Section Preview of the Teacher's Edition for

The Chemistry of Materials, *Issues and Physical Science, 2nd Edition*

Activities 15-17

Suggested student responses and answer keys have been blocked out so that web-savvy students do not find this page and have access to answers.

To experience a complete activity please request a sample found in the footer at lab-aids.com

Families of Elements 15

2
40- to 50-minute sessions

INVESTIGATION

ACTIVITY OVERVIEW

Students compare physical and chemical properties of 13 elements and sort them into groups based on common properties. They then compare their classifications with groups—or families—of elements as defined by scientists and displayed in the Periodic Table of the Elements.

KEY CONCEPTS AND PROCESS SKILLS

(with correlation to NSE 5–8 Content Standards)

1. Elements have characteristic physical and chemical properties. Substances often are placed in categories or groups if they react in similar ways; metals are an example of such a group. (PhysSci: 1)
2. Scientists classify elements into families, based on their properties. (PhysSci: 1)
3. Students develop descriptions based on evidence. (Inquiry: 1)

KEY VOCABULARY

atom

atomic mass

element

family (of elements)

metal

Periodic Table of the Elements

MATERIALS AND ADVANCE PREPARATION

For the teacher

- aluminum, iron, copper, and carbon samples from Activity 14, "Physical and Chemical Properties of Materials"
- 1 Transparency 15.1, "Information on Element Cards"
- 8 sets of 4 Element Family Cards
- 1 transparency of Student Sheet 16.1, "Periodic Table of the Elements"
- * 1 overhead projector
- * various samples of elements, such as sulfur, silver, and tin (optional)
- 1 Scoring Guide: Understanding Concepts (UC) and/or
- 1 Scoring Guide: Group Interaction (GI)

For each group of four students

- 1 set of 14 Element Cards
- * 4 half-sheets of paper of various colors
- * chart paper (optional)
- * markers (optional)

For each student

- 1 copy of Scoring Guide: Understanding Concepts (UC) (optional)
- 1 copy of Scoring Guide: Group Interaction (GI) (optional)
- 1 copy of Group Interaction Student Sheet 2, "Developing Communication Skills"

**Not supplied in kit*

You may wish to collect samples of elements such as sulfur, silver, and tin for display in Teaching Suggestion 1.

Prepare the half-sheets of paper. Students will place the Element Cards on these in Teaching Suggestion 2 as they group them according to physical and chemical properties. In Teaching Suggestion 2, consider asking groups to write their sorts on chart paper for display around the classroom.

Group Interaction Sheets are in Teacher Resources II: Diverse Learners. Masters for Scoring Guides are in Teacher Resources III: Assessment.

TEACHING SUMMARY

Getting Started

1. Introduce elements as the building blocks of matter.

Doing the Activity

2. (GI ASSESSMENT) Students sort elements based on characteristic physical and chemical properties.

Follow-Up

3. Introduce the the Periodic Table of the Elements.
4. (UC ASSESSMENT) Students compare classification systems and examine the periodic table.

BACKGROUND INFORMATION

Properties of the Elements

The Element Cards contain information about fourteen of the more simple elements (lowest atomic number and weight) from four columns on the periodic table. The properties chosen for the element cards are both physical and chemical. Atomic numbers are not included because this property of the elements, which depends on the number of protons in an atom of the element, was not known to the Russian scientist Dmitri Mendeleev when he grouped the elements to create the first periodic table. Were this information included on the cards, students would be likely to use it to sort the elements, rather than looking at the other properties. Students can usually best conceptualize the significance of the atomic number when they are introduced to the subatomic particles in the atom at the high school level.

Atomic mass is a physical property, but it is difficult for students to understand the idea of a particle of such small mass. The atomic masses given on the periodic table are relative masses based on the mass of carbon 12, which is defined as exactly 12.00. The atomic masses on the periodic table also take into account the abundance of different isotopes of an element. Isotopes have various numbers of neutrons, and are not discussed in the student materials. The atomic masses given on the Element Cards are the most common isotopes rounded to the nearest whole number. These are technically called mass numbers.

TEACHING SUGGESTIONS

GETTING STARTED

1. Introduce elements as the building blocks of matter.

Remind students that in the last activity, they grouped materials and sorted them into categories based on their properties. Tell them that efforts of scientists and philosophers to classify matter go far back in history. More than 2,000 years ago, the Greeks introduced the idea that there were some basic building blocks of matter, called **elements**. Today's scientists know that there are 90 naturally occurring elements—substances that cannot be broken down by any normal chemical means, such as heating, reacting them with acids or other chemicals, or exposing them to electrical currents. Each visible sample of an element is made of many billions of small particles called **atoms**. Introduce the idea that each kind of element is made of a particular kind of atom. One way in which the atoms vary is in their mass. Students will learn more about atoms in Activities 16–19.

Display the aluminum, iron, copper, and carbon samples from Activity 14, "Physical and Chemical Properties of Substances." Tell students that, of the materials they tested in Activity 14, these four are elements. In fact, they were among some of the first elements early scientists identified. You may wish to display any other element samples you have.

Tell students that in this activity, they will view data on 14 elements and investigate how these can be divided into subgroups based on their properties.

DOING THE ACTIVITY

2. (GI Assessment) **Students sort elements based on characteristic physical and chemical properties.**

Have students read the introduction and Challenge. Review the definition of an **element**, a substance that cannot be broken down into simpler substances by heating it or causing it to react with other chemicals. Project Transparency 15.1, "Information on Element Cards," and explain the information shown on each card. If necessary review the distinction between chemical and physical properties, as both are included on the Element Cards. Distribute the Element Cards.

