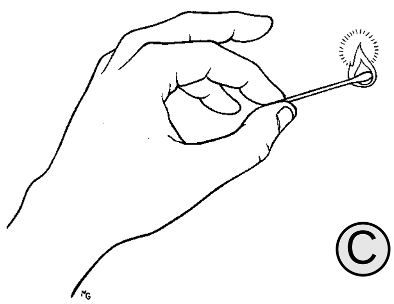
C. It is true that almost all of the energy released by a fire comes from the wood. We are using the terminology of "reasonable" to help students understand that scientific ideas are not dogma but based on reason.

Lesson 21: HOW DO CHEMICAL REACTIONS GET STARTED?

A Some people believe that the energy given off when wood or candles burn comes from the match that was used to start them. What do you think about this?

? ? ? ?

B Picture a burning match and a burning fire. Is there as much energy given off by a burning match as there is given off by a burning fire in a fire place? How can you explain your thinking?



If you think back to the last lesson and the idea that energy can be stored in substances, would you think it was possible that all of the energy released from the fire was stored in the match?

If it was all stored in the match, then what is the wood for?

C Does it seem reasonable to say that almost all of the heat and light of the fire come from the energy stored in the *wood,* not from the match?

Then why do you need a match? What does a match do? Of course it starts the fire. But it does this by giving the burning reaction a **boost to get started.**

Most chemical reactions don't start by themselves. Most need boosters.

Think about the idea of boosters for a minute. Picture a large boulder perched on top of a hill, about ready to roll down the side (maybe aimed at the Road Runner down in the valley). It's just sitting there, until… one little push, and it can do tremendous damage when it hits the ground way below.

What gave it the boost to get started? Did all of the energy given off when it hit the ground come from your little push?

LESSON STATEMENT: Students consider how paper and other fires get started, and construct an explanation of why many reactions need "boosters."

PURPOSE: To use familiar reactions to explore the role of "boosters" in chemical reactions.

APPROX. TIME: 1 class period.

D Can you think of other examples of things that need boosts to get started? Brainstorm on this for a few minutes.

? ? ? ?

How about the student who's having a hard time with his or her homework. Sometimes if someone comes along and gives them a little help, then they get started and do O.K. with the rest of the homework. They get a boost. Did all of the effort involved in doing the homework come from the person who helped a little at the beginning?

KEY QUESTION What does a booster do in a chemical reaction?

Try to answer this question for the example of a student who needs a little help to get started:

1. What does the "boost" do for the student who is having a hard time getting started on her or his homework?

Let's look closely at a boosted reaction that you've done already, to think about why boosters are needed in chemical reactions.

E

THE RUSTING REACTION THAT NEEDED A TORCH

Remember when you watched as steel wool turned *black* as it was heated vigorously by a torch (or Bunsen burner)? Think for a minute about this chemical reaction:

2. How was this different from the normal rusting reaction?
3. How was it similar?
4. Did the steel wool weigh more after the reaction? Why?
5. Was the torch (or Bunsen burner) needed throughout the entire reaction?

To check on the last question, try the experiment again.

D. Examples of processes that need boosts:

• Explosions. Dynamite, for example, is started by a small fuse, but gives off a tremendous amount of energy in its explosion, enough to level big buildings or blow out the sides of mountains.

• Other burning reactions. The butane lighter needs a boost to get started. What is it? (This is talked about later in this lesson.)

• A lawnmower needs a boost to get started, by pulling on the cord. The energy used to pull on the cord is small in comparison to the energy that drives the lawnmower during the entire time it is mowing grass.

• A car needs a boost from a starter motor to get it going. When the key is turned, a small electric starter motor next to the engine, that runs off the battery, starts the engine turning. (This is an analogy to boosters needed for chemical reactions, like the student studying and the boulder falling—none are chemical reactions, but help students construct the idea of "giving a boost.") Inside the engine, a spark is used to boost the gasoline and air mixture, which explodes, giving off considerably more energy than what was given off by the spark. A student or a team might like to research how an internal combustion engine works and report on it to the class. They might do this research by interviewing others (parents, older siblings, other family members, friends) who know about cars.

1. There are several possible answers. If the student doesn't understand the homework, then the "boost" might be a little explaining and teaching about the homework, enough so that they learn how to do

the homework and can continue by themselves. If the students doesn't have enough motivation to get started, then the "boost" might be a little encouragement or some kind of incentive.

E. You should do this experiment again, to show students how the steel wool glows after the bunsen burner is removed. The bunsen burner provides the initial boost to start this reaction, and the glow is the energy given off that provides the ongoing boost for small portions of steel that are reacting.

2. Some ways in which it was different included that normal rusting doesn't require added heat; normal rust is reddish brown, not black, and normal rusting takes longer.

3. Both reactions are between iron and oxygen, that is, the reactants are the same.

4. Yes. The reaction produced a new substance that was a combination of the iron in the steel wool and oxygen from the air. Since oxygen has weight and has "joined" the iron, the new substance (iron oxide) weighs more. Students might think of this as the black substance being added to the outside of the steel wool, and therefore it weighs more; but this is not the case. In fact, some of the iron is replaced by the iron oxide, which weighs more than iron.

5. No. Once the reaction started, it gave off its own energy, some of which was used to boost unreacted parts of the iron.

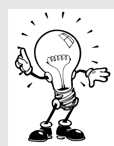
6. Yes. The bunsen burner's heat started the iron and oxygen reaction.

7. Yes. The evidence is that it glowed.

TRY THIS

TEACHER DEMONSTRATION

- steel wool
- Bunsen burner or propane torch
- ring stand and clamp, or something to hang the steel wool from



CAUTION!

DO NOT TOUCH THE STEEL WOOL!
The reaction is probably not finished even when it looks like it is, and the steel wool will still be hot.

A. Darken your room, if you can, so you can observe the energy involved in this reaction.

B. Watch closely as your teacher begins to heat the steel wool. After a moment of intense heating, the flame can be removed. Record what you observe.

C. After the reaction seems to be completed, turns the lights back on in the room and observe the steel wool carefully. Record your observations.

D. Go back to number 5 above, and change your answer if you need to.

6. Was there a booster in this reaction? If you think there was, what was it?
7. Did this reaction give off energy? What evidence do you have of this?
8. How is this reaction like burning?
9. Think of this reaction as happening to small pieces of iron throughout the steel wool: iron reacts with oxygen to form iron oxide, a black powdery substance. Why does the reaction eventually stop?
10. Why does it take heat to start this reaction? That is, why is the boost needed? *What's your guess?* Think about the molecules of iron and oxygen coming together to form iron oxide molecules.

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The last question is really difficult. Here's how scientists think about why boosters are needed:

Remember when you took apart molecules of reactants and put them together again to form molecules of products? In the actual chemical reaction, no one's hands take apart molecules and rearrange the atoms, of course.

(F) For the atoms of one molecule to rearrange themselves with the atoms of another molecule, the two molecules have to get very close together. Take baking soda and vinegar, for example. Put the two in the same bottle, mix them together, and a reaction just starts. No booster needed. At the molecular level, baking soda molecules and vinegar molecules get close together, close enough so their atoms can rearrange and make new molecules. The key here is that the molecules of baking soda and vinegar *have to be very close together.*

The same is true with iron and oxygen. Put the two in close contact, and rusting starts. Not the intense-heat rusting that produces the black product, but normal rusting. It happens to bikes, to tools, to cars. We have to protect iron and steel with paint and other coatings so they don't rust.

But not all reactions start immediately, without any help, without any boosters, like baking soda and vinegar or iron and oxygen. Butane doesn't just spontaneously ignite and burn. Good thing!

Why doesn't it start spontaneously? Could it be because butane and oxygen molecules can't get close enough together? If that was so, then what would a booster do?

11. Go back to question 10 and add to it, if you want.

But wait. Maybe you're thinking that it seems like butane molecules and oxygen molecules do mix together—when you open the butane lighter and some of the butane evaporates out of the container and goes into the air. Then butane molecules should be close to oxygen molecules. So why doesn't the reaction start by itself?

Or what about paper. It needs a booster. But it seems like oxygen molecules are floating all around paper.

8. It required a boost of heat to get it started; it gives off energy (heat and light); oxygen is one of the reactants.

9. Eventually all of the iron in the steel wool that is exposed to air reacts to form the black substance.

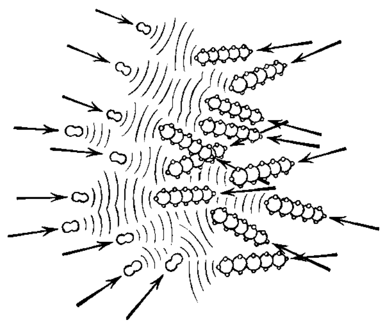
10. This question is just for speculation at this point. The answer is constructed as the lesson continues.

