



Activity 2

Elements and Their Properties



GOALS

In this activity you will:

- Apply ancient definitions of elements to materials you believe are elements.
- Test some properties of several common chemical elements.
- Classify elements as metals, nonmetals or neither.
- Learn to differentiate between chemical and physical properties of materials.
- Organize a table of the elements you tested based on their properties.
- Practice safe handling of corrosive chemicals in the laboratory.

What Do You Think?

Throughout the ages of history, philosophers and scientists have talked about “the elements.” Reference to elements is most frequent today in the field of chemistry.

- What is a chemical element?

Record your ideas about this question in your *Active Chemistry* log. Be prepared to discuss your responses with your small group and the class.

Investigate

1. Work individually first and then in your group.
 - a) Make a list of four or more substances you use or encounter in your everyday experience that meet your definition of element.
2. The ancient Greeks believed that the four elements were: earth, air, fire, and water.

The alchemists of the early Renaissance identified three elements: mercury, sulfur, and salt.

 - a) Does each of the above “elements” satisfy your definition of an element? Why or why not?

What Do You Think?

The current definition of an element is: An element is material that cannot be broken down into new material that is stable or simpler through chemical reactions.

Remember that the **What Do You Think?** question is not intended to reach a conclusion, but is a lead to inquiry.

Answers will vary depending on students' various backgrounds in science. Many of the students will probably already have a good idea of what an element is and they will point to the periodic table. They may also have a basic understanding of the information the periodic table offers. Some students, however, will classify compounds as elements and it might be best not to correct them at this time since the activity will get them on the right path to understanding what an element is.

Student Conceptions

This activity asks students to qualify their conceptions about what elements are and how to recognize them. Prior to high school, most students have probably been taught that elements are materials that cannot be further decomposed by chemical means. This is a definition that is difficult to apply, since it requires experience with the chemical behaviors of materials, and specifically, how to break down materials into their constituent elements. Students are more apt to classify materials based on perceptible properties, such as color and texture, than on behaviors, such as reactivity with acids. This results in students memorizing the definition without understanding it. The activity gives students materials that are elements and directs the students to perform tests to determine chemical and physical properties of the elements. These methodical tests allow students to form generalizations about classes of materials and their behaviors, to give them experiences on which to base applications of the definition of an element.

Investigate

Teaching Suggestions and Sample Answers

1. Have the students list all materials that they classify as elements. However, students should be able to justify why they included each material in the list. You may be surprised what they list as elements. Some students will probably classify materials that are pure as elements. They may think that a gold ring is an element, but it really is an alloy. Pure gold is very soft and in order to give it stability, gold is alloyed with other metals such as copper, silver, palladium, and nickel. Allow time for group discussion.

3. Your teacher will provide a series of jars containing several common chemical elements: aluminum, copper, iodine, iron, magnesium, silicon, sulfur, and zinc.

You will investigate the properties of these elements. By observing common properties, you may gain an insight into how an organizational chart can be created for all of the known elements. Observe the sample of the chemical element in each jar (without removing any).

on the apparatus goes on, that means that a complete circuit is created, and an electric current is passing through both the light bulb and the sample of the element in the jar.

It is important to make sure that the part of the apparatus immersed into the elements stays dry and is not contaminated by any of the other elements it has been immersed in. Also, use steel wool to polish the metal strips before you test them.

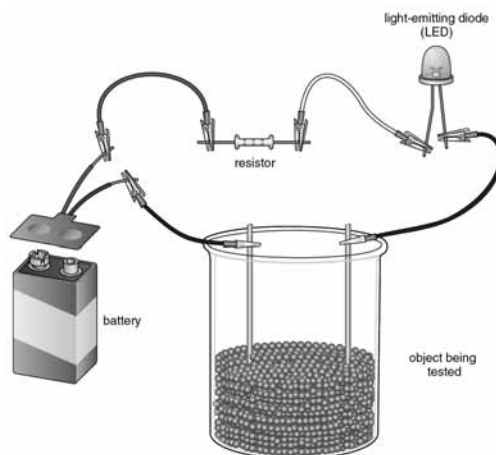


Safety goggles and a lab apron must be worn during this activity.

Element	Initial observations	Conducts electricity	Reacts with HCl	Metal or nonmetal
aluminum				
copper				
iodine				
iron				
magnesium				
silicon				
sulfur				
zinc				

- a) Record your observations in a table. You may wish to use a table similar to the above to record your observations in this activity.
4. One of the properties of the chemical elements on Mendeleev's cards was the ability of the element to conduct electric current.

