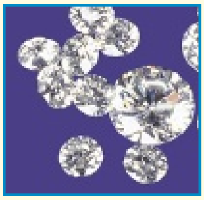
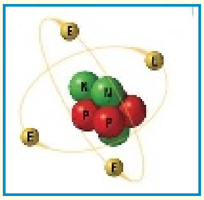
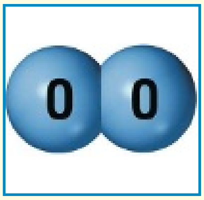
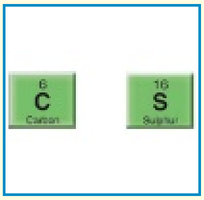
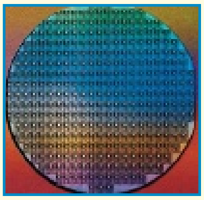
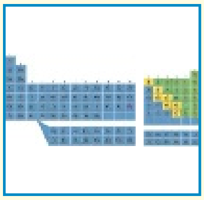
CHAPTER 7

Types of Matter

Vocabulary

	**volume**	the space an object takes up
	**mass**	the amount of matter in an object
	**matter**	anything that has mass and volume
	**density**	a measure of how tightly matter is packed in an object
	**element**	the simplest kind of substance there is
	**atom**	the smallest particle of an element that has all the properties of an element
	**molecule**	a particle that contains more than one atom joined together
	**metal**	a substance that conducts heat and electricity well
	**nonmetal**	an element that is a poor conductor of heat and electricity
	**metalloid**	one of a group of elements that have properties of metals and nonmetals

What do all types of matter have in common?



periodic table a table that arranges all known elements in rows and columns based on their properties

mixture a combination of two or more substances that keep their properties

suspension a mixture in which the particles settle and separate over time

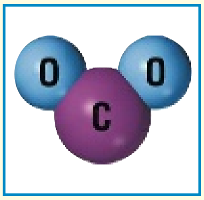
solution a mixture that stays mixed and you can see through clearly

solvent the part of a solution that does the dissolving

solute the part of a solution that gets dissolved

filtering a way of separating particles of different sizes

chemical change a change in matter that produces a new substance with new properties



compound a substance formed when two or more other substances are combined and a chemical change takes place

hydrocarbons compounds made of hydrogen and carbon

Lesson 1
Properties of Matter

What is matter?

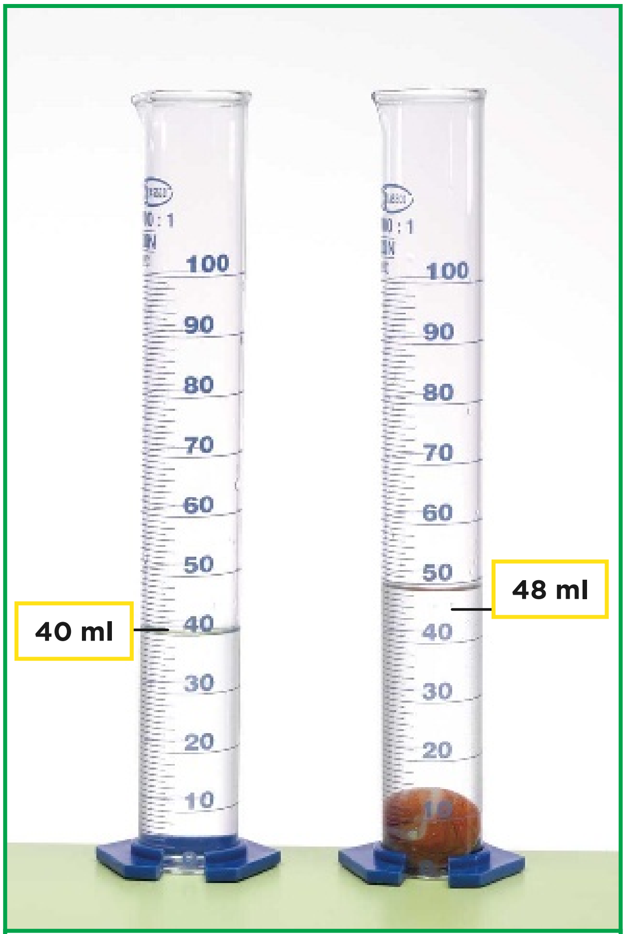
Put it on a balance and the pan goes down. Drop it into a cylinder of water. The water level goes up. What is it? The answer is matter.

Matter can be a solid, liquid, or gas. Matter takes up space. The amount of space it takes up is its **volume** (VOL•yewm).

To find the volume of a liquid, pour it into a clinder like the one shown here. Drop a solid into the liquid. The amount the liquid rises is the volume of the solid. Volume is measured in milliliters (mL) for liquids and gases, and cubic centimeters (cc or cm^3) for solids.

The amount of matter in any object is its **mass**. To find the mass, put an object on a balance. Mass is measured in grams (g).

In summary, **matter** is anything that has mass and volume.



A marble is dropped into 40 mL of water. The water level goes up to 48 mL. The volume of the ball is 48-40, or 8 mL.

Quick Check

Match the word with the description.

1. ____ volume **a.** any solid, liquid, or gas

2. ____ mass **b.** the space something takes up

3. ____ matter **c.** the measurement taken with a balance

Mass and Weight

When you step on a spring scale, you measure your weight. Weight is a measure of how strongly gravity pulls on an object. It is measured in newtons (N) or pounds (lb).

Weight can change. It depends on the pull of gravity on an object. On other planets, gravity is weaker or stronger than on Earth. So an object's weight would be less or more than on Earth.

Weight is not the same as mass. Mass is the amount of matter in an object. It is measured with a balance. It always stays the same, no matter where the object is.

Volume, mass, and weight are all ways of describing matter. These are some properties of matter.

The mass of the marble is measured with a pan balance. It is always the same.

Quick Check

Fill in each blank with *goes up* or *goes down*.

4. You drop a pebble into a cylinder of water. The water level

______________________________.

5. You place a pebble on a pan of a balance. The pan

______________________________.

6. Gravity is weaker on the Moon than on Earth. So on the

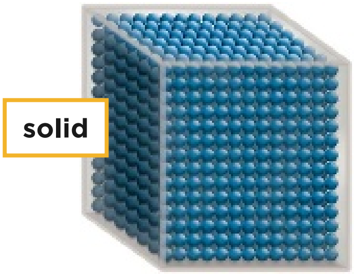
Moon, your weight ______________________________.

What are states of matter?

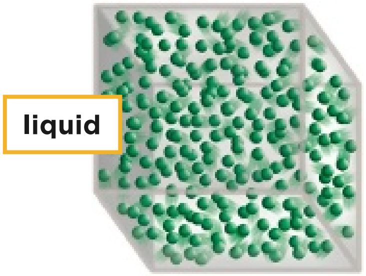
Matter includes all solids, liquids, and gases.

Solid, liquid, and gas are the three states of matter. They are the forms matter can take.

- **solids** Particles that make up a solid are packed together tightly. They hardly move, except to "wiggle" in place. So the shape or volume (size) does not change.



- **liquids** Particles that make up a liquid can move past each other but stay close. So the shape of a liquid changes with the container it is in. However, the volume does not change.



- **gases** Particles that make up a gas move around freely and can spread apart. So both the shape *and* the volume of a gas change to fit the container the gas is in.

Quick Check

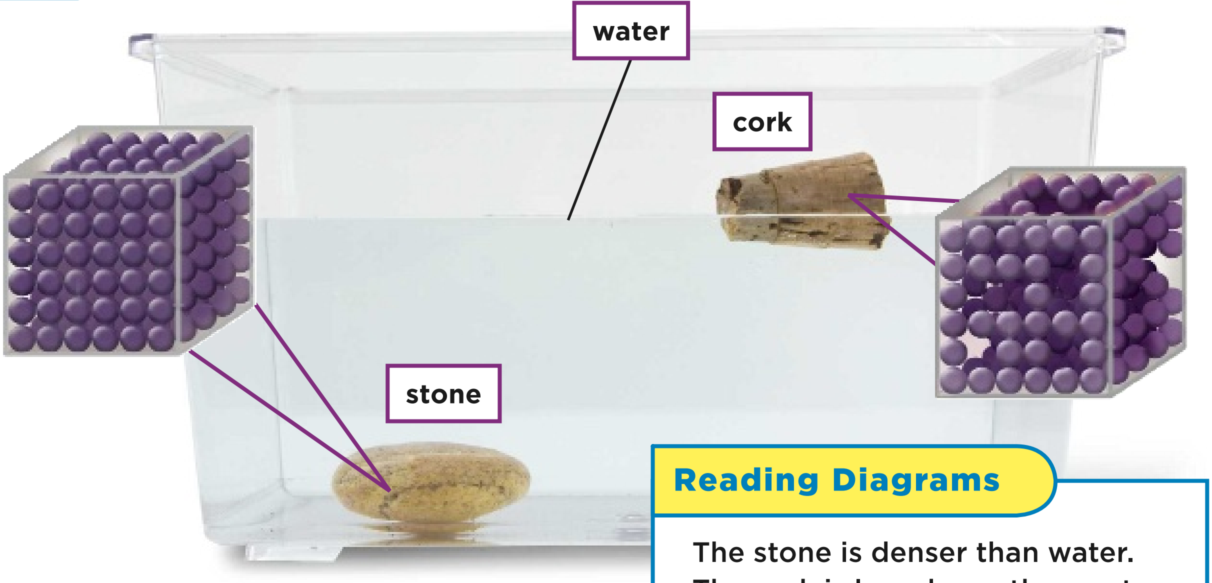
Match the state with the description.