F. There may be some boost needed to get the vinegar and baking soda reaction started, that comes from the heat of the vinegar liquid (vinegar in the bottle is really a mixture of mostly water with some vinegar in it.)

11. Students may add that a booster pushes the molecules closer together.

Think of the paper sitting on your desk. Oxygen molecules must be getting fairly close to it. But it doesn't just start on fire.

Although air breezes move across pieces of paper and sticks of wood all the time, it's not at this level that we need to look. We need to look at the level of individual molecules.

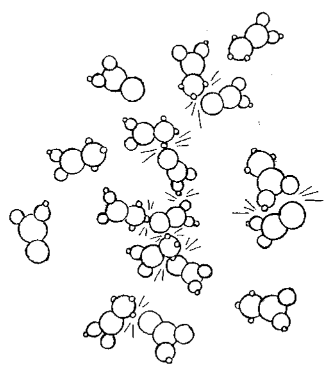


Butane and Oxygen molecules need a push to get them close enough to react.

Individual molecules of butane and oxygen apparently can't get close enough to each other, or hit hard enough, to let their atoms rearrange. A booster "pushes" them together.

What keeps them from getting as close as they need to? Good question. Some molecules tend to push away from each other, like magnets that repel, and keep each other far enough apart so they can't react.

When heat is the booster, it makes the molecules move faster, and push harder against the force that repels them, so they can get close enough to react.



Vinegar and Baking Soda molecules move close to each other.

And when they react, wow! Paper and oxygen, after they get started, give off lots of energy. Dynamite, whatever that chemical reaction is, releases a tremendous amount of energy!!

12. Use the ideas written above—about why boosters are needed in chemical reactions—to explain why a booster is needed to start the iron and oxygen reaction that you observed above.

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ANOTHER BOOSTED REACTION: STRIKING A MATCH

We've talked about how a match is needed to start a fire. But what about starting a match? This may sound silly, but have you ever thought about why you strike a match? What are you doing to the match when you strike it?

12. Students should say that a booster is needed to get certain molecules close enough to each other to begin the process of rearranging of atoms.

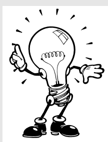
G. Students should observe carefully the match before it is struck.

Let the students speculate about the process of lighting the match and discuss it in their groups without any clues at this time. Even though striking a match is very familiar to students, most have never thought about how heat is provided to get the reaction started. This will be new and intriguing knowledge for most students.

TRY THIS

YOU WILL NEED

- wooden matches and a rough surface
- safety matches
- pan of water



SAFETY!

Tie back long hair to avoid flames.

A. Look carefully at a match before burning it and draw a picture of it.

B. Strike the match and observe what happens. Record your observations. You may need to repeat this several times in order to make good observations. If possible, use both a wooden kitchen match and a safety match. What differences do you observe in the two types of matches?

C. In your groups, discuss what happened: List all the factors involved in starting the reaction, that is, in lighting the match.

THINK AND WRITE

13. Describe the substances that react when a match burns. Use your observations of the match to think about what the substances are.
14. Why did you have to rub the match on a rough surface? (Hint: Rub your hands together very briskly and observe what happens.)
15. What was the booster for this reaction?
16. Is is possible that all the heat produced when burning the match may have come from striking it? How can you tell?

When you strike a match, you rub its tip on a very rough surface. This generates some heat, just as when you rub your hands together on a cold day in order to warm them. The small amount of heat, generated by the friction of rubbing, is enough to cause the chemicals in the match tip to react. These chemicals release enough heat to start burning the match wood.

13. Descriptions will vary. If students are using both kinds of matches, have them observe the differences in the two carefully. Safety matches usually have one of the chemicals needed to light the match on the strike area so you can’t accidentally light the match on just any surface.

14. To light the match, you supply a little heat from friction (the “boost”) to get the chemical reaction started.

15. The booster was the heat provided by the friction.

16. No. Friction can produce the kind of heat you feel when you rub your hands together—not nearly as much as given off by the match. The extra energy given off by the match was stored in the match chemicals and the wood or paper.

17. Again, the "booster" is heat. It is provided by turning a rough wheel (sometimes enclosed inside the lighter and not visible) against a piece of flint which is a hard stone. This friction creates enough heat to ignite the butane gas which is allowed to escape from the lighter when the lever is held down. In order to get the lighter to light, one must simultaneously hold down the lever to release the fuel and turn the wheel to create heat by friction. Even though butane is a liquid in the lighter, it escapes as a gas. This is because butane is a gas at room temperature and is compressed to a liquid when it is put inside the lighter.

THE BUTANE LIGHTER: WHAT'S THE BOOSTER?

Here is a check to see how well you understand boosters.

D. The booster in the butane lighter resembles the one used when striking a match. Examine the lighter and figure out what it is and how it works.

17. Tell what the booster is when lighting the butane lighter. Then explain how it is provided.

So far, all the boosters we have talked about provide heat to start the reaction. In the next lesson, you will look at other kinds of boosters that help start chemical reactions.

Cluster 4—Lesson 22

Lesson 22: OTHER KINDS OF BOOSTERS?

In the last lesson, you learned that many chemical reactions require boosters in order to start. So far, all the boosters you have observed were heat energy. Are there any other kinds of boosters?

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KEY QUESTION

What kinds of boosters, other than heat, can help start chemical reactions?

Here's the problem for the first part of this lesson: What's the booster in the decomposition of water reaction?

Remember this reaction?

1. Try to write the chemical equation for this reaction. Think about the reactant and the products. Look back to Cluster 3 if you need to.
2. Do you have any thoughts about what the boosters might be? Write your guesses in your journal.

TRY THIS

To figure out what the boosters are, you might try setting up your own experiment. The **question** you need to answer is:

Will this reaction work if any of the components are not used? If it works only with a certain component, that must be the booster.

A. First, think about how you did the experiment earlier, and draw a picture of the set-up in your journal. List the equipment you will need.

B. Think about what might be a booster, and set up the experiment without using that component. If you think there is more than one booster, you will

A. KEY QUESTION: Some students might mention the terms "catalyst" or perhaps "enzyme." Don't give students any clues here. Students will construct new knowledge as the lesson proceeds. This is a good opportunity to observe student thinking and decide how much they know already.

For the decomposition of water, students will use sodium sulfate dissolved in the water as an electrolyte. The sodium sulfate helps the current flow through the water.

1. $2H_2O \rightarrow 2H_2 + O_2$ Some students will simply write that water produces hydrogen gas and oxygen gas. The reason for this question is to remind them of what the reactants and products are, so they recognize that the sodium sulfate used in the experiment is not a starting or ending substance. But don't tell them this now: They construct this idea as the lesson progresses.

2. Students should make a prediction here, to help them focus their attention on the experiment.

Help students to design the experiment so that they try it once without electricity, using the sodium sulfate, and once without the sodium sulfate, using the electricity. Both the electricity and the sodium sulfate are boosters. The electricity is an energy booster, making the water molecules split apart. The energy that was originally stored in the battery is now stored in the hydrogen molecules and oxygen molecules: They have more energy than the water did, which is why the battery is needed. This can be seen if the hydrogen and oxygen are mixed and ignited, creating a large explosion and producing water.

LESSON STATEMENT: Students will design their own experimental procedure for decomposing water in order to decide which substance is the "booster". They will react iron and oxygen and investigate the role of salt water in the reaction.

PURPOSE: To extend their knowledge of "boosters" to include chemical substances and to perform carefully designed experiments that allow students to decide which substances are "boosters".

APPROX. TIME: 2 class periods.

This decomposition reaction is especially colorful if you put some BTB solution in the water. It turns yellow where hydrogen gas is produced, and blue where oxygen is produced. But we don't recommend doing this during the actual lesson, since it is confusing to the students, who are trying to figure out something about boosters. The BTB is not a booster: It just indicates that an acid is being produced where the oxygen forms. The reaction taking place where oxygen forms is actually $2H_2O \rightarrow O_2 + 4H^+ + 4e^-$ (that is, 2 water molecules react to form one oxygen molecule, 4 hydrogen ions (a hydrogen atom without its electron) and 4 free electrons. The free electrons flow through the wire.) At the other terminal, hydrogen gas is being produced by the equation $4H_2O + 4e^- \rightarrow 2H_2 + 4OH^-$ (that is, 4 water molecules are energized by 4 electrons from the circuit, producing 2 hydrogen molecules and 4 OH ions, which travel through the water and recombine with the hydrogen ions to form water.

Some students believe that the electricity that flows through the water is actually a substance that produces the bubbles. It is not a substance but a source of energy for making the reaction go. This is a critical idea for many students, since they see the bubbles being produced at the end of the battery, and see them stop when the battery is disconnected.