Make sure students understand that each card begins with the one- or two-letter symbol for each element and its name. Next come two physical properties: whether the element is metal or nonmetal, and is a solid, liquid, or gas at room temperature. The next line tells the color of the most common form(s) of the element. The atomic mass refers to the mass of one atom (the smallest bit of each element) as based on hydrogen, which has the lightest atom of all the elements. Hydrogen's atomic mass is 1, and the masses of the other atoms are expressed as multiples of the mass of hydrogen.

To further explain the concept of atomic mass, tell students that scientists have been able to figure out the mass of each type of atom, even though they can't weigh them directly. Point out that there are no units given on the cards: atomic masses are given in relative units called atomic mass units (amu). This is because atoms are so extremely small that it doesn't make sense to express their masses in grams, or even milligrams or micrograms.

The last two lines refer to chemical properties. **Reactivity** refers to how likely the element is to interact chemically, or **react**, with other elements. Students may know, for example, that pure oxygen is very **reactive**, so its reactivity is listed as high. The last line shows the number of bonds to hydrogen. The reason for using the formula with hydrogen on the cards, rather than some other element, is that it is the simplest element and can only make one bond. Students are likely to know that oxygen and hydrogen are the elements in water: H_2O. This formula is based on the fact that oxygen bonds to two hydrogens, as noted on the oxygen Element Card.

Distribute the element cards. Have student groups complete the Procedure. Before they begin working, consider incorporating some of the sentence starters from Group Interaction Student Sheet 2, "Developing Communication Skills." Encourage them to use these as they work. Consider providing feedback on student work using the GROUP INTERACTION (GI) Scoring Guide. Groups should work together to organize the various Element Cards and record the groupings they have formed. Their goal is to form at least three categories, with two similar characteristics within each. Most importantly, students should record the characteristics they chose for forming each of the categories. If students are having problems, suggest that they choose only one criterion to begin their sorting, but allow them to work as independently as possible. Students are likely to sort the elements based on the number of bonds each forms with hydrogen, the state at room temperature, and the element's reactivity.

For Procedure Step 5, hold a brief class discussion about how students classified the elements. Allow members of each group to briefly show their system and describe the choices they made. You could also provide chart paper and markers for students to display their systems. Highlight the similarities and differences between the systems that the student groups used by listing them on the board or overhead.

■ **Teacher's Note:** Students are likely to group hydrogen with the Halogen Family of Elements based on the physical and chemical properties of hydrogen shown on its element card. This is a reasonable classification with the information they are provided. Scientists also incorporate information about valence electrons when grouping elements. For this reason hydrogen is placed on top of Group 1 because it has one valence electron in an s orbital, similar to the other elements of Group 1. This information is beyond the scope of this activity, but will become apparent when students see the Periodic Table of Elements in Teaching Step 3.

Do not hand out the sets of Element Family Cards to each group until Procedure Step 6. Explain that scientists look for patterns in their observations and use the same data students used plus additional data to categorize the elements into groups called **families**. Students have investigated elements in four families, and now they will compare their classification schemes to scientists' schemes. (Note that the four family names are not included as key vocabulary. Students will use them in this activity, but are not expected to memorize them unless that is a local or state requirement.) The activity stresses that there are families of elements and that they are based on chemical and physical properties. Before students begin this step, it may be helpful to review with them the names and characteristics of each family shown on the Element Family Cards. Then hand out the Element Family Cards to each group.

■ FOLLOW-UP

3. Introduce the Periodic Table of the Elements.

Make sure students understand that the cards show only 14 of the more than 100 known elements. Tell them that scientists have taken a similar approach to classify and organize all of the elements onto a table called the Periodic Table of the Elements. Explain to students that the categories for the Element Family Cards are four of the accepted scientific classifications. Display the transparency of Student Sheet 16.1, "Periodic Table of the Elements," and point out the four families (alkali metals, alkaline earth metals, halogens, and noble gases) included in this activity. You may want to tell students that the term noble gases refers to the fact that these elements only very rarely react, or "associate," with other elements. They were once called inert gases, but this name was discarded because they do react under some circumstances.

Lead students to notice that the periodic table organizes a large number of elements into columns and rows and provides atomic numbers and atomic masses for each. Do not go into too much detail now; the next activity provides more information about the periodic table.

Emphasize the importance of systems for classification and organization, such as the periodic table. They allow scientists to organize and make sense of vast amounts of data. They also allow scientists from all over the world to communicate with each other and exchange information in a common scientific vocabulary. As scientists gather more data, a classification system will develop further. This has happened with the periodic table: as new elements have been discovered, new rows have been added and other modifications have been made.

Discuss some of the additional properties shown on the Element Family Cards. These include the physical properties of density and melting point and specific examples of chemical reactivity, such as the vigorous reactions of alkali metals with water. Students can refer to these properties to characterize elements.

Prompt students to compare their sorts with the Periodic Table of Elements shown on the transparency of Student Sheet 16.1. Ask them to identify similarities between their sorts and the accepted convention of sorting the elements as shown in the Periodic Table.

4. (UC Assessment) Students compare classification systems and examine the periodic table.

You may score Analysis Question 5 with the Understanding Concepts (UC) Scoring Guide to assess whether students understand the main idea of the activity. Here students must apply the characteristics of a family to an additional element—strontium. This element is in the same family as calcium and magnesium, so students should predict that it is likely to be a solid, silvery white metal that makes two bonds with hydrogen. Its reactivity is likely to be very high, since it is closer to calcium than magnesium. Students who look closely should predict a mass greater than 80, since they would see that the element will come after bromine, which has a mass of 80.