Insert the terminals of the electrical conductivity apparatus into the jar containing each element. If the light



2. According to the early definition of an element, it would seem logical that they would think of water as being only one thing. The alchemists were getting closer, but salt of course was a wrong choice. Their definition may still state that a material that is pure is classified as an element. As they continue the investigation they will continue to keep making revisions to their definition. History shows us that, as we collect more facts, we will continue to change our definition of an element until we arrive at the current definition.
3. The student must handle the iodine crystals with extreme care. Students may note that all of the samples are solids. (You may want to ask them how they would classify liquid mercury.) They may conclude that this is a property of a metal. The investigation should lead them to realize that nonmetals can also be solids.
4. a)

Element	Conducts electricity
Aluminum	Yes
Copper	Yes
Iodine	No
Iron	Yes
Magnesium	Yes
Silicon	Slightly
Sulfur	No
Zinc	Yes

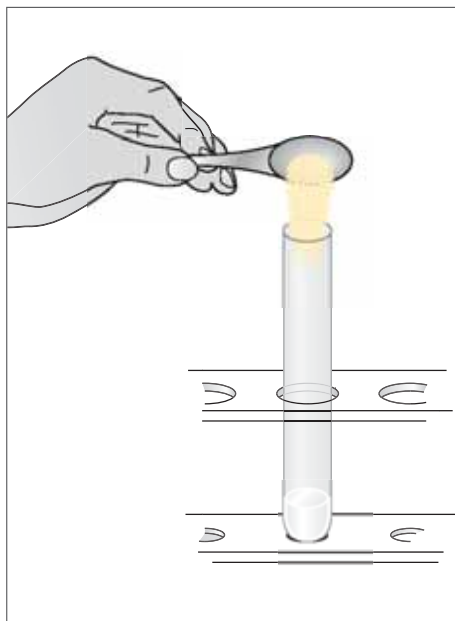
5. a–b)

Element	Reacts with HCl
Aluminum	Yes+
Copper	No
Iodine	No
Iron	Yes–
Magnesium	Yes+
Silicon	No
Sulfur	No
Zinc	Yes



Active Chemistry The Periodic Table

- a) Test the samples of each element with the electrical conductivity apparatus and record whether they conduct electric current (yes) or not (no).
5. Another of the properties of each chemical element known to Mendeleev was how it reacts with acid.
- You must still be wearing your safety goggles. Pour 5 mL of 1 M hydrochloric acid into each of eight small test tubes. Use a chemical scoop or tongs to remove a small portion of each element from the jar and add it to the hydrochloric acid. It is important to add the hydrochloric acid to the test tube first so that you will not be surprised by a reaction by

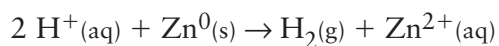
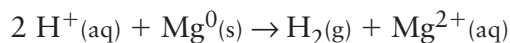
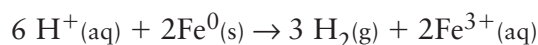
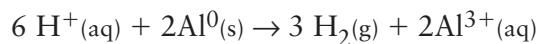


- pouring acid over a reactive chemical element. Place a piece of white paper in the background behind the test tube and observe the reaction between the element and hydrochloric acid by looking through the side of the test tube.
- a) Test small samples of each element for their reaction with hydrochloric acid and record whether they react with the acid (yes) or not (no).
- b) For those that do react, try to determine whether all exhibit the same type of reaction (do they all do the same thing?) and compare the relative vigor of the reactions. If the reaction is vigorous, include a + sign next to your “yes.” If the reaction is weak, place a – sign next to your “yes.”
6. Dispose of the contents of the test tubes and clean the test tubes as directed by your teacher. Wash your hands.
7. A metal is generally a solid that is shiny, malleable, and a good conductor of heat and electricity. A nonmetal is generally dull, brittle, and is a poor conductor of heat and electricity.
- Classify each of the elements you observed as either a metal or nonmetal.
- a) Record your observations in the table in your *Active Chemistry* log.
8. Create index cards for each of the elements and find a way to sort them

5. a-b) Metals appear to react with HCl with the exception of copper. Make certain that the metal strips used were polished so that they do not get false readings. The reactions agree with the activity of metals ($Mg > Al > Zn > Fe > Cu$).

The copper metal cannot be oxidized using hydrochloric or sulfuric acid.