7. ____ solid **a.** The volume changes.

8. ____ liquid **b.** The shape stays the same.

9. ____ gas **c.** Particles move but stay close.

Density



Reading Diagrams

The stone is denser than water.
The cork is less dense than water.

What is density?

Both the stone and the cork in the picture are solids. So why does the stone sink and the cork float? The particles that make up the stone are tightly packed. The particles that make up the cork are less tightly packed.

The rock has a greater density (DEN•si•tee) than the cork. **Density** is a measure of how tightly matter is packed in an object.

The stone and the cork have about the same size (volume). However, the denser stone has more mass—because it has more particles packed into its volume.

An object sinks in a liquid if it is denser than the liquid. The stone is denser than water. An object floats in a liquid if it is less dense than the liquid. The cork is less dense than water.

✓ *Quick Check*

Write *greater* or *lesser* in each blank.

10. Water has a ______________________ density than the stone.

11. The stone has a ______________________ density than the water.

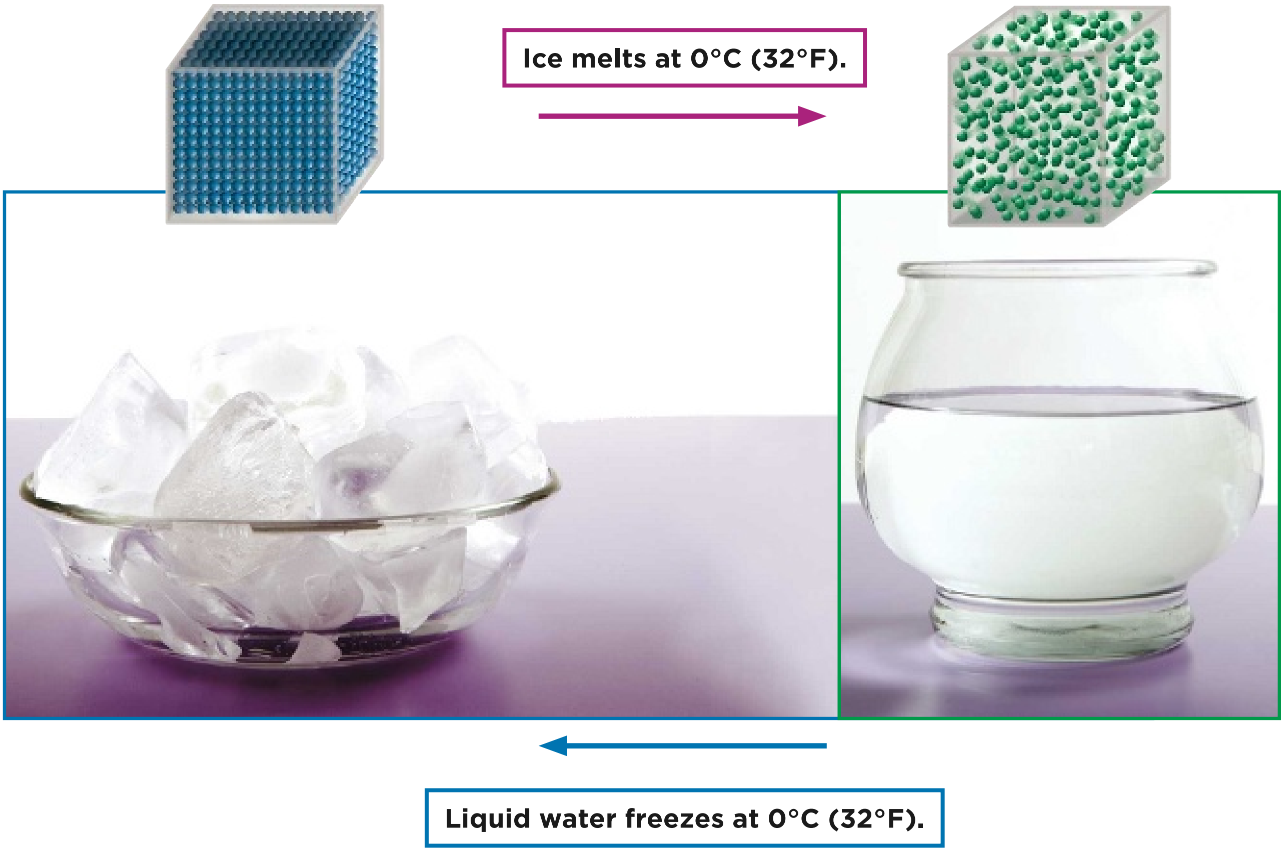
Can the state of matter change?

At room temperature, everything is a solid or liquid or gas. If the temperature changes, an object's state of matter can change.

For example, start with something that is lower than room temperature—ice. Hold a piece of ice in your hand. The warmth of your hand raises the temperature of the ice. The ice *melts*. That is, it changes from solid to liquid.

When a solid is warmed, its particles move faster and faster. The solid melts when the particles flow past each other. The temperature at which a solid changes to a liquid is its *melting point*. Ice starts to melt if it is warmed up to its melting point, 0°C (32°F).

If liquid water is cooled down to 0°C (32°F), it starts to freeze. The temperature at which something freezes is its *freezing point*.



Boiling

If you left a bowl of water uncovered in sunlight, evaporation (i•VAP•purh•ray•shuhn) would take place. During evaporation, warmed particles from the liquid slowly escape into the air. The liquid becomes a gas. Water in the form of gas is water vapor.

If you boil water, the particles of water escape into the air *quickly*. The boiling point is the temperature at which a liquid changes *quickly* to a gas. Water boils at 100°C (212°F).

When water vapor cools, the particles slow down and come closer together again. The gas changes into a liquid. The temperature at which a gas changes to a liquid is the *condensing point*. Some solids change directly to a liquid with melting.

Water boils at 100°C (212°F).

Water vapor condenses at 100°C (212°F).

Quick Check

Fill in two details to explain the main idea.

Main Idea	Details
Matter can change state.	**12.** ______________________
	13. ______________________