Analysis Question 5 focuses on the characteristics of the families. Review with your students your expectations for their responses, and let them know that you will use the UC Scoring Guide to give them feedback. If appropriate, distribute copies of the UC Scoring Guide to students. For more information about scoring guides, see Teacher Resources III: Assessment.

SUGGESTED ANSWERS TO QUESTIONS

1. *Which of the properties listed on the Element Cards are:*

   a. *physical properties?*

   Sample responses removed for preview

   b. *chemical properties?*

2. *How did your first classification system compare to the second classification with the Element Family Cards?*

3. *In what ways could grouping elements help scientists understand their properties?*

4. *Use the table of elements you constructed to find the family or families of elements that are:*

   a. *not usually reactive.*

   b. *highly reactive.*

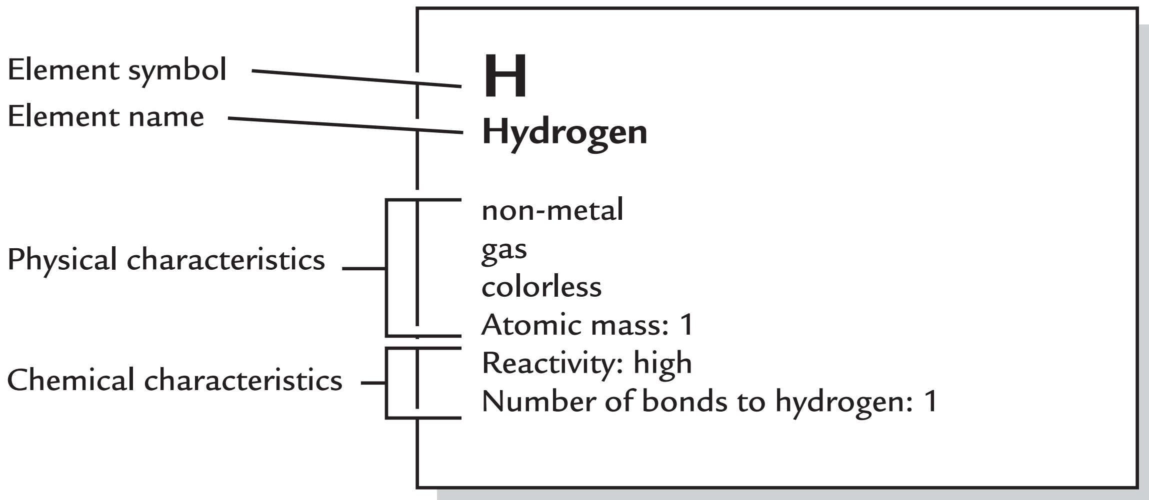
   c. *all metals.*

   d. *all solids.*

   e. *all gases.*

5. *(UC Assessment) The element strontium (Sr) is below calcium (Ca) in Column 2 on the periodic table. Design an Element Card that shows the properties you predict for strontium.*

Information on Element Cards



4. UNDERSTANDING CONCEPTS (UC)

What to look for:

- *Student's response identifies and describes scientific concepts relevant to a particular problem or issue.*

Scoring Guide

LEVEL	DESCRIPTION
Level 4 Above and beyond	Student accomplishes Level 3 AND goes beyond in some significant way, such as: • using relevant information not provided in class to elaborate on your responsee. • using a diagram to clarify scientific concepts. • relating the response to other scientific concepts.
Level 3 Complete and correct	Student accurately and completely explains or uses relevant scientific concepts.
Level 2 Almost there	Student explains or uses scientific concepts BUT has some omissions or errors.
Level 1 On your way	Student incorrectly explains or uses scientific concepts.
Level 0	Student's response is missing, illegible, or irrelevant.
X	Student had no opportunity to respond.

9. GROUP INTERACTION (GI)

What to look for:

- *Group members work together as a team and the ideas of all members were valued and weighed in working toward the common goal.*

Scoring Guide

LEVEL	DESCRIPTION
Level 4 Above and beyond	Group members accomplish Level 3 and go beyond in some significant way, such as: • actively asking questions about each others' ideas. • actively helping each other accomplish the task. • building on each other's ideas.
Level 3 Complete and correct	All group members participate and respectfully consider each others' ideas.
Level 2 Almost there	Unequal group participation OR group respectfully considered some, but not all, ideas.
Level 1 On your way	Significantly unequal group participation OR group totally disregarded some members' comments and ideas.
Level 0	Members do not work together OR single individual does entire task.
X	Student had no opportunity to respond.

NAME ______________________________ DATE ______________

Developing Communication Skills

COMMUNICATING	SENTENCE STARTERS
To better understand	*One point that was not clear to me was . . .* *Are you saying that . . .* *Can you please clarify . . .*
To share an idea	*Another idea is to . . .* *What if we tried . . .* *I have an idea. We could try . . .*
To disagree	*I see your point, but what about . . .* *Another way of looking at it is . . .* *I'm still not convinced that . . .*
To challenge	*How did you reach the conclusion that . . .* *What makes you think that . . .* *How does it explain . . .*
To look for feedback	*What would help me improve . . .* *Does it make sense, what I said about . . .*
To provide positive feedback	*One strength of your idea is . . .* *Your idea is good because . . .*
To provide constructive feedback	*The argument would be stronger if . . .* *Another way to do it would be . . .* *What if you said it like this . . .*

Elements and the Periodic Table 16

2
40- to 50-minute sessions

READING

ACTIVITY OVERVIEW

Students read about the history and organization of the Periodic Table of the Elements and are introduced to the difference between elements and compounds. The reading also introduces atoms, molecules, and chemical formulas. Students use the Stopping to Think literacy strategy while reading to improve their reading comprehension.