The reactions that are taking place with the metals and hydrochloric acid are:



Chem Tip:

Copper will not react with hydrochloric or sulfuric acid, but it will react with nitric acid. It is not the hydrogen proton (H^+) of nitric acid that reacts with the copper but the nitrate anion. The nitrate anion is a stronger oxidizing agent than the hydronium ion and thus we call nitric acid an oxidizing acid and we call hydrochloric and sulfuric acids nonoxidizing acids. The overall reaction is:



6. The acid in the test tube can be rinsed with water and then flushed down the drain. Any solid material that did not react can be disposed of in the waste receptacle.
7. a)

Element	Metal	Nonmetal
Aluminum	Yes	No
Copper	Yes	No
Iodine	No	Yes
Iron	Yes	No
Magnesium	Yes	No
Silicon	Metalloid	Metalloid
Sulfur	No	Yes
Zinc	Yes	No

based on their properties. You may try arranging them and/or color coding them. Your method of sorting will be successful if you can quickly find an element and know from its position whether it:

- conducts electricity;
 - reacts with HCl;
 - is metallic or nonmetallic.
- a) Record your method of sorting the cards in your *Active Chemistry* log.

ChemTalk

PHYSICAL AND CHEMICAL PROPERTIES

Classifying Elements Using Properties

You began this activity by trying to define the meaning of a chemical element. The ancient Greek philosopher Aristotle defined an element as “a body into which other bodies may be analyzed . . . and not itself divisible into bodies different in form.” The first modern definition of chemical element, which is not much different, is from Robert Boyle: “Bodies, which not being made of any other bodies, or of one another, are the ingredients of which all those . . . mixed bodies are . . . compounded.” We now state that an element is any material that cannot be broken down by chemical means into simpler materials.

Before the mid-19th century, scientists were preoccupied with discovering elements and observing and recording their properties. Then they tried to organize the elements they had discovered in a useful way. At first, they listed the elements alphabetically. However, every time a new element was discovered, the whole list had to be changed. They tried other methods. Could elements be organized by properties like state, color, or taste? None of these methods appeared practical or safe! However, chemists worldwide were sure that elements existed in families that had similar physical and chemical properties. To the Russian scientist, Dimitri Mendeleev (1843-1907), the development of a tool to organize the elements began the same way that so much of science inquiry begins, with a simple question. The question Mendeleev wanted answered was: “What is the relationship of the elements to one another and to the chemical families to which



8. Students will probably classify the metals by how they reacted with hydrochloric acid; most reactive to least reactive. They may group nonmetals by color (light color to dark color). At this time they will have difficulty in trying to figure out where silicon should be grouped (most likely they will place it with the metals). Hopefully, they will decide that it should be separate from the metals and nonmetals but close to the metals since it did indicate that it would conduct an electric current. Copper conducted an electric current and did not react with hydrochloric acid and silicon's behavior was similar to that of copper.

Chem Tip:

Silicon looks like a metal but we find that it is brittle and not malleable. It is also a poor conductor of electricity and heat and this would also have it favor the nonmetals. Silicon and other elements that are in between metals and nonmetals are classified as metalloids.



Active Chemistry The Periodic Table

Checking Up

1. Define a chemical element.
2. What question did Mendeleev use to guide his science inquiry?
3. In your own words, describe the difference between a physical and a chemical property.

Chem Words

physical property: a property that can be measured without causing a change in the substance's chemical composition

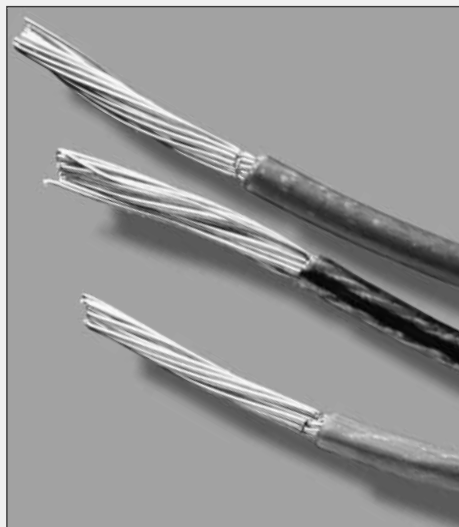
chemical property: a characteristic that a substance undergoes in a chemical reaction that produces new substance(s)

they belong?" At that time there were 63 known elements. To help him with his organization, he developed a card game, much the same as you did in this activity. He wrote the properties of each known element on a different card and then spent many hours arranging and rearranging the cards. He was looking for patterns or trends in the data in front of him. Mendeleev, however, had more information on his cards than you presently have. In the following activities, you will look at additional properties of elements that will help you organize your game.