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Lesson 2
Elements

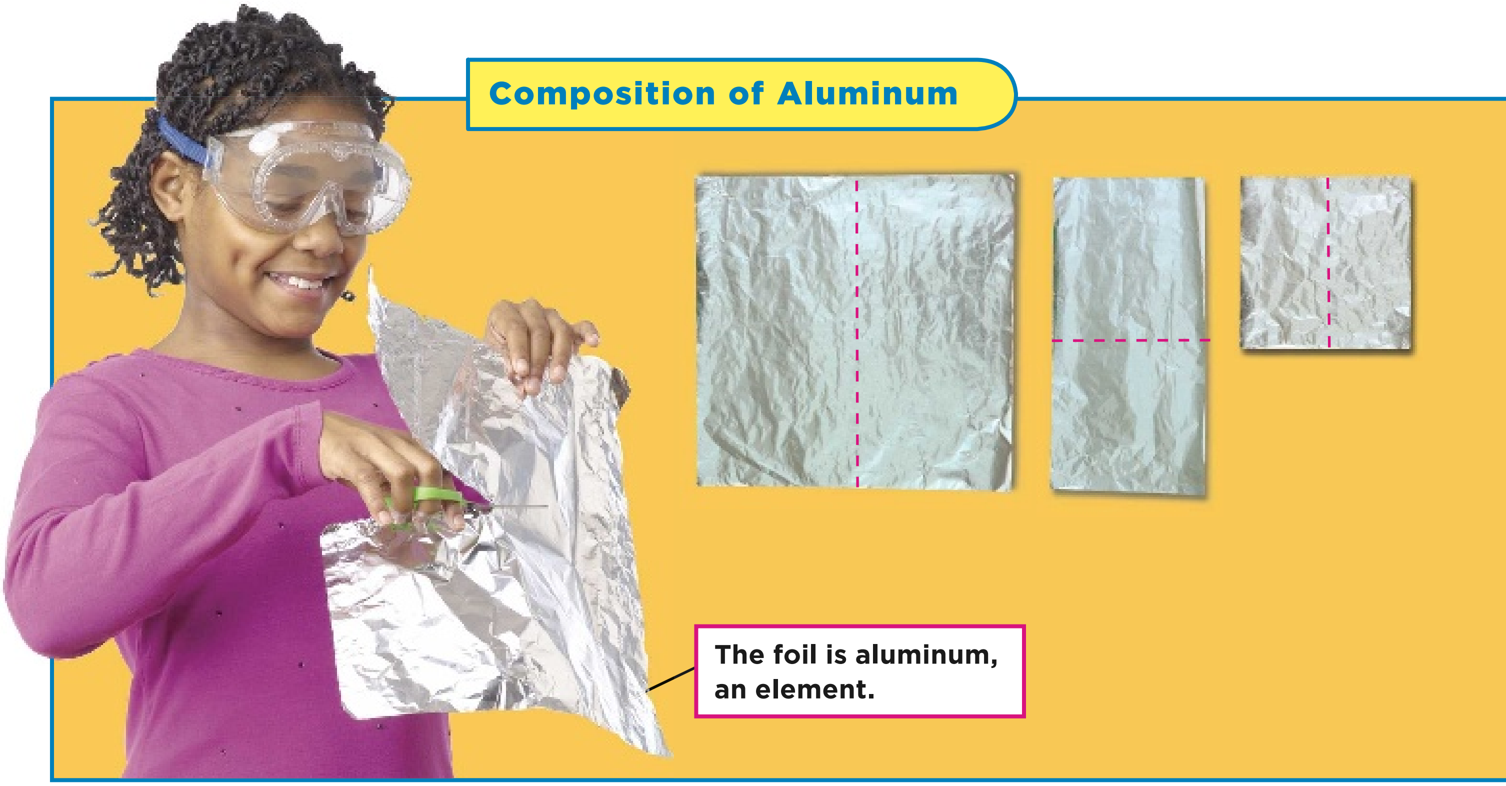
What is an element?

Centuries ago, the ancient Greeks thought that all kinds of matter were made of four simple substances. They identified air, fire, earth, and water as the building blocks of all matter.

Today, we know of over 100 building blocks of matter, the elements. An **element** is the simplest kind of substance, something that cannot be broken into anything simpler. These elements are the substances that are combined in all kinds of matter.

Some of the commonly known elements are:

- gases—oxygen, nitrogen, hydrogen
- liquids (only two)—bromine, mercury
- solids (the most)—carbon, aluminum, iron, copper, sulfur, nickel, siver, gold



Composition of Aluminum

The foil is aluminum, an element.

Names, Symbols, Atoms

The names of elements come from many places. The element mercury was named after a character from ancient Roman myths. The element californium was named for our state.

Each element has a symbol for its name. A symbol is made of:

- one capital letter, such as O for oxygen, OR
- a capital letter followed by a small letter, such as Zn for zinc.

Symbols come from many languages—such as Latin and Greek. For example, Au, for gold, is from the Latin word for gold, *aurum*.

Each element is made up of tiny particles called atoms (A•tuhmz). An **atom** is the smallest particle that makes up an element and has the properties of that element. To get an atom, you would have to keep breaking a piece of an element into smaller and smaller bits.

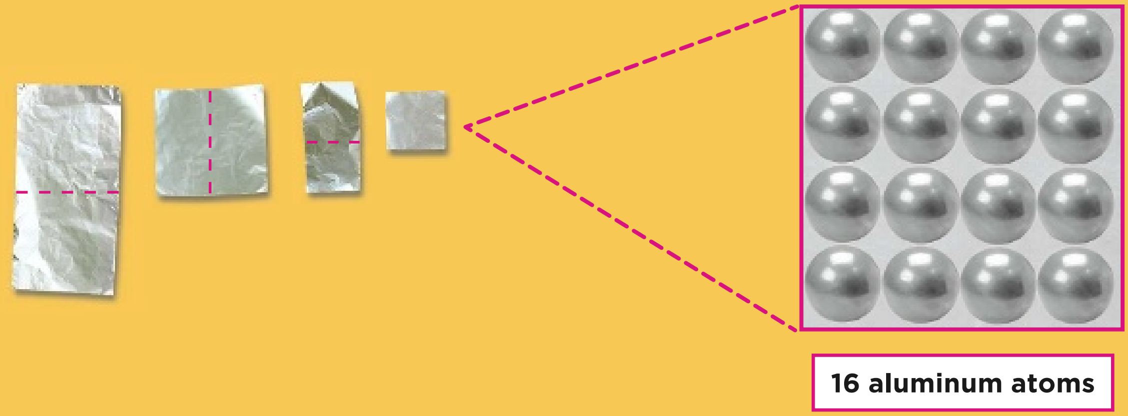
Quick Check

Match the word with the description.

14. ____ element **a.** a letter or two to stand for a name

15. ____ atom **b.** the simplest kind of substance

16. ____ symbol **c.** the smallest kind of particle



Reading Photos

Aluminum atoms are the smallest particles of aluminum.

What are the most common elements?

Of the over 100 known elements, 92 were found in nature. The others were made by scientists in laboratories. Only eight elements make up about 98% (by weight) of Earth's surface layer, the crust. Two elements, oxygen and silicon, head the list. The rest of the natural elements are in the crust as well, but in very small amounts.

The oceans are made largely of two elements, oxygen and hydrogen, 96% by weight. Chlorine and sodium from salt make up 3%.

Just two elements, nitrogen and oxygen, make up 99% of Earth's air. Most of the air is nitrogen, but we must breathe in oxygen. A few other elements make up 15% of the air.

✓ Quick Check

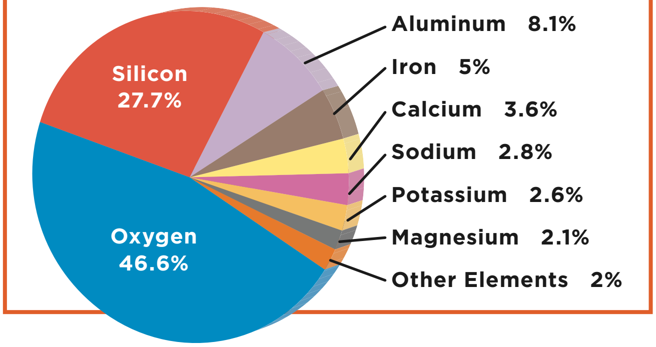
17. Which element is common in the air, water, *and* the crust?

____

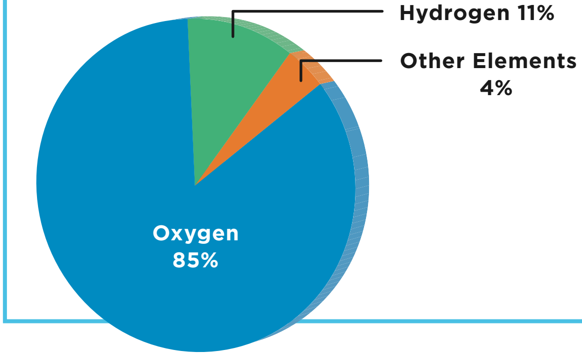
____

Composition of Earth

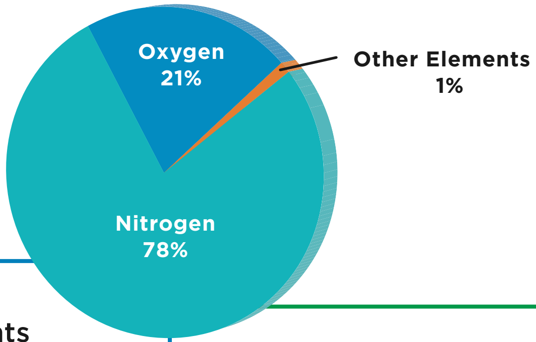
Crust



Water



Air



Reading Charts

The pie charts show elements found in Earth's crust, water and air.