Some students may say that the reaction won't work without water, so it must be a booster. Of course the reaction won't work without the water, since the reaction is water breaking apart into hydrogen gas and oxygen gas. The water is just the reactant—the starting substance.

need to set up the experiment a couple of times to try different boosters.

C. Conduct the experiments. Record your observations in your journal.

If you want help setting up these experiments, here are some possible approaches.

Experiment 1

Question: Is electricity a booster?

Procedure: Set up the experiment as in Lesson 3, but don't attach the wires to the battery. Place the lead in the water and look for bubbles.

Results:

Experiment 2

Question: Is sodium sulfate a booster?

Procedure: Set up the experiment as in Lesson 3, including attaching the wires to the battery. But don't add any sodium sulfate to the water.

Results:

3. Let's think about whether electricity was a booster.
   a. Would the reaction work if the battery was disconnected?
   b. So is electricity an energy booster, like heat? Or is the electricity something that flows into the water to make the hydrogen and oxygen gas?

You can answer this now because you know where the hydrogen and oxygen come from—from the water molecules! They don't come from the electricity.

So the electricity must be a booster like heat from a match. The reaction doesn't work unless electrical energy makes it work.

Was the pencil lead a booster? No. It's just a way to conduct the electricity into the water. If you place the bare wires into the water without the pencil lead, you'd still get bubbles of some kind.

What about the sodium sulfate? Does the reaction work without it? Not very well. But is the sodium sulfate a part of the reaction? Look at the equation:

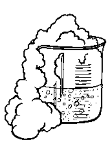
$$2H_2O \rightarrow 2H_2 + O_2$$

4. Is the sodium sulfate a reactant? Is it a product?
5. Would you say that the sodium sulfate is still in the water at the end of the reaction? Explain why you think this.
6. Is the sodium sulfate an energy booster? Why not?
7. Fill in the following chart.

COMPONENT	REACTANT, PRODUCT OR BOOSTER?	WHAT EVIDENCE DO YOU HAVE?
water	Reactant	Level decreases over time
electricity	Booster	Reaction doesn't work without it
sodium sulfate	Booster	" "
pencil lead	Neither	Just conducts electricty into the water
hydrogen gas	Product	Bubbles produced
oxygen gas	Product	Bubbles produced

Sodium sulfate is not an energy booster, but it is a booster—a different kind. It's a matter booster. That is, sodium sulfate is matter (made of molecules), not energy. Many reactions need matter boosters to work.

Here's another example of a matter booster:



TRY THIS

YOU WILL NEED

- 1 tbsp iron power
- 1 tsp. sand
- Ziploc bag or other plastic bag with tie
- 1 ml salt water solution

3. a. No.

b. Electricity is an energy booster, like heat. The hydrogen and oxygen gas do not flow out of the wires, although some students may think this.

4. No—neither.

5. Yes—it didn't change into any new substances.

6. No—it's not energy; it's matter, made of molecules. Since it is not a reactant or product, it is a booster—a matter booster.

A. Place the iron power, salt water, and sand in the plastic bag. Do not close the bag.

B. Use one hand to hold open the bag and the other to gently knead its contents for several minutes to thoroughly mix them.

C. Feel the bag. What happened?

D. Press all the air out of the bag and seal it very tightly. Knead the contents for several more minutes.

E. Feel what happens. Write your observations in your notebook.

F. Open the bag again and knead the contents for several more minutes.

G. Feel what happens. Write your observations in your notebook.

THINK AND WRITE

Discuss and then write your answers to the following questions.

8. What happened when you pressed all the air out of the bag and sealed it?
9. What happened when you let air back in the bag?
10. What substance in the air does this reaction need?
11. What in the bag reacts with the oxygen? (Hint: You observed this reaction in various ways in every cluster of this unit.)
12. What product is forming?

◆◆◆◆

Yes, this is the rusting reaction! It produces heat. But there are two other substances in the bag. How can you figure out whether one of them is a booster?

Write an experimental plan in your group to find out which is the booster, and check it with your teacher. The plan will be similar to the experiments you did with decomposing water and adding salt.

8. The bag got cool (because the reaction stopped).

9. The bag got warm (because the reaction started again).

10. Oxygen from the air.

11. The oxygen is reacting with iron powder.

12. Rust.

Students must do the experiment twice more in order to find out what the "booster" is, once with the salt water but no sand, and once with the sand but no salt water. Since salt water is the "booster," the reaction will not work without it.

I. Use your plan to conduct your experiment.

13. a. Which substance do you believe is the booster? Explain how you used your experimental evidence to determine which substances (if any) are boosters.

b. Is it a matter booster or an energy booster?

14. Which substances are not boosters? Explain your thinking. Fill in the following chart.

COMPONENT	REACTANT, PRODUCT OR BOOSTER?	WHAT EVIDENCE DO YOU HAVE?
iron		
oxygen		
rust (iron oxide)		
sand		
salt water		

15. If one substance is not a reactant, product, or booster, then what could be its role? Hint: It functions the same as bricks in a pizza oven or the rocks used to keep the heat in a sauna.

16. Does this reaction give off energy? Where does it come from?

Can you think of a practical use for this reaction?

Here's one: To warm cold hands or toes in winter, you may have bought commercial hand or toe warmers. Many of these warmers use the reaction of iron rusting to make heat. The warmers come in small, sealed packages. To use one, you open the package and shake it a little before putting it into your shoes or mittens. Since salt water dries very quickly, most commercial products use charcoal as the booster, premixed with iron powder before packaging. Your teacher may have a sample for you to examine.

17. Why doesn't the reaction in the commercial warmers start until you open the package?

18. Usually the commercial product states that it can supply heat for about six hours. Suppose you went skiing for two hours and wanted to use the toe warmers again later. Suggest what you might do to stop the reaction for awhile.

13. a. Salt water is the "booster" since nothing happened without the salt water. The reaction could not get started.

b. It is a matter booster.

14. The sand was not a "booster" since the reaction occurred even if the sand was not there. It was not needed in order for the reaction to get started.

15. The sand retains the heat that is formed so you can feel it better and longer. They should be able to figure this out if they can figure out why bricks are sometimes used in ovens or saunas where their purpose is to retain heat longer.

16. Energy is released as the product forms. It comes from the chemical substances, iron and oxygen.

17. There is no oxygen available.

18. Put them in a Ziploc bag, squeeze all the air out and seal it very securely. Then take them out again when you want to use them. Obviously, the manufacturers do not tell you this since they would sell fewer products.

19. Iron rusts much faster near the oceans where there is salt in the air or in winter when salt is put on icy roads.

20. Probably because heat is formed slowly and in small quantities and it dissipates immediately. It is not stored so it is generally not observed. The sand in the student reaction absorbed the heat and retained it longer.

B. An optional experiment about enzymes is found in the yellow lab prep pages for this lesson.

You were probably surprised to find such a common reaction used in many commercial hand and foot warmers. There are many other everyday situations where iron rusts: cars, lawn mowers, snow blowers, tools, and pipes all rust when exposed to air.

19. Why does iron rust much more readily near oceans or lakes than in deserts?

20. You usually don't notice heat being emitted in these every-day rusting situations. Can you think of some reason why you don't?

(B) There are many, many reactions that require matter boosters to make them happen. Many occur in your body all the time. The matter boosters are called enzymes in your cells. Matter boosters outside of living things are called catalysts.

Millions of enzymes in the human body act as boosters to start the chemical reactions necessary for your body to function properly. The absence or improper functioning of these enzymes cause many serious diseases.

Energy and other boosters in chemical reactions are very complex topics that you have barely scratched the surface of in this study. But you do see by now that there is much more to chemical reactions than just the substances written in chemical equations.

You are now ready to investigate how the production and disposal of your research substance uses boosters.

Cluster 4—Lesson 23

Lesson 23: RESEARCH SUBSTANCE—ANY BOOSTERS?

You are now ready to finish your research! You have learned many things about your substance:

- the chemical name and any other name it goes by;
- a complete description of it;
- its use, present and past;
- its importance to various cultures and ethnic groups;
- the history of its discovery and development;
- how we get more of this substance; and
- how we dispose of this substance at the end of its useful life.

Now you are ready to discover how making and discarding your substance uses energy. Use the knowledge gained in this cluster to help you answer these final questions about your substance. Then get ready for the grand finale!

1. How does producing your substance use energy? What form of energy does it use and how is it supplied?
2. Which boosters does the production of your substance require? Remember that boosters can be energy or matter. Include any information you can find as part of your report.
3. How does eliminating your substance involve energy? What form of energy does it use and how is it supplied?
4. Even disposal can require boosters. Investigate what these boosters are and include them as part of your report.