KEY CONCEPTS AND PROCESS SKILLS

(with correlation to NSE 5–8 Content Standards)

1. Elements do not break down under ordinary laboratory reactions involving such treatments as heating, exposure to electrical current, or reaction with acids. (PhysSci: 1)
2. There are more than 115 chemical elements that combine in a multitude of ways to produce compounds. (PhysSci: 1)
3. Elements combine with each other in characteristic ways to form new substances (compounds) with different characteristic properties. (PhysSci: 1)
4. Substances are often placed in categories or groups if they have similar properties. Metals are an example of such a group. (PhysSci: 1)
5. Scientists communicate their findings and build on each other's work. (HistSci: 2, 3)
6. Studying Mendeleev provides insights into scientific inquiry and the nature of science. (HistSci: 3)

KEY VOCABULARY

atom

atomic mass

chemical formula

compound

element

family

molecule

MATERIALS AND ADVANCE PREPARATION

For the teacher

1 transparency of Student Sheet 16.1, "Periodic Table of the Elements"

* 4 different colored transparency markers (optional)

For each group of four students

1 set of 4 Element Family Cards (optional for Getting Started review)

For each student

1 Student Sheet 16.1, "Periodic Table of the Elements"

**Not supplied in kit*

TEACHING SUMMARY

Getting Started

1. Review element families and the Periodic Table of the Elements.

Doing the Activity

2. (LITERACY) Students read the text and answer Stopping to Think questions.

Follow-Up

3. (UC ASSESSMENT) The class applies concepts from the reading to their use of the periodic table and chemical formulas.

BACKGROUND INFORMATION

The Elements

Elements 1 (hydrogen) through 92 (uranium) are generally referred to as the natural elements, although two of these elements—43 (technetium) and 84 (polonium)—are not actually found naturally on earth. Elements 43, 84, and all elements beyond 92 are referred to as artificial, or synthetic, elements. They have been produced through nuclear reactions in laboratory settings. Since nuclear reactions are generally a part of high school science curriculum, this course focuses on the 90 natural elements that are the building blocks for matter on earth. At the time of this writing, elements 93 through 111 have been verified by the International Union of Pure and Applied Chemistry (IUPAC) and named by the laboratories that first synthesized them. Evidence for the synthesis of elements 112, 113, 114, 115, 116, and 118 has also been reported, and it is expected that most or all of these will eventually be verified by IUPAC. Since the status of these elements makes it difficult to give an exact number, we indicate in the student materials that more than 115 elements are known. Recent versions of the periodic table differ slightly depending on what reports of elements they choose to accept. Although additional elements may be synthesized in nuclear laboratories, the basic number of elements found naturally stays the same.

When two or more elements are held together by chemical forces, or bonds, they form a compound. These bonds can be ionic, which occurs when electrons are transferred from one atom to another, or covalent, which occurs when atoms share electrons. Compounds have none of the characteristics of the original elements. Hydrogen (H) for example is a colorless, odorless gas that is very light and highly explosive when it meets air, and oxygen (O) is also a clear, colorless gas that is very flammable. However, when these two elements bond and form a molecule, that compound is a non-flammable liquid—water (H_2O). Water illustrates another defining characteristic of compounds: the elements in a compound are in a fixed ratio. In water this ratio is 2 hydrogens to 1 oxygen, as expressed in the formula H_2O. Water cannot be separated into hydrogen and oxygen by physical methods—only a chemical reaction can separate it.

Mixtures are combinations of two or more substances (elements and/or compounds) that are held together by physical forces. They can be separated by physical methods, such as filtering or evaporation. A solution of solids in water, for example, is a mixture. In a saltwater solution, the water can be evaporated, leaving the salt. The ratio of substances in a mixture can vary greatly because they are not chemically bonded and can combine in various proportions.

■ **Teacher's Note:** This activity continues a discussion on the nature of elements, atoms, compounds, molecules, and mixtures to build students' understanding of the Particulate Theory of Matter. Understand that the treatment of these topics in this unit is very basic and does not explore ions and subatomic particles. This will be take place in greater detail in Unit C, "Water," of *Issues and Physical Science.*

TEACHING SUGGESTIONS

GETTING STARTED

1. Review element families and the Periodic Table of the Elements.

Review the four chemical families that students explored in Activity 15, "Families of Elements." To each group, pass out a set of Element Family cards used in Activity 15. Help students locate each of the families on Student Sheet 16.1, "Periodic Table of the Elements." You might also outline each of the four families – alkaline metals, alkaline earth metals, halogens, noble gases – using different colored transparency markers on a transparency of Student Sheet 16.1. To review the properties of each group prompt students with such questions as, ***Of the four families you investigated, which two seem the most alike? Which one seems most different from the others? What kinds of properties can you use to distinguish groups of elements?*** Also review some of the properties used to categorize the elements: such physical properties as their color, whether they are metals or not, whether they are solid, liquid, or gas at room temperature; and such chemical properties as their reactivity and the number of bonds they form with hydrogen.

Point out to students that although color is not a characteristic of such mixtures as plastic products, which can have coloring agents added, color is a characteristic of pure elements, such as the characteristic yellow of sulfur or the characteristic colors of copper and gold.

Have students read the introduction and Challenge. Review, as introduced in Activity 15, "Families of Elements," the fact that everything on earth is made of elements, either in pure form or in chemical combinations of the elements, which are called **compounds**. Also reiterate that all elements are made of smaller particles, or bits of matter. The smallest particle that is characteristic of an element is an **atom**.

DOING THE ACTIVITY

2. (LITERACY) Students read the text and answer Stopping to Think questions.