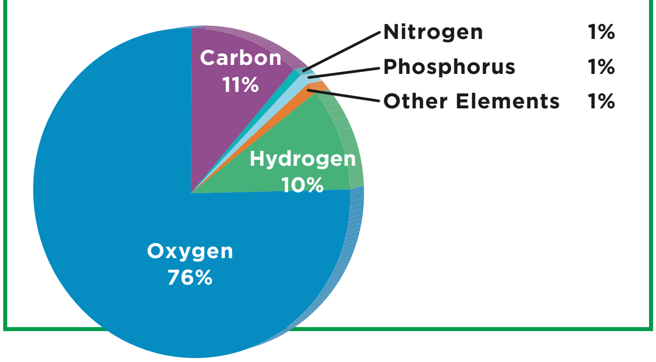
Elements in Living Things

Plants have thick cell walls and other parts for support. These parts are made mainly of the elements carbon, hydrogen, and oxygen.

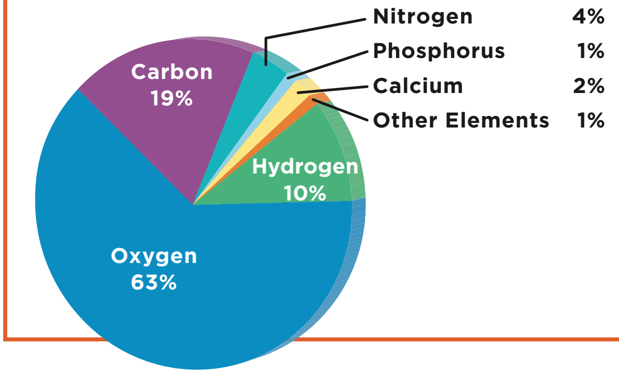
Animals, too, are made mainly of the elements carbon, hydrogen, and oxygen. The bodies of animals contain a great deal of water. Human body weight is over 60% water. Much of the oxygen and hydrogen in our bodies is from the water we contain.

Bones, teeth, and other parts also contain nitrogen, phosphorus, and some chlorine and sulfur.

Common Elements in Plants



Common Elements in Animals



✓ *Quick Check*

18. Circle the row that has the three most common elements in living things, listed from the most to the least:

nitrogen	oxygen	carbon
oxygen	carbon	hydrogen
mercury	calcium	oxygen

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Lesson 3
Classifying Elements

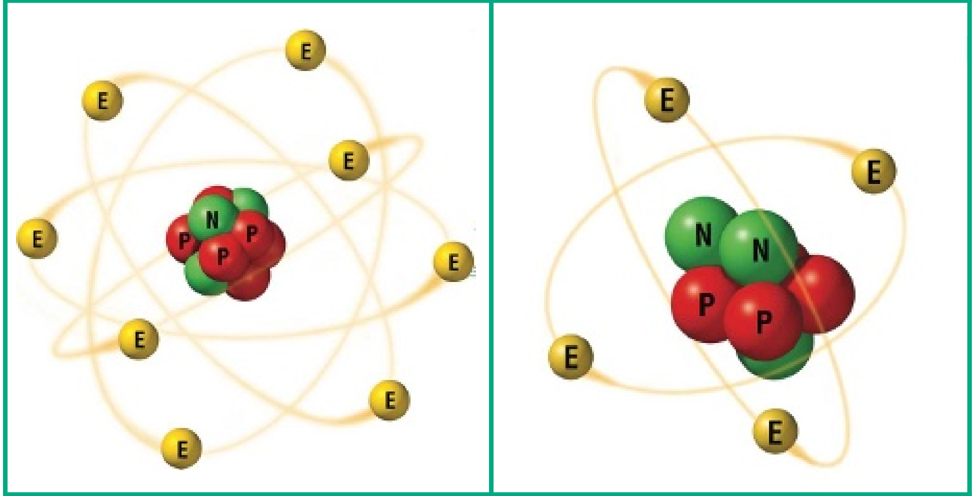
What are atoms made of?

Remember, if you split an element into smaller and smaller pieces, you eventually get an atom of the element. If you could split an atom, you would see the pieces the atom is made of.

- *protons* (PROH•tahns) and *neutrons* (NEW•trons) are located in the center, nucleus, of an atom. Each proton carries a positive electrical charge. Neutrons are not charged.
- *electrons* (e•LEK•trahns) move around the nucleus very quickly. Each carries a negative charge. Electrons are very small.

The number of protons in an atom is the atomic number. Atoms of different elements have different atomic numbers. An atom of helium has only 2 protons. An atom of carbon has 6 protons.

Each element has an atom with its own number of protons. The number of protons is the same as the number of electrons.



An oxygen atom has:
- **8 protons (atomic number)**
- **8 electrons**
- **8 neutrons**

The atomic weight = 8 + 8 = 16.

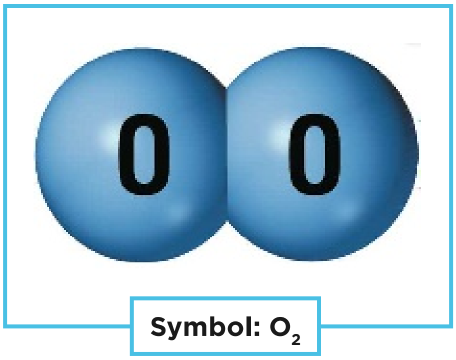
A boron atom has:
- **4 protons (atomic number)**
- **4 electrons**
- **3 neutrons**

The atomic weight = 4 + 4 = 8.

Atoms of each element have their own atomic weight. The atomic weight is the sum of the protons and neutrons of an atom. Electrons are not counted because they have so little mass.

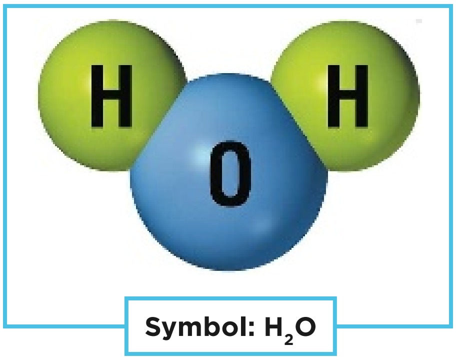
Atoms of some elements are found naturally as molecules (MOL•uh•kyewls). A **molecule** is a particle made of more than one atom joined together. For example, oxygen exists as molecules. A molecule of oxygen is made of 2 oxygen atoms joined together. The symbol for an oxygen molecule is O_2.

Molecules can be made of atoms of different elements. For example, water molecules are made of 2 hydrogen atoms and 1 oxygen atom.



Symbol: O_2

An oxygen molecule is made of 2 oxygen atoms that are joined together.



Symbol: H_2O

A water molecule is made of 1 oxygen atom and 2 hydrogen atoms joined together.

Quick Check

Cross out the word or term in each row that does not belong. Explain your answer.

19. proton neutron electron molecule

____

____

20. atomic weight protons neutrons electrons

____

____

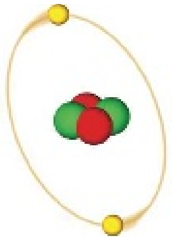
What are properties of elements?

Many elements have similar properties.

- Most elements are metals. **Metals** conduct heat and electricity well. They can be bent or flattened without breaking. They are usually solids at room temperature. Examples are: aluminum, gold, iron, copper, and silver.
- There are 17 nonmetals. **Nonmetals** do not conduct heat and electricity well. Solid nonmetals, like carbon, break rather than bend. Most nonmetals are gases, like helium, oxygen, and nitrogen. Bromine is a liquid.
- A small group of elements called **metalloids** (MET•uh•loids) conduct heat and electricity, but not as well as metals. Boron and silicon are metalloids.

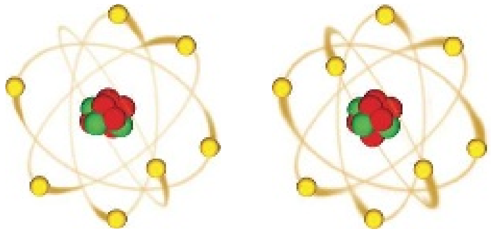
✓ *Quick Check*

Label each as a *metal* or *nonmetal*.



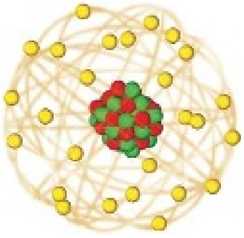
Helium inflates floating balloons.

21. ______________________



Nitrogen/Oxygen make up 98 percent of air.