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Students will use the information learned in this cluster as they do the final bit of research on their substance. They will use the information they learned earlier about the manufacturing of the substance from its raw material and find out how energy and/or catalysts are involved in the process. Likewise, they will find out how energy and/or catalysts are involved in the disposal of the substance, be it reusing, recycling or trashing. They can compare various disposal methods and find out which is more efficient. Some of this information may be quite difficult to find, especially for disposal methods. Encourage students to do the best they can in their search for this information.

LESSON STATEMENT: Students will continue the investigation of their substance and find out how energy is involved in its manufacture as well as any special conditions or boosters. They will also investigate how energy or special conditions are required for its disposal.

PURPOSE: To investigate the energy requirements and any special conditions (boosters) required for the manufacture and disposal of the substance.

APPROX. TIME: 1 class period.

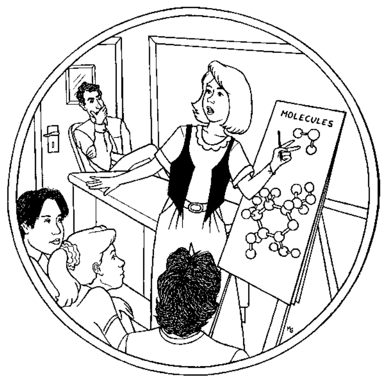
Cluster 4—Lesson 24

This is the culminating activity of this entire unit. Encourage different groups to use various methods of presentation. Also, depending on your specific situation, students can choose from a variety of audiences with whom to share their research. Be sure that students get all the proper approvals in advance.

Presentations should be roughly divided into the specific questions of each cluster:

1) Common and chemical names for the substance
2) Uses, including cultural and historic
3) Source of the substance and disposal methods
4) Energy and "boosters" involved in the manufacture and disposal of the substance

Lesson 24: THE GRAND FINALE OF YOUR RESEARCH



One of the major activities of science is to share your research with others so they, too, can learn about, benefit from, and question your findings. Scientists do this in many ways, some of which include writing articles, talking at meetings, giving slide presentations or poster sessions, preparing videos, etc. Choose one method for your presentation, either one mentioned above or that you think of yourself.

Having decided how you want to present your material, you must now decide to whom you would like to present it—your class, another class in your school, or perhaps the entire student body.

Perhaps it is possible for you to set up a poster session in the hallway or cafeteria in order to share it with other students. You may be able to visit another science class with your slide presentation or video. Of course, you must get permission from the teacher or supervisor if you plan to visit another class or use a hall or cafeteria display.

Think about the possibilities and each of the following:

- how you will present your research findings—whether the necessary equipment is accessible and needed supplies available;
- whom you will share it with and whether you have the necessary permission; and
- when you will make your presentation.

Write a plan and get approval from your teacher before you start preparing. Then get ready for your grand finale!

LESSON STATEMENT: Students will share their research findings, using any method and audience they choose.

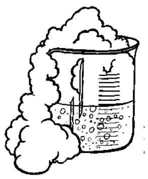
PURPOSE: To communicate the results of their research to others; to choose an appropriate method and an audience suitable for the presentation.

APPROX. TIME: Varies depending on types of presentations.

Appendices

Lesson 17: THE CAVE
An Optional Activity

Have you ever been inside a natural cave and observed the beautiful crystalline formations hanging from the ceiling or growing from the floor? Try the following activity and see if you recognize what is going on.



TRY THIS

YOU WILL NEED

- 250 ml beaker
- Wire screen, 10 cm by 10 cm
- Household ammonia, NH_4OH
- Large crystals of copper sulfate, $CuSO_4$

Obtain or prepare a chart as before.

A. Write the names, formulas (see list above) and description of each reactant on your chart.

B. Place about 30 ml of household ammonia in a 250 ml beaker.

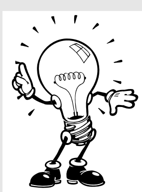
C. Fill the beaker to the top with water and stir well.

D. Bend the screen to make a depression in it so that when it is placed on top of the full beaker, the middle of the screen will rest in the solution. Notice that the screen is there simply to hold the crystal and does not react.

E. Place 1 or 2 fairly large crystals of copper sulfate in the middle of the screen.

F. Now don't disturb it and watch what happens.

1. Describe carefully in your journal what you see happening. Contrast the physical appearance of the visible products with the appearance of the copper sulfate crystals.



SAFETY!

Wear safety goggles during this experiment!

Ammonia has a very strong smell. Be careful not to breathe too much of it.

The stalactites (formations growing from the top) and stalagmites (formations growing from the bottom) are similar to the reactions that form caves.

2. Where does the material in these formations come from? In your group, try to figure out an answer to this question. Think about chemical reactions.

In this reaction, copper from the copper sulfate crystals combines with the OH from the ammonia to form copper hydroxide, which is a solid. This solid is what you see forming in the beaker. In caves, as underground water runs through the cave, some substances in the cave walls and floor dissolve in the water. Then, as the amount of water that is flowing slows down, crystals of new substances form, as in this experiment.

Try to fill in the rest of your data sheet including balancing the equation. The solid growing in the beaker—copper hydroxide—has the formula $Cu(OH)_2$. The other product, which cannot be seen, is dissolved in the water. It is a molecule made of the NH_4 (left over when the ammonia comes apart), and the SO_4 (left as the copper separated). To balance the equation, you need 2 molecules of ammonia.

In a class discussion, answer the following questions:

a) Tell where the reactants are at the beginning of this reaction.

b) Tell where are the products are at the end of the reaction.

c) Are there any invisible reactants or products?

d) How does the Law of the Conservation of Matter apply in this case? Explain your reasoning.

Plan a little class skit that will demonstrate how this reaction took place. Use different students to represent each atom of the reactants, and have them combine to form the molecules of the reactants. How many students do you need? You will need to find a way to show what atoms or molecules each student represents. Then you need to find a way to show what happens when reactants form products. Use your imagination! You may want to form several groups to work on different parts before putting it all together.

Lesson 17: OPTIONAL ACTIVITY

Lesson 17: THE CAVE
An Optional Activity

Have you ever been inside a natural cave and observed the beautiful crystalline formations hanging from the ceiling or growing from the floor? Try the following activity and see if you recognize what is going on.

TRY THIS

YOU WILL NEED

- 250 ml beaker
- Wire screen, 10 cm by 10 cm
- Household ammonia, NH_4OH
- Large crystals of copper sulfate, $CuSO_4$

Obtain or prepare a chart as before.

A. Write the names, formulas (see list above) and description of each reactant on your chart.

B. Place about 30 ml of household ammonia in a 250 ml beaker.

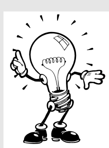
C. Fill the beaker to the top with water and stir well.

D. Bend the screen to make a depression in it so that when it is placed on top of the full beaker, the middle of the screen will rest in the solution. Notice that the screen is there simply to hold the crystal and does not react.

E. Place 1 or 2 fairly large crystals of copper sulfate in the middle of the screen.

F. Now don't disturb it and watch what happens.

1. Describe carefully in your journal what you see happening. Contrast the physical appearance of the visible products with the appearance of the copper sulfate crystals.



SAFETY!

Wear safety goggles during this experiment!

Ammonia has a very strong smell. Be careful not to breathe too much of it.

Some students may have visited Mammoth Cave or other natural caves, in which case this activity will have special interest. The growing crystals are copper hydroxide, $Cu(OH)_2$ which is a greenish color rather than the same blue as the crystal of copper sulfate. At first when the precipitate forms, it may appear to be the same color as the copper sulfate crystals. Students can dump the solution at the end of the experiment, at which time they will clearly see that the color of the final product is different from the reactants. At the end, the ther new product, ammonium sulfate, $(NH_4)_2SO_4$ is present in the solution as a colorless dissolved solid.

Once again the teacher will have to help construct the explanation of the chemical change taking place. As students build the molecular models of the reactants and products, they should see how the atoms rearrange themselves to form new molecules. In this reaction, "chunks" of atoms stay together—the NH_4, stays together, as well as the SO_4 and the OH.

For building the molecular models, students need one copper atom, one sulfur atom, six oxygen atoms, 2 nitrogen atoms and ten hydrogen atoms.

Depending on how well your students understand this cluster, you may want to skip the data sheet altogether and just do the class skit.

DISCUSSION QUESTIONS:

1. Students should describe the formation of the stalactites and stalagmites in words that indicate that some new solid substance is being formed—new because the color and texture are significantly different from the original copper sulfate crystals.

The stalactites (formations growing from the top) and stalagmites (formations growing from the bottom) are similar to the reactions that form caves.

2. Where does the material in these formations come from? In your group, try to figure out an answer to this question. Think about chemical reactions.