This activity is supported by a Directed Activities Related to Text (DART) strategy called Stopping to Think. The Stopping to Think questions prompt students to think about what they are reading and in some cases to apply what they have read. These questions do not require a written response, and are different from the Analysis Questions found at the end of the activity. Stopping to Think questions are intended to focus students' attention on important ideas in the text as they read. They may require students to identify the main idea of a previous paragraph or to synthesize ideas presented in two or more preceding paragraphs. Sample responses to the questions are listed below. For more information on this strategy, see the Literacy section of Teacher Resources II: Diverse Learners.

Stopping to Think 1

In what way were the ancient Greek philosophers right about elements?

Sample responses removed for preview

In what way were the ancient Greek philosophers wrong?

Stopping to Think 2

How did Mendeleev build on other scientists' work?

How did other scientists build on Mendeleev's work?

Stopping to Think 3

Use the Periodic Table of the Elements on the next page to decide whether each of the following is a metal or nonmetal: lithium (Li), carbon (C), sulfur (S), calcium (Ca), titanium (Ti), and bromine (Br).

Stopping to Think 4

Find magnesium on the periodic table.
What is magnesium's chemical symbol?

What family does magnesium belong to?

Is magnesium a solid, a liquid, or a gas?

Based on its family, would you expect magnesium to be very reactive, somewhat reactive, or not reactive at all?

Stopping to Think 5

What are two ways that compounds are different from the elements that form them?

Stopping to Think 6

The chemical formula for baking soda is NaHCO3. What elements are in baking soda? How many of each type of atom is represented by the formula for baking soda?

■ FOLLOW-UP

3. (UC ASSESSMENT) **The class applies concepts from the reading to use of the periodic table and chemical formulas.**

Begin by discussing what students have learned about the organization of the periodic table. Review the symbols and key for the periodic table in the Student Book. Refer students to Student Sheet 16.1, "Periodic Table of the Elements." Stress that groups of similar elements are often found in columns in the periodic table, and that these comprise families in that their physical and chemical properties are similar. The Periodic Table of the Elements is be helpful in that it helps to us predict or categorize an element's properties based on its position on the table. Review the changes that take place as you go from left to right across the table, from metals to nonmetals.

It is key that students understand that the Periodic Table of Elements is a reference tool used to describe and help understand elements and interactions with each other. To this end, analysis Question 2 emphasizes the difference in properties of the compound NaCl (table salt) from its constituent elements, sodium and chlorine. Explain that it is often the case that compounds are not at all like the elements that make them. For example, sugar contains: carbon, the solid that forms coal and diamonds; oxygen, necessary for human respiration; and hydrogen, an explosive odorless gas. Yet sugar is a white, crystalline, edible solid. Analysis Question 3 lets students apply information from the reading—that water and salt are compounds—to conclude that seawater must be a mixture.

✓ Analysis Question 4 is an opportunity to check students' understanding of the relationship between an atom and a molecule.

SUGGESTED ANSWERS TO QUESTIONS

1. *Make a copy the table below into your science notebook. Use the Periodic Table of Elements to find out which atoms make up a molecule for each of the substances listed. The first row has been completed for you.*

Chemical Formulas of Common Substances

Substance	Chemical formula	Atoms that make up the molecule
Water		
Hydrogen peroxide		
Carbon dioxide		
Sucrose (table sugar)		
Alanine (an amino acid)		
Oleic acid (a fat)		

2. *Sodium is a metallic solid, and chlorine is a poisonous yellow-green gas. Sodium and chlorine react to form sodium chloride, which is common table salt.*
   a. *Is table salt an element or a compound? Explain.*
   b. *Describe the physical properties of table salt.*
   c. *How do the properties of table salt compare with those of sodium and chlorine?*

3. *Is seawater an element, compound, or mixture? Explain your answer.*

4. ✓ *Explain the relationship between an atom and a molecule.*

Periodic Table of the Elements

SHADING KEY
- **A** solid at room temperature
- A (liquid) liquid at room temperature
- A (outline) gas at room temperature

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 H hydrogen 1.008																	2 He helium 4.003
3 **Li** lithium 6.941	4 **Be** beryllium 9.012											5 **B** boron 10.81	6 **C** carbon 12.01	7 N nitrogen 14.01	8 O oxygen 16.00	9 F fluorine 19.00	10 Ne neon 20.18
11 **Na** sodium 22.99	12 **Mg** magnesium 24.31											13 **Al** aluminum 26.98	14 **Si** silicon 28.09	15 **P** phosphorus 30.97	16 **S** sulfur 32.07	17 Cl chlorine 35.45	18 Ar argon 39.95
19 **K** potassium 39.10	20 **Ca** calcium 40.08	21 **Sc** scandium 44.96	22 **Ti** titanium 47.87	23 **V** vanadium 50.94	24 **Cr** chromium 52.00	25 **Mn** manganese 54.94	26 **Fe** iron 55.85	27 **Co** cobalt 58.93	28 **Ni** nickel 58.69	29 **Cu** copper 63.55	30 **Zn** zinc 65.39	31 **Ga** gallium 69.72	32 **Ge** germanium 72.64	33 **As** arsenic 74.92	34 **Se** selenium 78.96	35 Br bromine 79.90	36 Kr krypton 83.80
37 **Rb** rubidium 85.47	38 **Sr** strontium 87.62	39 **Y** yttrium 88.91	40 **Zr** zirconium 91.22	41 **Nb** niobium 92.91	42 **Mo** molybdenum 95.94	43 **Tc** technetium (98)	44 **Ru** ruthenium 101.1	45 **Rh** rhodium 102.9	46 **Pd** palladium 106.4	47 **Ag** silver 107.9	48 **Cd** cadmium 112.4	49 **In** indium 114.8	50 **Sn** tin 118.7	51 **Sb** antimony 121.8	52 **Te** tellurium 127.6	53 **I** iodine 126.9	54 Xe xenon 131.3
55 **Cs** cesium 132.9	56 **Ba** barium 137.3	71 **Lu** lutetium 175.0	72 **Hf** hafnium 178.5	73 **Ta** tantalum 180.9	74 **W** tungsten 183.8	75 **Re** rhenium 186.2	76 **Os** osmium 190.2	77 **Ir** iridium 192.2	78 **Pt** platinum 195.1	79 **Au** gold 197.0	80 Hg mercury 200.6	81 **Tl** thallium 204.4	82 **Pb** lead 207.2	83 **Bi** bismuth 209.0	84 **Po** polonium (209)	85 **At** astatine (210)	86 Rn radon (222)
87 **Fr** francium (223)	88 **Ra** radium (226)	103 **Lr** lawrencium (262)	104 **Rf** rutherfordium (267)	105 **Db** dubnium (268)	106 **Sg** seaborgium (271)	107 **Bh** bohrium (272)	108 **Hs** hassium (277)	109 **Mt** meitnerium (276)	110 **Ds** darmstadtium (281)	111 **Rg** roentgenium (280)	112 **Cn** copernicium (285)	113 Uut ununtrium (284)	114 Uuq ununquadium (289)	115 Uup ununpentium (288)	116 Uuh ununhexium (293)	117 Uus ununseptium ( )	118 Uuo ununoctium (294)