22. ______________________



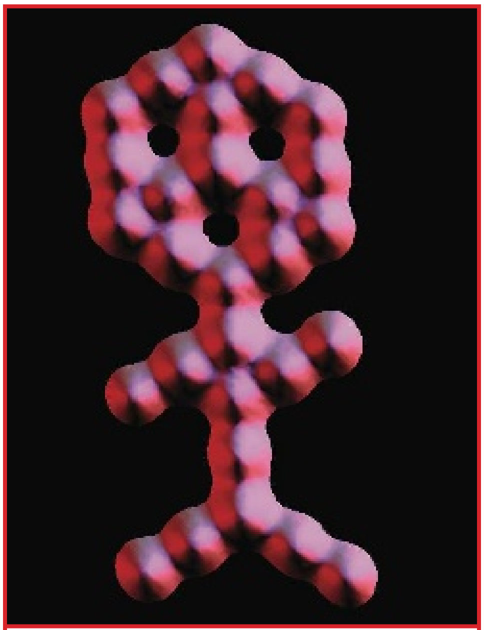
Iron in the fence is strong and heavy.

23. ______________________

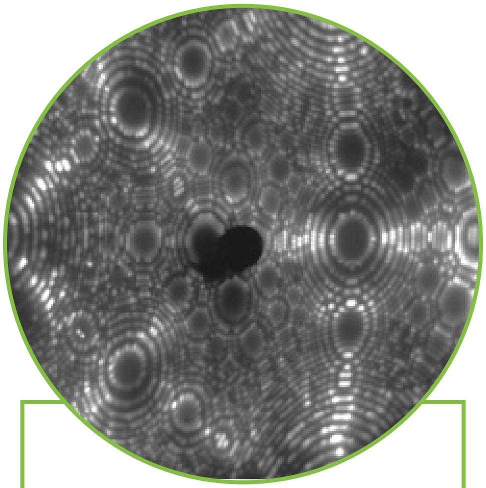
Can we see atoms?

In a pinch of salt there are over a half billion sodium atoms and a half billion chlorine atoms. That's how small atoms are. We can't see them with just our eyes. However, we can see them with special microscopes.

- The electron microscope, invented in 1932, hits atoms with a beam of electrons. It allowed us to see molecules.
- The field ion microscope, invented in 1951, bounces electrically charged particles called ions (EYE•ahns) on atoms. It allowed us to see molecules and large atoms.
- The modern scanning tunneling microscope uses a very fine tip to grab atoms or groups of atoms. The tip can then drag them on a surface.
- The very new one-angstrom microscope shows the atoms lined up inside a metal.



With a tunneling microscope, 28 two-atom groups were moved onto a platinum surface in a shape called Molecule Man.



With a field ion microscope, atoms appear as bright spots.

Quick Check

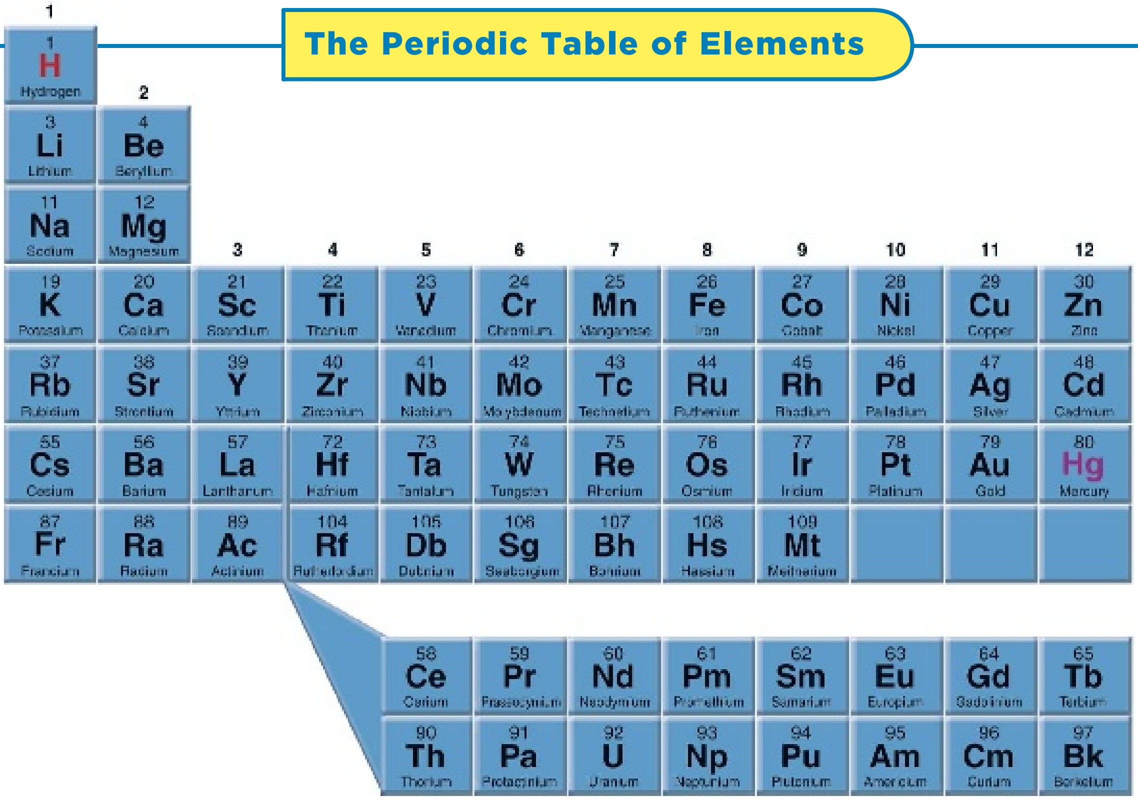
24. Circle the microscope that is out of order.

electron   scanning tunneling   field ion   one-angstrom

25. Why are these special microscopes important? ______________________

____

The Periodic Table of Elements



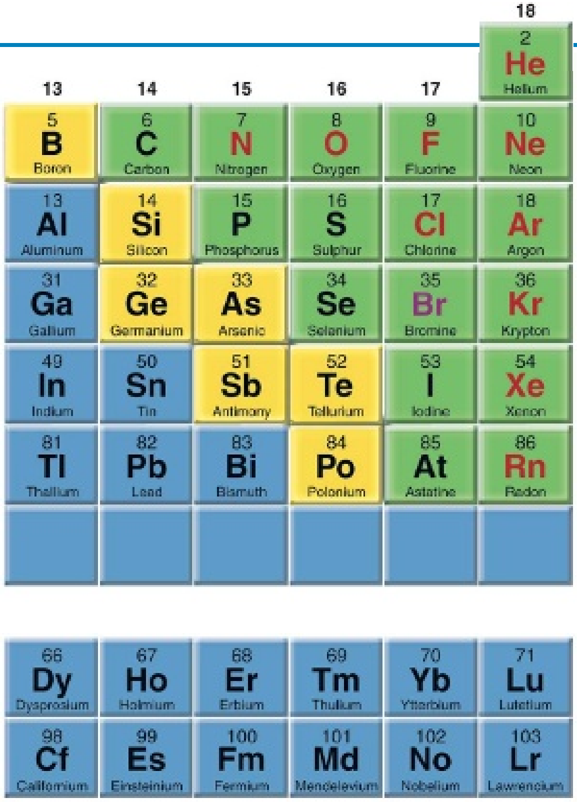
1	2	3	4	5	6	7	8	9	10	11	12
1 H Hydrogen											
3 Li Lithium	4 Be Beryllium										
11 Na Sodium	12 Mg Magnesium										
19 K Potassium	20 Ca Calcium	21 Sc Scandium	22 Ti Titanium	23 V Vanadium	24 Cr Chromium	25 Mn Manganese	26 Fe Iron	27 Co Cobalt	28 Ni Nickel	29 Cu Copper	30 Zn Zinc
37 Rb Rubidium	38 Sr Strontium	39 Y Yttrium	40 Zr Zirconium	41 Nb Niobium	42 Mo Molybdenum	43 Tc Technetium	44 Ru Ruthenium	45 Rh Rhodium	46 Pd Palladium	47 Ag Silver	48 Cd Cadmium
55 Cs Cesium	56 Ba Barium	57 La Lanthanum	72 Hf Hafnium	73 Ta Tantalum	74 W Tungsten	75 Re Rhenium	76 Os Osmium	77 Ir Iridium	78 Pt Platinum	79 Au Gold	80 Hg Mercury
87 Fr Francium	88 Ra Radium	89 Ac Actinium	104 Rf Rutherfordium	105 Db Dubnium	106 Sg Seaborgium	107 Bh Bohrium	108 Hs Hassium	109 Mt Meitnerium			
				58 Ce Cerium	59 Pr Praseodymium	60 Nd Neodymium	61 Pm Promethium	62 Sm Samarium	63 Eu Europium	64 Gd Gadolinium	65 Tb Terbium
				90 Th Thorium	91 Pa Protactinium	92 U Uranium	93 Np Neptunium	94 Pu Plutonium	95 Am Americium	96 Cm Curium	97 Bk Berkelium

What is the periodic table?