In this reaction, copper from the copper sulfate crystals combines with the OH from the ammonia to form copper hydroxide, which is a solid. This solid is what you see forming in the beaker. In caves, as underground water runs through the cave, some substances in the cave walls and floor dissolve in the water. Then, as the amount of water that is flowing slows down, crystals of new substances form, as in this experiment.

Try to fill in the rest of your data sheet including balancing the equation. The solid growing in the beaker—copper hydroxide—has the formula $Cu(OH)_2$. The other product, which cannot be seen, is dissolved in the water. It is a molecule made of the NH_4 (left over when the ammonia comes apart), and the SO_4 (left as the copper separated). To balance the equation, you need 2 molecules of ammonia.

In a class discussion, answer the following questions:

a) Tell where the reactants are at the beginning of this reaction.

b) Tell where are the products are at the end of the reaction.

c) Are there any invisible reactants or products?

d) How does the Law of the Conservation of Matter apply in this case? Explain your reasoning.

Plan a little class skit that will demonstrate how this reaction took place. Use different students to represent each atom of the reactants, and have them combine to form the molecules of the reactants. How many students do you need? You will need to find a way to show what atoms or molecules each student represents. Then you need to find a way to show what happens when reactants form products. Use your imagination! You may want to form several groups to work on different parts before putting it all together.

2. The material that makes up the formations must come from something in the crystals and something in the solution; there are no other places where material can come from in this reaction. This is a primary learning objective for this unit: that new materials comes only from old material—nothing appears out of nothingness. Students may say that the new material is some new substance formed from a chemical reaction between the crystals and the solution.

a. The reactants are the copper sulfate crystals and the ammonium hydroxide in the solution. These chemicals make up the crystals on top of the screen and part of the solution.

b. The products are in the precipitate that is forming (stalactites and stalagmites) and in the solution.

c. There are no gases but students might consider the clear substances in solution as invisible.

d. Yes, in balancing the equation, all the atoms (and therefore matter) that are present in the reactants are also present in the products.

CLASS SKIT:

Allow students to use their own ideas but following are some suggestions in case they need help in getting started. Students can use colors or placards to show what kind of atom or molecule they represent. They can link arms to show atoms attaching to each other. After they form the reactant molecules, they should rearrange themselves and reform into the product molecules.

	REACTANTS	PRODUCTS
COMMON NAMES	Copper Sulfate / Ammonium Hydroxide	Copper Hydroxide / Ammonium Sulfate
DESCRIPTION OF SUBSTANCES	Blue crystals / Clear solution	Bluish-green solid / Clear Solution
FORMULA	$CuSO_4$ / NH_4OH	$Cu(OH)_2$ / $(NH_4)_2SO_4$
ACCOUNTING OF ATOMS	Cu 1, S 1, O 6, N 2, H 10; 20 ATOMS TOTAL	Cu 1, S 1, O 6, N 2, H 10; 20 ATOMS TOTAL
BALANCED EQUATION	$CuSO_4 + 2\ NH_4OH$	$Cu(OH)_2 + (NH_4)_2SO_4$

Lesson _______	REACTANTS	PRODUCTS
COMMON NAMES		
DESCRIPTION OF SUBSTANCES		
FORMULA		
PICTURES OF MODELS FOR THE REACTION		
ACCOUNTING OF ATOMS IN REACTANTS AND PRODUCTS		
BALANCED EQUATION		

Lesson 1: MIXING IT UP . . . . (page 2)

In this activity, students will investigate the changes that occur when two or three common, household substances are mixed together. Each suggested set below has at least one reaction that is significant enough to catch students' attention. They will use this activity for a class demonstration. Students should work in groups. Three or four in each group seem to work best. They should mix no more than 3 substances (water not counted) at a time. They should plan all possible combinations of mixtures as a team and write them down before trying them.

If possible, you should arrange to project the students' demonstrations in order for all students to be able to see and observe carefully what is happening. A good way to do this is to use a microcam or a video camera. If these are not available, an overhead projector will work for most of the reactions.

MATERIALS NEEDED:

Make up enough kits so that each group has a different kit. Materials are listed below for 9 different kits.

A.
- tumeric (1/4 tsp)
- rubbing alcohol (15 ml)
- window cleaner (15 ml)
- flour (1 tsp)
- eye dropper
- 50 ml beaker

B.
- Ex-Lax (1/2 tablet)
- rubbing alcohol (20 ml)
- water (10 ml)
- Alka-Seltzer (1 tablet)
- window cleaner (15 ml)
- mortar and pestle
- eye dropper
- 50 ml beaker

C.
- Alka-Seltzer (1/2 tablet)
- water (30 ml)
- 50 ml beaker
- corn starch (1 tsp)
- flour (1 tsp)

D.
- baking soda (1 tsp)
- flour (1 tsp)
- vinegar (20 ml)
- water (30 ml)
- eye dropper
- 50 ml beaker

E.
- Alka-Seltzer (1 tablet)
- flour (1 tsp)
- test tube with cork
- water (30 ml)
- iodine solution
- 50 ml beaker
- micro tray

F.
- corn starch (1 tsp)
- flour (1 tsp)
- sugar (1 tsp)
- ammonia water (10 ml)
- iodine solution
- water (30 ml)
- eye dropper
- micro tray

G.
- cranberry juice (10 ml)
- window cleaner (10 ml)
- sugar (1 tsp)
- salt (1 tsp)
- eye dropper
- 50 ml beaker

H.
- dishwashing detergent (20 ml)
- baking soda (2 tsp)
- citric acid (2-3 tsp)
- water (30 ml)
- 50 ml beaker

I.
- egg white (1)
- water (30 ml)
- baking soda (1 tsp)
- citric acid (1 tsp)
- 50 ml beaker
- eye dropper

PITFALLS AND CAUTIONS:

1. Teams of three or four work best for this activity. If the teams are any larger, students are distracted too easily.
2. Students need to be reminded to leave the kits in the same condition in which they received them.

PROBABLE MOST INTERESTING REACTIONS FOR EACH KIT:

A. Tumeric and rubbing alcohol and window cleaner turn red.

B. Ex-Lax dissolved in rubbing alcohol and window cleaner turn pink or red. If Alka-Seltzer is added to this mixture, it turns green.

C. Alka-Seltzer in water fizzes releasing bubbles of gas.

D. Baking soda and vinegar react vigorously releasing bubbles of gas.

E. Iodine turns flour (starch) dark blue. Alka-Seltzer in iodine forms bubbles and releases gas.

F. Iodine turns corn starch dark blue.

G. Window cleaner and cranberry juice turn to a green-colored soda.

H. Dishwashing detergent in baking soda with citric acid causes a profusion of suds.

I. Raw egg white in baking soda and citric acid stirs into a stiff “mousse.”

Lesson 2: IS IT A NEW SUBSTANCE? . . . . . (page 6)

The four reactions chosen for this lesson are ones that involve everyday materials and are the basis for this entire unit. Students come back to these reactions in every cluster for more in-depth study. In this first cluster, they observe and describe the reactions. Detailed explanations of each of these reactions are provided in Cluster 3, Lessons 13, 14, 15, and 16.

Reaction 1
Rusting Iron

MATERIALS NEEDED:

- steel wool
- 100 ml beaker
- 25-30 ml of vinegar with which to clean the steel wool
- paper towel to dry the steel wool

PITFALLS AND CAUTIONS:

1. Be sure students dry the steel wool thoroughly and then stretch it so the strands are loose. The rusting will begin almost immediately.

Reaction 2
Baking Soda and Vinegar

MATERIALS NEEDED:

- small vial or test tube with about 1 tsp of baking soda
- small vial or test tube filled with vinegar (or this could be put directly into the beaker); 100 ml beaker

PITFALLS AND CAUTIONS:

1. Be sure the beaker is large enough to hold the fizzing and bubbling reaction. Or, if necessary, reduce the quantities of baking soda and/or vinegar.

Reaction 3
Butane Lighter

MATERIALS NEEDED:

- clear plastic butane lighter
- balance

PITFALLS AND CAUTIONS:

1. When purchasing the lighter, be sure that the butane liquid is visible through the plastic. It will be helpful if the top part (just below the little lever that releases the fluid) is flat, since, in a later experiment, students attach a rubber band to hold the lever open. This works better if the top is flat.
2. Do not allow students to hold the lever down when there is no flame as this allows the butane gas to escape into the room.

Reaction 4
Decomposition of Water

MATERIALS NEEDED:

- 9 volt battery
- 2 pieces of wire, 12” or more with alligator clips at each end
- petri dish
- salt
- 2 pencils to be used as electrodes

PITFALLS AND CAUTIONS:

1. Telephone wire works well and it can be attached by winding it around the pencil lead and the battery.
2. The pencils should be sharpened so that about 1/2” of lead is exposed at each end where the wires can be attached. The reaction is more obvious if the pencils are not sharpened to a point. Rather, try to shave the wood away leaving the blunt, thick end.
3. When putting the electrodes into the petri dish, the lead electrodes must not touch.
4. Batteries do not work well when they are getting worn down.