Lanthanides	57 **La** lanthanum 138.9	58 **Ce** cerium 140.1	59 **Pr** praseodymium 140.9	60 **Nd** neodymium 144.2	61 **Pm** promethium (145)	62 **Sm** samarium 150.4	63 **Eu** europium 152.0	64 **Gd** gadolinium 157.3	65 **Tb** terbium 158.9	66 **Dy** dysprosium 162.5	67 **Ho** holmium 164.9	68 **Er** erbium 167.3	69 **Tm** thulium 168.9	70 **Yb** ytterbium 173.0
Actinides	89 **Ac** actinium (227)	90 **Th** thorium 232.0	91 **Pa** protactinium 231.0	92 **U** uranium 238.0	93 **Np** neptunium (237)	94 **Pu** plutonium (244)	95 **Am** americium (243)	96 **Cm** curium (247)	97 **Bk** berkelium (247)	98 **Cf** californium (251)	99 **Es** einsteinium (252)	100 **Fm** fermium (257)	101 **Md** mendelevium (258)	102 **No** nobelium (259)

Modeling Molecules 17

2
40- to 50-minute sessions

MODELING

ACTIVITY OVERVIEW

Students continue their exploration of the organization of atoms and molecules as they use models to investigate atoms, elements, chemical bonds, molecules, and compounds.

KEY CONCEPTS AND PROCESS SKILLS

(with correlation to NSE 5–8 Content Standards)

1. There are more than 115 known elements that react in a multitude of ways to produce compounds, which account for the living and nonliving substances that we encounter. (PhysSci: 1)
2. An element is a substance made up of only a single type of atom. (PhysSci: 1)
3. Molecules are combinations of atoms held together by forces of attraction called bonds. (PhysSci: 1)
4. A compound is a substance made up of atoms of more than one kind of element, bonded together to form molecules. (PhysSci: 1)
5. Scientists often use models to demonstrate scientific concepts. (Inquiry: 2)

KEY VOCABULARY

atom

chemical bond

chemical formula

compound

element

molecule

MATERIALS AND ADVANCE PREPARATION

For the teacher

1 transparency of Student Sheet 16.1, “Periodic Table of the Elements”

1 Literacy Transparency 3, “Reading Scientific Procedures”

1 Scoring Guide: Understanding Concepts (UC)

* overhead projector

For each pair of students

1 molecular model set containing:
- 32 white “atoms”
- 18 black “atoms”
- 14 red “atoms”
- 4 blue “atoms”
- 54 white “bonds”

* 1 set of red, blue, and black pencils (optional)

For each student

1 Student Sheet 16.1, “Periodic Table of the Elements”

1 copy of Scoring Guide: Understanding Concepts (UC) (optional)

**Not supplied in kit*

Provide colored pencils if you would like students to use them when they draw their models of molecules. Prepare Literacy Transparency 3 which can be found in the Literacy section of Teacher Resources II: Diverse Learners.

TEACHING SUMMARY

Getting Started

1. Introduce the molecular model set as a tool for studying atoms and molecules.

Doing the Activity

2. Introduce strategies for reading scientific procedures
3. Students build models of molecules.

Follow-Up

4. (UC Assessment) The class discusses the principles illustrated by the model-building experience.

BACKGROUND INFORMATION

Chemical Bonding

In this unit, there is no discussion of subatomic particles and only a brief mention of the nucleus, as these concepts are usually taught in depth in high schools. The following background is provided in case your local standards require you to go into more depth in middle school.

Atoms consist of a nucleus, which contains positively charged protons and uncharged neutrons, and a cloud of negatively charged electrons. The number of protons is the atomic number and determines the identity of the element. In a neutral atom, the number of positively charged protons and negatively charged electrons is equal. The number of neutrons, however, can vary, forming different isotopes of the atom.

The atoms of most elements, except the noble gases found in Column 18 of the periodic table, are chemically unstable because their outer electron orbital is not full. As a result, most atoms tend to bond with other atoms to form compounds. Bonding causes each atom involved to have a filled outer orbital, making each atom more stable in the bonded state.