Physical and Chemical Properties

In this activity you observed several properties of the elements you were provided. You probably initially observed the color and the state of the element. You then investigated whether or not the chemical element conducted electricity. You could have also observed the luster, measured the density

or the strength, or determined the malleability of each element. In each case, you would not have changed the element itself. In this investigation the element still looked the same in the jar after you removed the electrical conductivity apparatus as it did when you initially inserted it. If measuring a property of a substance does not change the chemical identity of one substance, it is called a **physical property**.



On the other hand, when you observed whether the chemical element reacted with hydrochloric acid, the element clearly changed.

A **chemical property** is the kind of reaction that a substance undergoes. Measuring chemical properties changes the chemical composition of a substance.

ChemTalk

Checking Up

1. A chemical element contains only one kind of atom, or a chemical element is any material that cannot be broken down into simpler material.
2. Mendeleev's question used in organizing his periodic table was: "What is the relationship of the elements to one another and to the chemical families to which they belong?"
3. Physical properties of a material or element are thought of as characteristic qualities. If the process used to test for the property, such as conductivity, melting, and boiling, does not change the element or material, then we classify these as examples of physical properties. Additional physical properties that we look at are malleability, ductility, and density.

Chemical properties of an element or material are how it reacts with different materials. The reaction causes the material or element to change into a new material. An example of a chemical property is a metal reacting with hydrochloric acid to produce hydrogen gas.

Reflecting on the Activity and the Challenge

In this activity you learned not only the definition of a chemical element but also some of the properties of chemical elements. Measuring these properties not only enabled Mendeleev to place the elements in his periodic table but

also allowed other chemists to identify the elements. You have tried to sort the cards of elements in the same way that Mendeleev did. Perhaps your periodic table game can have sorting cards as one part of the strategy.

Chemistry to Go

1. Make a list of three more physical properties of a chemical element that you could observe.
2. Make a list of three more chemical properties of a chemical element that you could measure.
3. Why did you want the metals to be clean or polished before you tested them for electrical conductivity?
4. What criteria did you use to differentiate metals from nonmetals in this investigation?
 - a) Is this a valid statement of a trend you saw: as the color of the element becomes darker, the element is less metallic? Support your assessment of this statement with evidence that you observed in your investigation.
 - b) Is this a valid statement of a trend you saw: the elements react with hydrochloric acid more as you move down a list of the elements listed in alphabetical order? Support your assessment of this statement with evidence that you observed in your investigation.

Preparing for the Chapter Challenge

Prepare a set of index cards for each of the elements with which you are familiar. Record as many properties of each element you know on the card.

Use your observations in the following activities and any research you complete on your own to add information to each card.

Chemistry to Go

1. Students' lists will vary but they should include properties like: melting point, boiling point, and density as the most common choices. They may also include malleability, ductility, and luster. If they hold a piece of metal in their hands they will have a cold feeling which is related to thermal conductivity. Nonmetals will be brittle and will lack luster.
2. Students' lists will vary again. They may include reactions with oxygen, other chemicals, and the property to burn.
3. Since the metals react to form oxides or other compounds on their surfaces, we want them to be clean. If they are not clean we could get a false reaction and the acid could be reacting with the oxides or surface compounds.
4.
 - a) Sulfur is nonmetallic and it is light in color. Color can be very deceiving. An example is silver. A sheet of silver is shiny and white. However, if it is in the powder form it is black. So, color cannot be used to differentiate between metals and nonmetals.
 - b) Copper does not react with hydrochloric acid and would defeat the concept that alphabetical order of the metals can be used to determine which metals will react with hydrochloric acid.

Preparing for the Chapter Challenge

Their mini-periodic table should have the metals on one side and the nonmetals on the other side. Students may have four of the metals grouped together, and copper by itself. Silicon will give them some problems (they may put this in a separate group, since they may not be sure whether it is a metal or nonmetal). The nonmetals are probably grouped together. Since hydrogen and oxygen are gases, they should have them separate from the metals and nonmetals. They should also conclude that hydrogen gas is produced in the reaction with metals and hydrochloric acid. However, oxygen gas reacts with the elements and causes the metals to corrode or form a compound. Thus, they will probably separate the hydrogen and oxygen gas.