Suppose you wrote out the name of each element on a card. Along with the name, you list properties of each element. How would you organize your cards to show which elements are alike?

Dmitri Mendeleev (DMEE•tree men•DEL•ee•ef) did just that in the 1800s. He organized the cards in order of increasing mass. He laid them out into rows and columns. He found that all the elements in any column have similar properties.

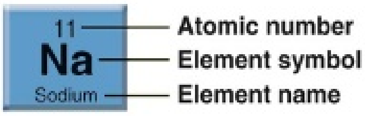
Mendeleev organized the periodic (peer•ee•OD•ik) table. The **periodic table** is a chart with the elements in rows and columns of increasing atomic number. You see the atomic number in each box in the table. As you go from row to row, the properties repeat themselves (periodic refers to “repeating”).



13	14	15	16	17	18
					2 He Helium
5 B Boron	6 C Carbon	7 N Nitrogen	8 O Oxygen	9 F Fluorine	10 Ne Neon
13 Al Aluminum	14 Si Silicon	15 P Phosphorus	16 S Sulphur	17 Cl Chlorine	18 Ar Argon
31 Ga Gallium	32 Ge Germanium	33 As Arsenic	34 Se Selenium	35 Br Bromine	36 Kr Krypton
49 In Indium	50 Sn Tin	51 Sb Antimony	52 Te Tellurium	53 I Iodine	54 Xe Xenon
81 Tl Thallium	82 Pb Lead	83 Bi Bismuth	84 Po Polonium	85 At Astatine	86 Rn Radon

66 Dy Dysprosium	67 Ho Holmium	68 Er Erbium	69 Tm Thulium	70 Yb Ytterbium	71 Lu Lutetium
98 Cf Californium	99 Es Einsteinium	100 Fm Fermium	101 Md Mendelevium	102 No Nobelium	103 Lr Lawrencium

Key



🟦 Metals
🟨 Metalloids
🟩 Nonmetals

State at Room Temperature:
Black: solid
Purple: liquid
Red: gas

Reading Tables

The key helps you find information about elements on the periodic table.

Similar Elements

When the elements are listed by increasing atomic number in rows of no more than 18,

- all the metals are together (blue boxes)
- all the nonmetals are together (green boxes)
- all the metalloids are together (yellow boxes)
- all the gases are together (symbols in red)

The columns have groups or families of elements, elements with similar properties. For example, column number 17 has all the *halogen* (HAL•uh•jen) gases. These gases have a foul smell. They can burn flesh and combine with metals. Column 18 has the noble gases. These gases are "inactive" elements. They don't combine with other elements.

Quick Check

26. How many gases are there? How can you tell?

____

____

____

27. How many metalliods are there? How can you tell?

____

____

____

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Lesson 4
Mixtures

What is a mixture?

Trail mix is a tasty mixture (MIKS•chuhr). A **mixture** is a combination of two or more things that keep their own properties. You can pick apart the things that make up trail mix—such as nuts and pretzels. Each item keeps its taste and shape.

Trail mix is a mixture in which the particles inside are big enough to see. Tossed salad is another example. These mixtures do not look the same throughout. There may be more nuts in one part and more pretzels in another.

In other mixtures, the particles that are mixed together are too small to see. Milk is an example. You cannot see the particles inside.

Concrete is a solid mixture. It is made up of small pieces of rocks, fine sand, fine cement powder, and water. The parts are thoroughly mixed into a pourable mud that hardens into a strong material that does not settle out.

The CN Tower in Toronto, Canada, is made from a solid mixture, concrete.

◀ Trail mix is a mixture of many kinds of tasty snacks in one.

To Settle or Not to Settle

The particles in some mixtures settle out. In others, the particles do not settle out. A **suspension** (suh•SPEN•shuhn) is a mixture in which the particles settle and separate into layers over time. For example, shake oil and vinegar to make a smooth suspension. Then let it sit. In time the oil layers out on top of the vinegar.

The particles in some mixtures are the size of atoms or molecules. These mixtures are solutions (suh•LEW•shuhns). A **solution** is a mixture that stays mixed because its particles are as small as atoms or molecules.

You make a solution by dissolving one substance in another, like sugar in water. Solutions are the same throughout. If they are liquid or gas, you can see through them clearly.

A suspension of oil and vinegar separates into its parts when it stands still.

Window cleaner is a solution. It stays mixed. You can see through it.

Quick Check

28. You shake oil and water together. How can you tell if you have made a suspension or a solution? ____________________

____

29. Circle the word that includes the other two:

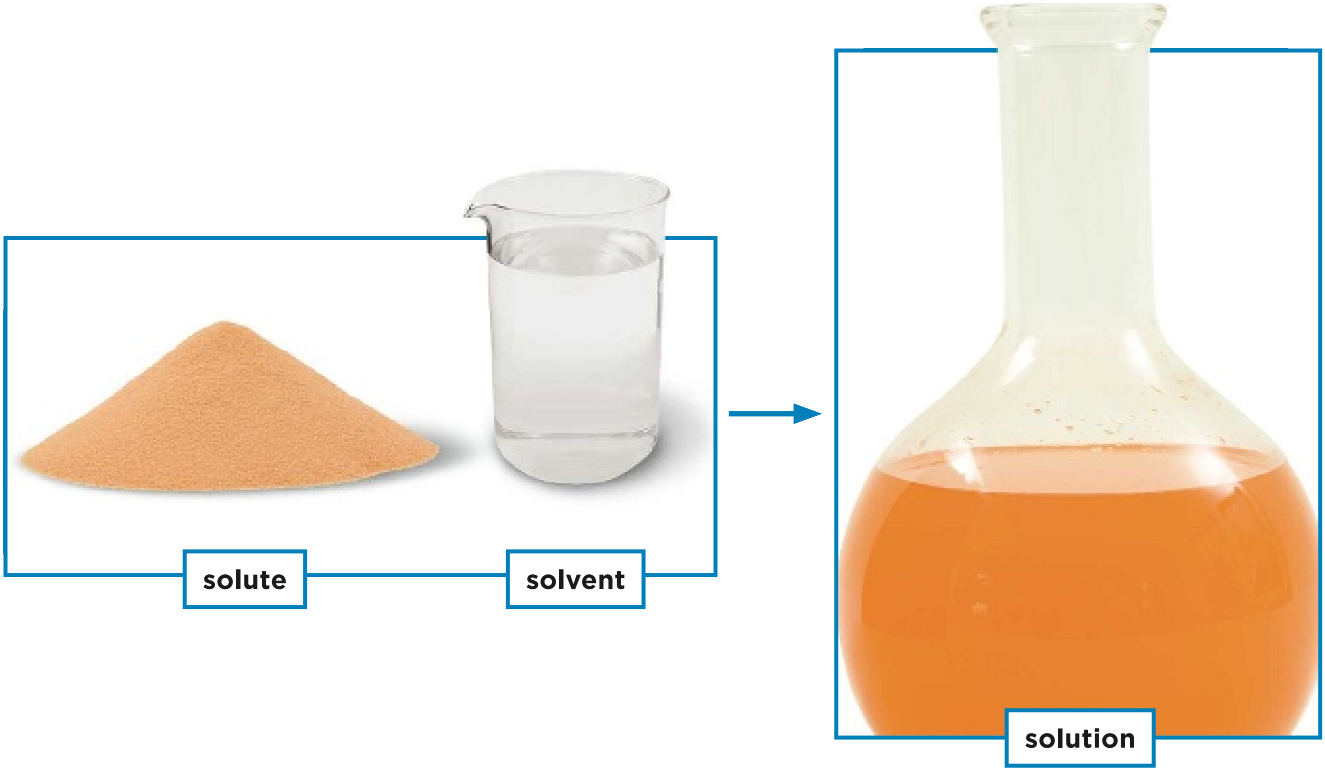
mixture solution suspension

What are the parts of a solution?

Add sugar to water and stir. The sugar *dissolves*. That is, it breaks into particles the size of molecules and seems to disappear in the water. However, the sugar is still there because the mixture is sweet.