Chemical bonds are typically categorized as covalent or ionic. In this unit, only covalent bonds are modeled. In general, a covalent bond is formed when two atoms share the same electrons. Groups of atoms held together by covalent bonds tend to form molecules. The resulting compounds are called molecular compounds. An example of this is water. Covalent bonds can be single, double, or triple, referring to the number of electrons that are shared between the atoms. In single bonds, two electrons (one from each atom) are shared. Double bonds have four shared electrons. Triple bonds have six shared electrons.

In ionic compounds, electrons are transferred from one atom to another. The resulting positively and negatively charged particles, called ions, are held together by the attraction between their opposite charges. However, they do not form distinct molecules. For example, a crystal of table salt has positive sodium ions and negative chloride ions in a 1:1 ratio. Atoms held together by ionic bonds tend to form matrices, and the resulting compounds are generally referred to as nonmolecular compounds. A common example is NaCl, table salt.

Ionic bonds are formed when one atom "borrows" one or more electrons from another atom, forming two ions, each having an electrical charge opposite to the other. These opposing charges cause the ions to be attracted to each other.

"Sharing" and "borrowing" of electrons between atoms can be more accurately described using the concept of electronegativity. Electronegativity is a measure of the attraction between an atom's nucleus and bonded electrons. This property determines the type of bond formed between atoms. If the difference in electronegativity between two atoms is great, the bond they form is ionic, which means that the electrons involved in the bond spend more of their time orbiting the more electronegative atom. If the difference in electronegativity is not so great, the bond is considered covalent, because the electrons spend approximately equal amounts of time orbiting each atom.

In this activity, the atomic models are presented as spheres with spikes representing their bonding sites. At a more sophisticated level, students would view the models as the spherical center representing the nucleus and the spikes as unpaired electrons. They would see covalent bonding as the sharing of previously unpaired electrons with each bonding tube representing a pair of electrons.

TEACHING SUGGESTIONS

■ GETTING STARTED

1. Introduce the molecular model set as a tool for studying atoms and molecules.

Ask students to recall that an atom is the smallest building block of matter, and an element is composed of only one type of atom. Familiarize students with the molecular model that they will first use in this activity. Distribute a molecular model set to each pair of students. A complete set should contain 4 elements (black, white, blue, and red) and 64 atoms (32 white, 18 black, 14 red, 4 blue). The set also contains 54 white "bonds." Once they begin the activity, students will see in their Student Books that white represents hydrogen, black represents carbon, red represents oxygen, and blue represents nitrogen. Impress on students that the colors do not correspond to actual physical properties of the atoms, and so should not be viewed as important. In this unit they are only used to distinguish between atoms having different numbers of bonding sites.

Tell students that the spherical center of each model represents the center of the atom, while the protruding "sticks" represent the bonding sites. If your students are familiar with nuclei and electrons, you can explain that the center of the model represents the nucleus and the protruding sticks represent electrons that can be shared with another atom to produce a bond. The white tubes, which connect, or **bond**, atoms together, fit over the "sticks" of the atoms.

■ **Teacher's Note:** The holes in the atoms are artifacts of the manufacturing process and are not to be used when making molecules.

Be sure to point out that the models represent some aspects of the structure and behavior of atoms, but that they are not at all to scale in their representation of the size of the center and bonding sites of an atom or in showing the differences between atoms of different elements, other than the usual number of bonding sites. Also stress that a bond is not an object, but a force of attraction that holds atoms together to form a molecule.

■ DOING THE ACTIVITY

2. Introduce Strategies for Reading Scientific Procedures

Reading scientific procedures is a genre of reading unique from other types of reading in that its goal is to complete a series of steps in a specific order to complete a task. The most frequent obstacle that arises when student read a scientific procedure is that they do no understand what the procedure step is asking him or her to do. This impedes their ability to complete the investigation. To strengthen their ability to read and understand procedures, introduce the strategies shown on Literacy Transparency 3, "Reading Scientific Procedures." Model how these reading strategies, if used frequently, will increase students' ability to read and work independently.

In introducing these strategies is it important that you model how they can be used. Act them out. Find a complicated scientific procedure that you are not familiar with and show students how you might get stuck, and then model how you might use the strategies to independently determine what to do next. Show them how you would use the strategies to figure out what to do. Provide many opportunities for students to practice the strategies. Reinforce the use of the strategies when students are working with procedures that are challenging. Most importantly, continue to reinforce student use of the strategies to foster independent reading skills.

3. Students build models of molecules.

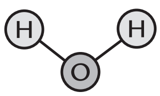
For Procedure Step 3 review with students the notation for writing chemical formulas. Students will need to understand that elements are written using the capitalized chemical symbols shown on the periodic table. The number of atoms in one molecule is noted by writing the number as subscript after the atomic symbol. Point out that when there is one atom in a molecule, such as the one oxygen molecule in H_2O, the one is not written, it is implied.

This activity is exploratory in nature and will help students realize that each type of atom can be joined to others only in certain ways. In some cases, atoms of the same element can form single or multiple bonds with each other. It is all right if students come up with combinations that do not take place in nature. Here it is important for them to see the bonding possibilities and to discover that double and triple bonds can form. At this point, allow students to build all possible molecules when combining different atoms according to the rules provided. Students may come up with actual compounds, such as HNO_3 (nitric acid) and H_2O_2 (hydrogen peroxide).

You may wish to stop after students have completed Procedure Part A , "Making Simple Molecules," and discuss what they have discovered so far. Encourage greater independence as they move on to Part B, "Making More Complex Molecules."

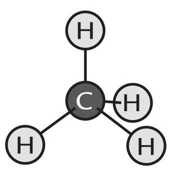
Sample student diagrams and answers to the procedure steps follow.