Lesson 3: RESEARCHING A COMMON SUBSTANCE . . . (page 13)

Students select a substance of interest that they will research at intervals throughout the unit.

MATERIALS NEEDED:

- Resource materials

The best place to begin looking for information on the various substances is the **Merck Index** (Merck and Co. Inc., Rahway, NJ), **The Handbook of Chemistry and Physics** (CRC Press, Inc., Boca Raton, FL) which is especially good for the elements, the **Physician's Desk Reference** (PDR), or the Physician's Desk Reference (PDR) for Non-prescription Drugs (Medical Economics Company, Inc., Oradell, NJ). Also, various encyclopedias have a wealth of information.

Following is a list of suggested possible substances: gasoline, plastic milk jug, post-1983 penny, dime, nickel, quarter, pop can, nylon, polypropylene, amethyst, diamond, ruby, garnet, turquoise*, emerald*, 18K gold, sterling silver, henna*, indigo*, alizarin*, bauxite, ambergris*, amber*, bronze, iron, rubber, rayon, methane, saran wrap, ethylene, acetylene, kerosene*, styrene, freon, ethanol, cresol, DDT*, cocaine, morphine, alizarin*, juglone, lawsone, cinnamon, quinine, oil of almond, jasmine, vanilla, camphor, cochineal, curare, brass, tobacco, sucrose, aspirin*, glass, marijuana*, Tylenol*, beer*, whiskey*, cholesterol*, etc. Feel free to add your own.

** Indicates substances that are either more complex in nature or may be several different substances. If you use these, you will probably want to assign them to more capable students.*

Laboratory Background Information for
Cluster 2

Lesson 4: DOES THE WEIGHT CHANGE? . . . . (page 16)

The teacher will demonstrate four physical changes: compacting steel wool, melting an ice cube, dissolving sugar in water and boiling water. For each of these, students will predict what happens to the weight—increase, decrease or remain the same.

MATERIALS NEEDED:

- steel wool
- glass or beaker
- ice cubes
- sugar
- hot plate or Bunsen burner

PITFALLS AND CAUTIONS:

1. Be careful not to spill or lose any of the substance. Some students will take this lost substance into account as they make their prediction.

Lesson 5: GATHERING EVIDENCE ABOUT WEIGHT (page 21)............FROM EXPERIMENTS

In this lesson students design experiments to test their hypotheses and then use their findings to prove or disprove their predictions.

MATERIALS NEEDED:

- sensitive balance
- steel wool
- beaker or glass of water
- ice cubes
- sugar
- teaspoon
- Bunsen burner or hot plate

PITFALLS AND CAUTIONS:

1. Data sheets have been provided to use with this lesson if you wish. They will help students focus on the critical parts of each experiment. Each group will need four separate sheets, one for each experiment. Alternatively, you may make a transparency or copy the data sheet on the blackboard for students to use as a model.
2. Students should handle the steel wool gently. If it “sheds,” it will weigh less. Although students usually notice this and put it into their discussion, it is better if this does not happen.
3. Caution students about spilling any of the sugar. A small coffee scoop might be better than a spoon to help avoid any spills.
4. You may want to have the students start with Experiment 4 and let it boil while they do the other experiments. Alternately, you could have them start the group discussion while they boil the water.

Lesson 6: DOES THE WEIGHT CHANGE IN CHEMICAL REACTIONS . . . . (page 25)

In this activity, students turn their attention to chemical reactions and begin to examine weight changes that occur. When two solutions are mixed and stirred, they form a solid mass with no change in weight.

MATERIALS NEEDED:

- balance
- 25 ml each of saturated calcium chloride and potassium carbonate for the teacher demonstration
- 250 ml beaker for the teacher demonstration
- 10 ml of each solution for each student group
- test tubes with stoppers
- 100 ml beaker
- stirring rod

Saturated solution of calcium chloride, $CaCl_2$. The solution is made by dissolving 75 g of $CaCl_2 \bullet 2H_2O$ (calcium chloride dihydrate) per 100 ml of solution; or dissolve 55 g of anhydrous $CaCl_2$ per 100 ml of solution. Add enough water to dissolve and bring the total volume to 100 ml. Note that the total volume of the solution is 100 ml. Do NOT add 100 ml of water.

Saturated solution of potassium carbonate, KCO_3. The solution is made by dissolving 112 g of KCO_3 per 100 ml of solution. Add enough water to dissolve the solid and bring the total volume to 100 ml. Note that the total volume of the solution is 100 ml. Do NOT add 100 ml of water. These solutions will be fairly thick solutions.

PITFALLS AND CAUTIONS:

1. Each student group needs about 10 ml of each solution in a stoppered test tube. Any quantities are suitable as long as there are equal quantities of the solutions. Larger quantities may require more stirring before the product becomes solid.
2. The purpose of the stopper is so that drops do not fall off the lip of the test tube after the solutions are poured and cause a loss in weight.
3. You may want to give each student group a small test tube of each substance to examine before the teacher demonstration and then, for the demonstration, collect all the solutions in two beakers and then mix them. It is a little extra

effort, but it is more impressive for the students if you actually use the solutions the students examined. If you do it this way, students will need another set of solutions for their own experiment.

4. When planning the experiment, be sure that students account for all the substances both before and after the reaction. For instance, after they pour the solutions into the beaker, they must put the stoppers back on the test tubes so they do not lose any of the solution. Also, the stirring rod and beaker must all be weighed with the reactants at the beginning, and the test tubes with any remaining solutions must be weighed at the end. A good way to do this is to place the two test tubes with the solutions and the stirring rod in the beaker and weigh the beaker and its contents both at the beginning and at the end of the reaction.

5. You may want to use the same student worksheet that was used earlier in this cluster for making predictions about physical changes.

Lesson 7: WHAT'S INSIDE THE BUBBLES? INVISIBLE PRODUCTS . . . . . (page 28)

Students perform two simple activities that produce bubbles. They then repeat each activity in a closed system which shows that gases occupy space.

MATERIALS NEEDED:

- large test tube fitted with stopper
- vinegar
- baking soda
- spoon
- 250 ml Erlenmeyer flask
- Alka-Seltzer
- balloon

PITFALLS AND CAUTIONS:

1. Be sure that the test tube is large enough to hold all the bubbles.
2. The cork pops off the vinegar and baking soda reaction so be sure students point the test tube away from themselves or other students.
3. The size of the balloons should be such that they will fit tightly over the end of the Erlenmeyer flask.

Lesson 8: DO GASES
(page 31) ....HAVE WEIGHT?

It is probably best to do this activity as a teacher demonstration. The apparatus is large enough and the results visible enough for all students to observe easily. This demonstration provides visual evidence for students that gases do have weight.

MATERIALS NEEDED:

- meter stick balance
- 2-liter soda bottles hanging from each end of the meter stick by a string or wire
- Alka-Seltzer,
- string

A large class-size balance is made from a suspended meter stick and two big, 2-liter soda bottles with about an inch of water in the bottom. The soda bottles are hung from a meter stick with string or wire. A coat hanger which has been bent to fit around the neck of the bottle on one end and bent into a hook to hang over the meter stick on the other end works well. The hangers should be taped in place on the meter stick. One of the bottles has two Alka-Seltzer tablets broken in half, tied with a string and suspended from the string and taped inside the soda bottle just above the water level. Two Alka-Seltzer tablets give enough CO_2 to observe a weight difference. For the closed system, the cap is screwed very securely onto the bottle.

PITFALLS AND CAUTIONS:

1. Either string or wire works well to attach the soda bottles to the meter sticks. Be sure to tape the bottles in place so they do not move during the reaction.
2. Do NOT use the full length of the meter stick for the balance as it will probably not tip far enough to convince students it has moved. Placing the bottles about 20 cm from the pivot point seems to work well.
3. Be sure to use two Alka-Seltzer tablets in order to generate enough carbon dioxide to show a weight difference. Also, Alka-Seltzer must be fresh in order to generate enough gas.
4. To suspend the Alka-Seltzer inside the bottle, break it neatly in half (between, not through, the letters of the writing on the tablet), stack the four pieces and tie them with a long piece of string or cord. Suspend this Alka-Seltzer inside the bottle about two inches above the water. Tape the string or cord just inside

the neck of the bottle and cut the excess string. Be sure that this string is all the way inside the bottle and will not interfere with tightening the cap on the bottle. Using cheese cloth or pieces of old nylons to hold the Alka-Seltzer does not work well as it slows the reaction significantly and usually not all of the Alka-Seltzer reacts.