All solutions have a part that dissolves another part. The **solvent** (SOL•vuhnt) is the part that does the dissolving, such as water. The part that gets dissolved, such as sugar, is the **solute** (SOL•yewt).

The solute or the solvent can be a solid, a liquid, or a gas. The solvent is usually the part there is more of. For example, air is a mixture of gases. Most of the air is nitrogen. Nitrogen is the solvent. Other gases, like oxygen, are the solutes dissolved in the nitrogen.



Reaching a Limit

Have you ever tried stirring table salt into water? At first the salt dissolves. However, as you add more, the added salt falls to the bottom, no matter how hard you stir.

A solvent (water) can dissolve only a certain amount of solute (salt). At room temperature, only 37 grams of table salt dissolves into 100 grams of water. Extra salt does not dissolve.

There is a limit to how much solute can disolve. When the limit is reached, the extra solute falls to the bottom.

Is there a way to get the extra salt to dissolve? One way is to use warm water. Heating water can allow more solid solute to dissolve.

However, heating can have the opposite effect when the solute is a gas. For example, seltzer is a solution of a gas (carbon dioxide) and water. Cool seltzer holds more carbon dioxide gas than warm seltzer.

Quick Check

30. Circle the word that includes the other two:

solute solution solvent

31. What effect can heating have on a solution? ______________________

____

Separating Mixtures

▲ Sand and water: Sand particles cannot pass through the holes in the filter. Water goes through, but sand collects on the filter.

▲ Sawdust and sand in water: Let the mixture stand still. Sawdust floats to the top and sand collects on the bottom.

How can you take mixtures apart?

Make three mixtures: sand in water, sawdust and sand in water, sugar and sand in water. Can you get the solids back? Mixtures are *physical combinations*. That means their properties do not change. So you should be able to separate the solids from the liquid.

- One way to separate them is by filtering (FIL•ter•ing). **Filtering** separates substances that have particles of different sizes. Pour the mixture over a filter. A filter has small holes. Small particles pass with the liquid through the holes. Larger particles are trapped by the filter.
- If substances have different densities, some may float or sink in water. For example, sand is denser than water. It sinks when the mixture is kept still. Sawdust is less dense than water. It floats to the top.

▲ Sugar and sand in water: Sand falls to the bottom. Pour the liquid through a filter. Let the water evaporate. The sugar remains behind.

▲ Iron and sand in water: A magnet attracts the iron filings, but not the sand.

- If you have a solid solute (like sugar) dissolved in water, just let the solution stand open to the air for several days. The water evaporates and leaves the solid solute behind.
- Suppose you spilled iron filings into sand. You can separate the iron by using a magnet. The magnet attracts iron, while the sand remains behind.

Reading Diagrams

How would you separate a mixture of sand, sawdust, sugar, and iron filings in water?

LOG ON *Science in Motion* Watch how mixtures are separated @ www.macmillanmh.com

Quick Check

Match each solid with a way of separating it from water.

32. ____ sawdust

33. ____ sand

34. ____ sugar

35. ____ iron filings

a. evaporating

b. using a magnet

c. floating

d. sinking

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Lesson 5
Compounds

Iron in this ship combined with oxygen in the air and formed rust, a brownish material that crumbles.

What change produces new substances?

Have you ever seen rust on a bicycle fender or a car? Rust forms when iron comes into contact with oxygen, a gas in the air. Iron and oxygen combine and form rust.

Rust is a different substance from iron or oxygen, with its own properties. For example, rust has a different color than iron. You cannot separate the iron and oxygen from rust as simply as you can separate parts of a mixture.

Rust forms from a chemical change. A **chemical change** is change in matter that produces substances different from the substances you started with. To separate the iron from the oxygen would take another chemical change.

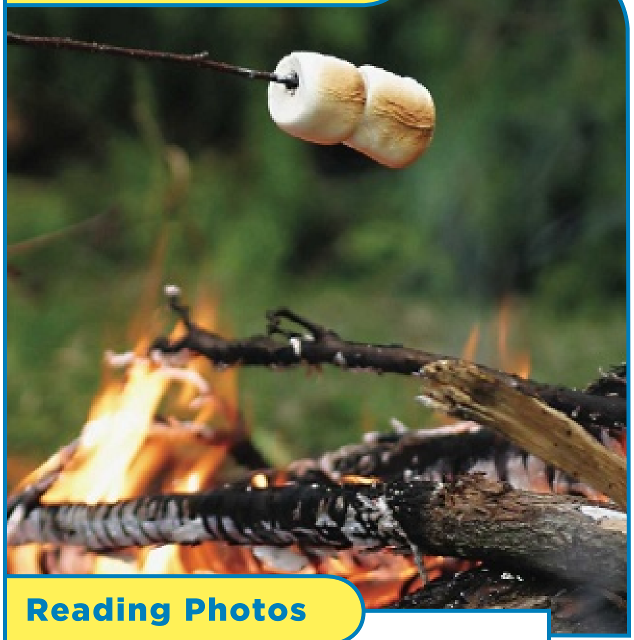
Compounds

Rust forms when atoms of iron combine with atoms of oxygen. Rust is an example of a compound (KAHM•pownd). A **compound** is formed when atoms of two or more elements are combined. The chemical name of rust is iron oxide. The name shows that rust is made of iron and oxygen.

Sugar is another example of a compound. Sugar molecules are made of atoms of three elements: carbon, hydrogen, and oxygen.

A marshmallow is white sugar. What happens when a marshmallow is toasted? There is a chemical change. In this change, heat moves about the atoms in the sugar to produce a black material, the carbon, and steam. Steam is water, a compound of hydrogen and oxygen.

Chemical Changes



Reading Photos

The marshmallows, sugar, are changing chemically. The burning sticks are also changing chemically. Both are producing a black substance, carbon.

Quick Check

Write *true* or *false*. If it is false, explain why.

36. A chemical change produces new substances. ____________________

37. A compound is a kind of mixture. ____________________

How are compounds named?

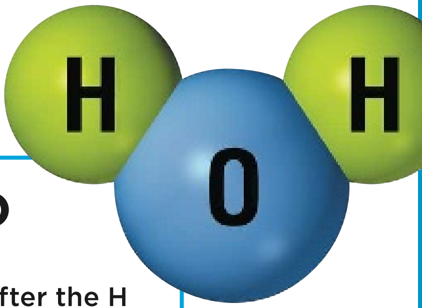
What we call rust is a compound made from two elements—iron and oxygen. The chemical name of rust is iron oxide. The name comes from one element (iron) plus a changed form of the other element (oxygen ⟶ oxide).

iron + oxygen ⟶ iron oxide (rust)

Another example is table salt. It is a compound made of the metal element sodium and the gaseous element chlorine. The chemical name of salt uses both the element names:

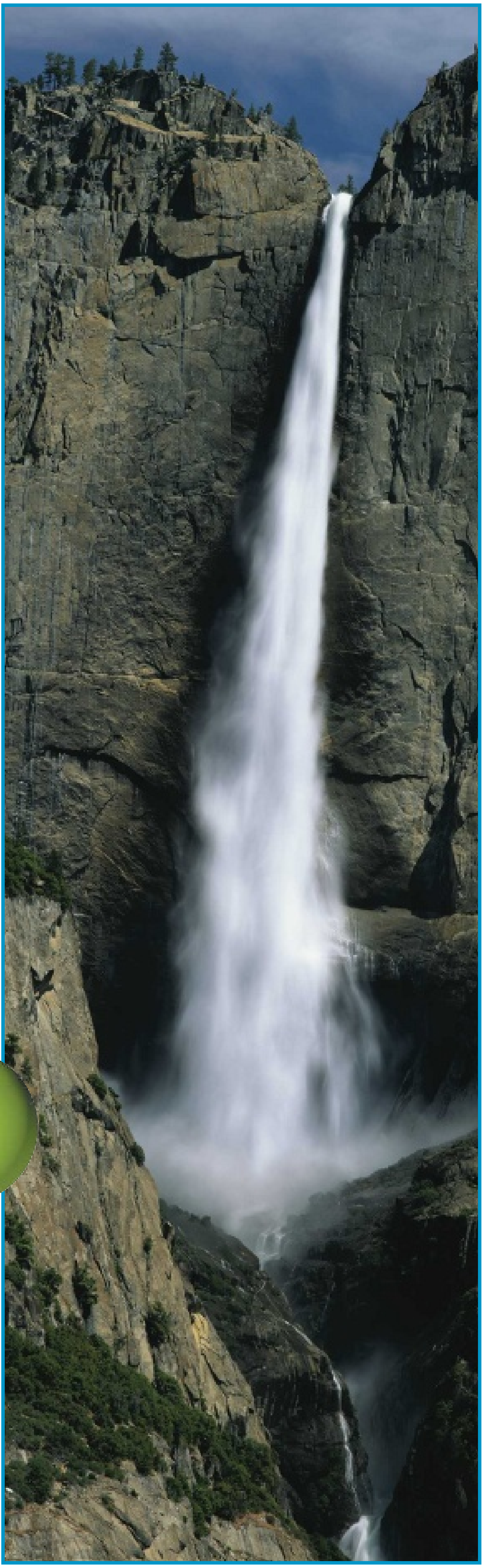
sodium + chlorine ⟶ sodium chloride (table salt)

Compounds can also be written in a short way called a *chemical formula* (FOR•myew•luh). A chemical formula uses symbols and sometimes numbers. For example, water is a compound of hydrogen (H) and oxygen (O). We can use symbols to write it as:



Water: H_2O

The small 2 placed after the H means that a molecule of water is made of 2 atoms of hydrogen combined with an oxygen atom.