Procedure Steps 2 and 3

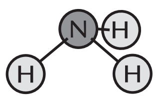


Water, H_2O

Procedure Step 5



Methane, CH_4



Ammonia, NH_3

Procedure Step 6

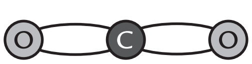
Oxygen, O_2

Procedure Step 7

Hydrogen, H_2

Nitrogen, N_2

Procedure Step 15



Carbon Dioxide, CO_2

■ FOLLOW-UP

4. (UC Assessment) **The class discusses the principles illustrated by the model-building experience.**

Ask students, ***What information do the models show about atoms, elements, and molecules?*** The model set includes models of the atoms for four elements. Students should comment that each model atom shows the number of bonds that a particular atom can make. From this information students can predict the molecules the atom can form and the formulas of compounds that will result. Ask them to choose one of the atoms and describe what the model shows about its chemical properties and its bonding to hydrogen. For example, nitrogen tends to make three bonds and hydrogen tends to make one bond. Thus one nitrogen atom will combine with three hydrogen atoms, and the formula of the resulting compound is NH_3. Relate these to the formulas given on the Element Cards students used in Activity 15, "Families of Elements."

Point out that some elements, such as oxygen and nitrogen, can also form molecules. The oxygen and nitrogen in air are elements, but they are present as molecules with two atoms. Even though they are elements, their formulas as they exist in nature are O_2 and N_2. Hydrogen also exists as a molecule (H_2).

Project the transparency of Student Sheet 16.1, "Periodic Table of the Elements," and ask students to consult their copies of the periodic table either on Student Sheet 16.1, or in the Student Book. Note the placement of the elements that the students have been working with. Remind them that each column contains elements that have similar chemical properties. Point out that these chemical properties are related to the ability of an atom to form bonds with other atoms. Ask, ***Given that nitrogen forms three bonds with hydrogen to make NH_3, how many hydrogen atoms do you think will bond with an atom of phosphorus?*** Students should be able to predict that phosphorus would bond with three hydrogen atoms to form PH_3. Based on observations they made when using the molecular model sets, and because phosphorus is in column 15 underneath the element nitrogen, a phosphorus atom, like nitrogen, would bond with three hydrogen atoms. Similarly, and using the same thinking, students should also predict that sulfur, like oxygen, would bond with two hydrogen atoms; and sodium, like hydrogen, with one. Use this line of questioning to reinforce that the Periodic Table is a tool that can be used to predict and describe the properties of elements and the bonds that form between elements.

Analysis Question 6 presents an opportunity for students to show their understanding of the relationship between an atom and a molecule by making a drawing. Encourage them to include labels and an explanatory written description of what their answer shows about the relationship. Let students know that you will be scoring this with the UNDERSTANDING CONCEPTS (UC) Scoring Guide. Review with students your expectations for this assessment item. You might have partners review each other's diagrams for clarity and accuracy, and allow them to improve their diagrams based on that feedback before you collect and score them.

Analysis Question 7 asks students to think about the strengths of a molecular drawing versus a structural formula. To stress the point that each describes stresses different information, ask several students to share their sketches with the class. Point out variations among students' sketches. Explain that scientists have agreed on a standardized method of representing molecules called a "structural formula." Using a standardized approach helps scientists avoid miscommunication.

SUGGESTED ANSWERS TO QUESTIONS

1. *How many different elements were you working with?*

2. *What was the role of the "sticks" on each atom model?*

3. *Was it possible for an atom to make more than one bond? Explain, and give an example.*

4. *How many bonds could each of the following to make with hydrogen? Copy the table below into your science notebook. Use the atomic numbers to help you find the elements on the periodic table.*
   a. *Si (Atomic # 14)*
   b. *Se (Atomic # 34)*
   c. *I (Atomic #53)*
   d. *As (Atomic # 33)*

5. *If you had two oxygen atoms and one hydrogen atom, could you form a molecule? Explain.*

6. *(UC ASSESSMENT) Make a drawing of the models to show the difference between an atom and a molecule.*

Level 3 Response

7. *Which model provides more information—a chemical formula or a sketch of the molecule?*

4. UNDERSTANDING CONCEPTS (UC)

What to look for:

- *Student's response identifies and describes scientific concepts relevant to a particular problem or issue.*

Scoring Guide

LEVEL	DESCRIPTION
Level 4 Above and beyond	Student accomplishes Level 3 AND goes beyond in some significant way, such as: • using relevant information not provided in class to elaborate on your responsee. • using a diagram to clarify scientific concepts. • relating the response to other scientific concepts.
Level 3 Complete and correct	Student accurately and completely explains or uses relevant scientific concepts.
Level 2 Almost there	Student explains or uses scientific concepts BUT has some omissions or errors.
Level 1 On your way	Student incorrectly explains or uses scientific concepts.
Level 0	Student's response is missing, illegible, or irrelevant.
X	Student had no opportunity to respond.

Reading Scientific Procedures

The purpose of reading a scientific procedure is to find out exactly what to do, when to do it and with what materials, in order to complete all the steps of an investigation.

If you read a step and are not sure what to do, try these strategies:

- Re-read the previous step.
- Re-read the step that confuses you. Sometimes re-reading clarifies the information.
- Ask your partner if he or she understands what the step says to do.
- Ask your partner to explain what the step says to do.
- Ask your partner to read the step aloud as you listen and try to do what your partner is describing.
- Re-read the purpose (Challenge) of the investigation.
- Try to say the purpose of the step out loud in your own words.
- Look at the clues in the pictures of the activity.
- Peek at other groups and listen to see if they are doing the step that confuses you.
- Tell your teacher exactly what you are confused about and why it doesn't make sense.