5. The caps on the soda bottles must fit properly and be tightened very securely. It is best to keep caps with the bottle they came on by writing corresponding numbers or letters on them.
6. Balance the apparatus by moving the meter stick slightly to the right or left in its holder. Do not try to move the bottles.
7. You will need to hold the tipped bottle for a moment while the Alka-Seltzer begins to react. It will soon free itself from the string and then the bottle can hang freely.
8. To demonstrate the fact that gases have weight is difficult, not only because the weight of gases is so small as to be detected only on very sensitive balances, but also becauseit must be done in a rigid container. If one uses such things as Ziploc bags for the closed system, the buoyancy effect causes an apparent gain in weight. Do not substitute plastic bags to demonstrate this principle. Do not attempt to discuss this with students.

Lesson 9: RUSTING METAL AND THE DEFLATING (page 36) ....BALLOON

Once again, students observe steel wool rusting. This time, they put a deflated balloon over the top of the flask. As this reaction proceeds, the balloon is sucked into the flask, usually with a pop. The balloon (and the air on the outside of it) rush in to fill the space as the oxygen is used. If left to react long enough, the balloon will fill about 1/5 of the flask. This is equivalent to the amount of gas in the air that is oxygen. The new product is rust or iron oxide. By now, students will probably recognize what is forming.

MATERIALS NEEDED:

- steel wool
- beaker with vinegar for cleaning the steel wool
- paper towel
- 250 ml Erlenmeyer flask
- balloon to fit over top of Erlenmeyer flask

PITFALLS AND CAUTIONS:

1. Smaller balloons work best since the effect is more obvious and faster. However, the end has to fit over the neck of the flask.
2. The balloon must be completely deflated when placing it over the top of the flask. Squeeze out any trapped air.

Students examine what happens as they raise and lower a funnel in a beaker of water. They close off the end of the funnel with their finger and find that if the air cannot get out, the water cannot get in. They then trap the air in a deflated balloon as it leaves the funnel. By squeezing on the balloon, they can force the air back into the funnel again. This pushes the water out.

MATERIALS NEEDED:

- funnel
- balloon that will attach securely to the smaller end of funnel
- beaker in which to immerse the larger end of the funnel

PITFALLS AND CAUTIONS:

1. If necessary, fit a rubber stopper over the end of the funnel so that a balloon will attach securely to it. The teacher should do this before class since serious cuts can result if done incorrectly.
2. If the balloon is not securely attached to the funnel, air will leak out. When purchasing balloons, pay attention to how large the end is. Balloons come in all different sizes.
3. The balloon must be completely deflated when it is attached to the funnel. If any air gets trapped inside it, allow it to escape by

Lesson 10: DOES RUSTING (page 39) ....NEED AIR?

squeezing on the balloon while releasing the end of the balloon.

This lesson focuses on the weight changes that occur as steel wool reacts with oxygen from the air to form products. In order to make observations about weight changes, this reaction is a variation of that of rusting. The steel wool is heated intensely with a Bunsen burner. When the heating is first started, the balance with the heated steel wool begins to rise and students think it is loosing weight (usually, just like they predicted). However, this is really caused by the expansion of the heated air around the steel wool. There is no need to discuss this. Let them watch and wonder. A couple of minutes after the reaction is started, the reverse begins to happen. The steel wool, ever so slowly, begins to sink. This continues even after the reaction is completed and it eventually goes down below the balance point indicating that it has gotten heavier. It gained weight because it combined with the oxygen from the air. The product may look similar to the original steel wool. However, upon close examination, differences become obvious. Both this reaction and that of rusting combine with oxygen from the air. Both reactions produce iron oxide. The black product is iron oxide, FeO. Rust is iron oxide, Fe_2O_3.

MATERIALS NEEDED:

- meter stick balance used earlier with the ends wrapped securely with aluminum foil so they won’t burn
- 2 compacted wads of steel wool about the size of ping-pong balls
- iron wire (to prevent melting)
- Bunsen burner

PITFALLS AND CAUTIONS:

1. When heated intensely, the steel wool will eventually begin to glow and the reaction will go to completion without the further addition of heat. If you have trouble getting the reaction going, check what part of the burner flame you are using to heat the steel wool. The hottest part of the flame is at the tip of the inner (blue) cone. Other parts of the flame are not hot enough to start the reaction. Once started, the steel wool will glow for a long time. If the room is darkened a little, you’ll see this effect much more readily.
2. Some students may think that the black product is soot. Allow them to examine the product more closely ***when it is cool.***

Students observe butane burning in a closed system. Once again, the reaction uses oxygen from the air. This time, as the oxygen is used, water rushes in to fill the space. This activity is a culminating activity for this cluster and allows students to use everything they learned about invisible reactants and products to make predictions about weight gain and weight loss.

MATERIALS NEEDED:

- butane lighter
- aluminum pie tin
- clay or florist's adhesive
- rubber band
- 400 ml beaker (to fit over top of butane lighter)

PITFALLS AND CAUTIONS:

1. The rubber band should not be attached to the fluid release until students light the lighter since butane would be released.
2. If students do not get water rising in the beaker, the beaker did not remain completely submerged. Probably the lip came out of the water. They should do it again.
3. When the flame goes out, the butane lighter will continue to release butane until the rubber band is disengaged. Students will discover that this will push the water back out of the beaker. Try to avoid this since butane is an asphyxiant and

Lesson 11: RESEARCH [redacted] (page 44) ....CONTINUED!

can cause headaches.

MATERIALS NEEDED:

- resources such as library, reference books, encyclopedias, etc.

Laboratory Background Information for

Cluster 3

Lesson 13: ATOMS IN EQUALS ATOMS OUT: Decomposing Water . . . . (page 56)

Students build molecular models and use them to show how water decomposes to form hydrogen and oxygen.

You may want to conduct the decomposition of water activity again, perhaps as a demo, to refresh students' memories about what happens in the process.

MATERIALS NEEDED:

For demostrating the decomposition of water: The set of materials from Cluster 1 or a Hoffmann or other apparatus (see note below) for decomposing water where the gases can be collected and tested.

For the student activity of building models: Kits composed of marshmallows or gumdrops; toothpicks broken into halves or thirds; data charts.

PITFALLS AND CAUTIONS:

1. Every student must be actively involved in the model-building if a good understanding of these concepts is to take place. A good way to do this first activity, which has very simple molecules, is for every student to do it individually within a group of either two or four students who can help each other if they have trouble.
2. Colored, miniature marshmallows are cheap (if students don't eat too many) and come in colors to represent different kinds of atoms.
3. Students will be drawing five identical data charts in their journals. You may want to Xerox these for students, each on a different color paper. It will help avoid a lot of confusion on the part of both the teacher and the students.
4. A compact electrolysis apparatus (catalog number 32207) is available for $29 from Central Scientific Company, 11222 Melrose Avenue, Franklin Park, IL 60131, 1-800-262-3626/Fax (708) 451-0231. This apparatus is small, easy to use, and contains everything you need except a 9-volt battery and a 6% sodium hydroxide solution. The gases are generated quickly and easily in quantities that give a good test.

Lesson 14: ATOMS IN EQUALS (page 64)............ATOMS OUT: Rusting

Students build molecular models and use them to show how rust forms from iron and oxygen molecules.

MATERIALS NEEDED:

In order to remind students of the rusting reaction again, you will need fresh steel wool as well as some that has reacted in a flask with the balloon on the top (from Cluster 2).

For the model building, you will need kits composed of marshmallows or gumdrops; toothpicks broken into halves or thirds; data charts.

PITFALLS AND CAUTIONS:

See #1, #2 and #3 from Lesson 13 about building models.

Lesson 15: ATOMS IN EQUALS ATOMS OUT: Baking Soda & Vinegar . . . . (page 69)

Students build molecular models and use them to show how baking soda and vinegar react to form sodium acetate, water, and carbon dioxide.

MATERIALS NEEDED:

Set-up from Cluster 2 for demonstrating the reaction of baking soda and vinegar; model kits composed of marshmallows or gumdrops; toothpicks broken into halves or thirds; data charts.

PITFALLS AND CAUTIONS:

See #1, #2 and #3 from Lesson 13 about building models.

1. You will probably want to have students build these models in groups of two.

Lesson 16: ATOMS IN EQUALS ATOMS OUT:

(page 74)...................Burning Butane

Students build molecular models and use them to show how butane burns with oxygen to form water and carbon dioxide molecules.

MATERIALS NEEDED:

Set-up from Cluster 2 for burning butane under a beaker; dilute Bromthymol blue; kits composed of marshmallows or gumdrops; toothpicks broken into halves or thirds; data charts.

BROMTHYMOL BLUE SOLUTION (BTB)

Bromthymol blue solution may be purchased already prepared from most chemical supply companies or you may prepare you own as follows: Prepare a 0.1% solution by dissolving 0.5 grams of bromthymol blue in 500 ml of water. To this add ammonium hydroxide (NH_4OH) or sodium hydroxide (NaOH), drop by drop, until the solution is a deep blue. Dilute as needed.

PITFALLS AND CAUTIONS:

1. Carbon dioxide is formed and is present in the beaker when the lighter goes out. To test for it, turn the beaker upright and put about a teaspoon of BTB in it and swirl. Since carbon dioxide is heavier than air, you don't have to worry about it escaping as you turn the beaker over.
2. Since the amount of carbon dioxide formed is quite small, the BTB must be very dilute (a very light blue color) in order for it to react and change to yellow-green or yellow. If the reaction doesn't work, dilute it some more and try again. It is probably a good idea to try it in advance to be sure you have it dilute enough.
3. Since this reaction involves many more molecules making it a little more complex, you may want students to do this one in groups of two.
4. Colored, miniature marshmallows are cheap (if students don't eat too many) and have five colors to represent different kinds of atoms.
5. The data chart is the same one used in the last two activities. As suggested earlier, you may want to use a different color for this data chart.

Lesson 17: WHERE DOES IT GO? . . . . (page 78)

MATERIALS NEEDED:

- copper chloride solution
- piece of aluminum cut from an aluminum pie pan
- a piece of weathered copper, if possible
- model kits composed of marshmallows or gumdrops
- toothpicks broken into halves or thirds
- data charts

COPPER CHLORIDE SOLUTION

Prepare the solution by dissolving 27 grams of copper(II) chloride ($CuCl_2$) in 1 liter of water.

PITFALLS AND CAUTIONS:

1. The data charts are the same as the one used in the last lesson.
2. It is more interesting if the aluminum is twisted or cut from the folded sides of the pan since the shapes produced will make it more obvious that the aluminum is being replaced by copper.

Lesson 17: OPTIONAL ACTIVITY. . . . . (Appendix)

(Both student pages and teachers guide are printed in appendix)

Students will do a very simple activity which simulates the formation of stalactites and stalagmites in caves.

MATERIALS NEEDED:

- 250 ml beaker
- 10 cm by 10 cm piece of wire screen
- household ammonia (NH_4OH)
- large crystal of copper sulfate ($CuSO_4$).

PITFALLS AND CAUTIONS:

1. In order to see the formations, the beaker must remain absolutely undisturbed.

Lesson 18: MORE [redacted] (page 81) ....RESEARCH!

MATERIALS NEEDED:

Resources such as library, reference books, encyclopedia, etc.

Cluster 4

Lesson 20: WHERE DOES FUEL GET ITS ENERGY? . . . . (page 88)

Students examine how energy can be stored in rubber band and magnets as well as ways to increase or decrease the amount of stored energy.

MATERIALS NEEDED:

- rubber bands
- strong magnets
- paper, about 2 inch squares
- forceps
- pan of water
- wooden splint
- butane lighter

PITFALLS AND CAUTIONS:

1. Be sure students do not use the matches to light larger pieces of paper or anything else. Careless handling of fire can easily get out of control.
2. When burning the paper, students should hold it with the forceps and should drop it into the pan of water when it is finished burning.
3. Use small pieces of paper. Two inches square is about the right size for students to make observations but yet not have too big a flame as to be dangerous.
4. Try to find strong magnets as these will demonstrate the concepts better. Radio Shack usually carries a good supply of strong magnets.
5. You may need to combine groups when using more than 2 magnets.

Lesson 21: HOW DO CHEMICAL (page 94) ..REACTIONS GET STARTED?

Fast Rusting of Steel Wool with a Bunsen Burner or Torch

This is a teacher demo of an earlier lab. This time, the focus is on the heat that begins the reaction and sustains it. As before, the torch is applied to the steel wool until a reaction begins (the steel wool turns black.) If the lights are turned off, the steel wool can be seen to glow—the glowing is the release of energy from the reaction. Some of the heat released continues to boost other parts of the steel wool.

MATERIALS NEEDED:

- steel wool
- Bunsen burner or propane torch
- ring stand and clamp,
  or something to hang the steel wool from

PITFALLS AND CAUTIONS:

1. The steel wool is very hot, and remains hot even after the glow has disappeared. Do not let students touch it.

Striking Matches; The Butane Lighter

Students strike two kinds of matches, wooden kitchen matches and safety matches. They observe what is needed to light the match and what is needed to keep it burning. Then they light a small piece of paper and decide what “booster” is needed. They end the activity by figuring out how the butane lighter works and writing about it.

There are actually two reactions needed to successfully light a match. The match head contains phosphorus sesquisulfide (P4S3) which has a low ignition temperature and is ignited by the low heat of friction when striking. The heat from burning the P4S3 then ignites the sulfur which burns at a slightly higher temperature. Finally, the wood ignites and sustains burning. Students are not expected to know what the chemicals are or that there is more than one chemical reaction involved.

MATERIALS NEEDED:

- wooden matches and a rough surface
- safety matches

- small pieces of paper
- pan of water
- forceps

PITFALLS AND CAUTIONS:

1. Be sure students do not use the matches to light larger pieces of paper or anything else. Careless handling of fire can easily get out of control.

Lesson 22: OTHER KINDS (page 101) ....OF BOOSTERS?

Decomposing Water

Students will perform the decomposition reaction again, setting it up to discover which of the components of the reaction are boosters. They perform the reaction without connecting the wires to the battery, to see if electricity is a booster. Then they perform it again, leaving out the salt from the water.

The salt is a “matter booster,” also known as a catalyst. The electricity is an energy booster.

MATERIALS NEEDED

- battery, wires and pencil leads from Lesson 3
- Petri dish
- water
- pinches of salt (you may substitute sodium sulfate for the salt)

PITFALLS AND CAUTIONS

1. Either short pieces of lead removed from a pencil or pencils sharpened at both ends will work well for these electrodes.
2. Salt (sodium chloride, $NaCl$) is not as good as sodium sulfate since it produces chlorine gas at the anode.

Making Handwarmers

Students will make their own hand warmers, just like some of the commercial ones that use the rusting reaction to release heat. The reaction uses salt water as a booster (catalyst). They perform the experiment with and without the salt water as well as with and without oxygen. They use their results to identify which is the “booster” and what the role of the other substance is as well as to decide how energy is involved in the reaction.

Students will first observe the iron filings with the bag open (oxygen available) without the salt water in which case nothing happens. Then they add the salt water and observe again. They discover that salt water is the “booster” since it is required for the reaction to get started. They close the bag (cutting off the supply of oxygen) and the reaction stops even though the “booster” is still available. The sand in this reaction is necessary to absorb and store the heat. Without it, the heat dissipates so quickly that it cannot be felt.

MATERIALS NEEDED

- 1 tbsp iron powder
- sand
- Ziploc bag
- salt water solution
- commercial hand or toe warmers for observation and comparison

PITFALLS AND CAUTIONS

1. It may take a few minutes of kneading in order to feel the heat being produced.
2. The bag must be held open in order to allow contact with plenty of oxygen from the air which is required in order for the iron and oxygen to react.
3. Since sand retains heat very well, these warmers can get quite hot.

Lesson 22: OPTIONAL ACTIVITY: Reaction of Ground Liver or Potato with Hydrogen Peroxide . . . . (page 106)

Since almost all biological reactions proceed only with a catalyst (booster), students may investigate a biological reaction that requires an enzyme. The liver or potato cell contains a booster which is called an enzyme. It immediately decomposes the hydrogen peroxide produced in some cells into two harmless substances, oxygen gas and water. This is an important chemical reaction in cells, since the hydrogen peroxide produced in some cells is toxic to them. The reaction is $2H_2O_2 \rightarrow O_2 + 2H_2O$. The liver or potato is a matter booster.

A potential difficulty with this experiment is that students may confuse what they know about hydrogen peroxide with what is happening in this reaction. They know that hydrogen peroxide is used to disinfect wounds, and may, in a naive way, think of the hydrogen peroxide as the “active” component in this reaction, rather than the enzyme in the potato as the “active” component.

MATERIALS NEEDED:

- ml of fresh, 3% hydrogen peroxide solution, H_2O_2
- freshly ground liver or freshly ground potato pulp (red-skinned or Idaho potatoes work best)
- large test tube

Procedure: Put a small amoung of freshly ground liver or potato in a test tube. Add fresh hydrogen peroxide. Observe.

PITFALLS AND CAUTIONS

1. Enzymes are very sensitive and decompose very readily. Therefore, be sure that the liver or potato is freshly ground.
2. Large amounts of heat are generated in this reaction. Use Pyrex test tubes and provide a way to support the test tubes.
3. Hydrogen peroxide decomposes after being opened. You may want to test it ahead of time if it has been open for a while.

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