Mon & Di

Sometimes we add prefixes to a chemical name to help tell one compound from another. For example, carbon and oxygen can combine in two ways. One atom of carbon can combine with one atom of oxygen: We put the prefix *mon* with the oxygen to show one oxygen atom:

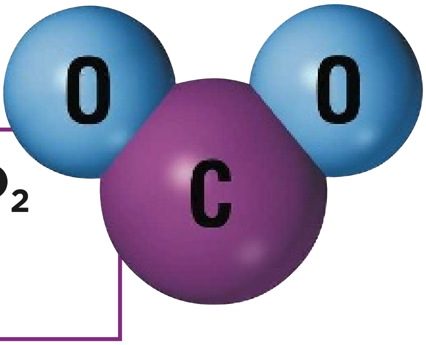
CO (carbon *mon*oxide) is made of 1 C atom + 1 O atom.

Carbon monoxide is the dangerous gas that you must watch out for at home.

A carbon atom can also combine with two oxygen atoms. That forms carbon dioxide (*di* means "two," as in 2 oxygen atoms). Carbon dioxide is a gas that you release when you exhale. It is also present in smoke.

Carbon dioxide: CO_2

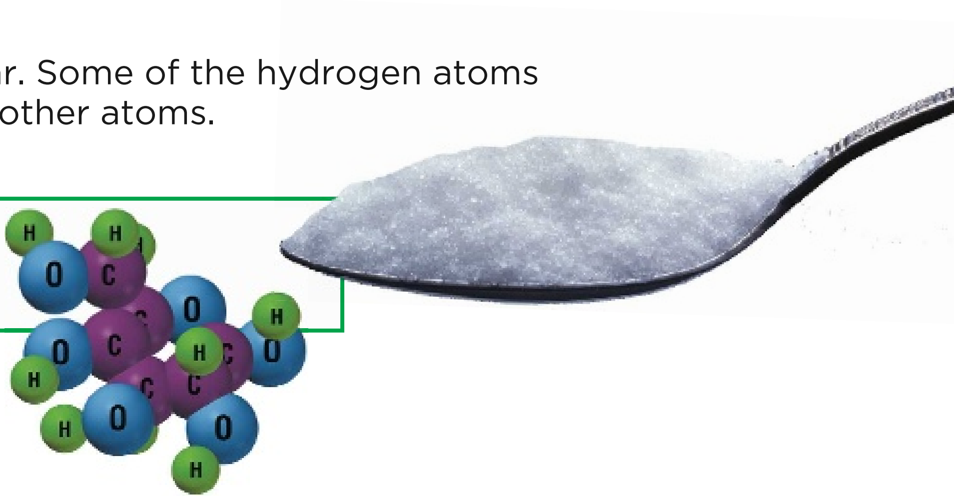
CO_2 (carbon *di*oxide) is made of 1 C atom + 2 O atoms.



✓ *Quick Check*

Here is a molecule of sugar. Some of the hydrogen atoms are not visible behind the other atoms.

Sugar: $C_6H_{12}O_6$



Tell how many of each atom are in one molecule of sugar.

38. ____ carbon atoms

39. ____ hydrogen atoms

40. ____ oxygen atoms

How can you identify compounds?

There are millions of compounds all around. Each one has its own properties. Some properties include: density, color, and freezing, melting, and boiling points. How a compound changes chemically is also a property.

You can use these properties to tell one compound from another. For example:

water	carbon dioxide
clear *liquid* at room temperature	colorless *gas* at room temperature
freezes at 0°C (32°F) boils at 100°C (212°F)	changes from gas directly to solid at –78°C (–108°F)
density = 1 gram per mL	1.5 times denser than air
puts out a flame	puts out a flame

You can tell what is in some compounds by the color a compound makes when it is held in a flame. Special computers are used today to heat compounds until they give off colors. The colors show what elements are in the compounds.

Compounds that contain potassium have violet flames.

Compounds that contain sodium (such as salt = sodium chloride) have bright yellow flames.

Quick Check

41. One way you can tell water from carbon dioxide is ____________________ ____.

42. Heating a compound may help you tell what is in it because __________ ____.

How are compounds used?

People today are finding many uses for compounds. For example, crude oil is a mixture of many useful products. It can be separated into gasoline, kerosene, diesel fuel, heating oil, and light fuel gases. These products are hydrocarbons (high•druh•KAHR•buhns). **Hydrocarbons** are compounds of hydrogen and carbon.

We use hydrocarbons every day. We use gasoline to run cars. We use oil and natural gas for heating. Rubber is made of hydrocarbons. We use rubber in tires, erasers, and the wrap on electrical wires.

Plastics are compounds made of long strings of carbon with other elements. Plastics are used to make paints, furniture, boats, and toys.

Clothing is made of natural compounds of cotton and wool, as well as of human-made compounds like polyester or nylon.

Quick Check

43. Why are compounds important to us? ______________________________

____

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Vocabulary Review

Types of Matter

density element mass mixture matter metal
metalloid molecule nonmetal solution volume

Fill in the blanks with a word from the box.

1. ____________________ the space an object takes up

2. ____________________ the amount of matter in an object

3. ____________________ anything that has mass and volume

4. ____________________ a measure of how tightly matter is packed

5. ____________________ the simplest kind of substance there is

6. ____________________ a particle that contains more than one atom joined together

7. ____________________ a substance that conducts heat and electricity well

8. ____________________ a combination of substances that keep their properties

9. ____________________ an element that is a poor conductor

10. ____________________ one of a group of elements that have properties of metals and nonmetals

11. ____________________ a mixture that stays mixed

Fill in each blank with a letter to spell out the answer.

1. the smallest particle of an element __ __ __ __
5

2. a mixture in which the particles settle and separate over time

__ __ __ __ __ __ __ __ __ __
1 4

3. the part of a solution that does the dissolving __ __ __ __ __ __ __
2 9

4. the part of a solution that gets dissolved __ __ __ __ __ __
13

5. a way of separating particles of different sizes

__ __ __ __ __ __ __ __ __
12 3

6. a change in matter that produces a new substance with new

properties __ __ __ __ __ __ __ __
7 8

7. a substance formed when two or more other substances are

combined and a chemical change takes place __ __ __ __ __ __ __ __
6

8. compounds made of hydrogen and carbon

__ __ __ __ __ __ __ __ __ __ __ __
10 11

Use the letters in the numbered blanks to answer the riddle.

Riddle: What is the name of the list of the building blocks all matter is made of? (**Clue:** The name is two words.)

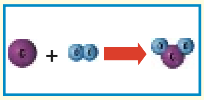
___ ___ ___ ___ ___ ___ ___ ___   ___ ___ ___ ___ ___
1 2 3 4 5 6 7 8   9 10 11 12 13

CHAPTER 8

Changes in Matter

Vocabulary

chemical reaction a change in which substances before the change are different from those after the change



reactant a substance before a chemical reaction happens

product a substance that is formed by a chemical reaction

reactive how easily a substance takes part in a chemical reaction

metal a substance that lets heat and electricity pass through easily

conductor anything that lets heat and electricity flow through easily

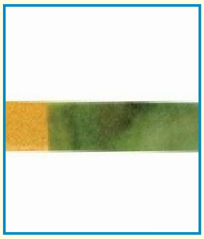
insulator something that prevents heat, electricity, and even sound from moving through

alloy a mixture of two or more metals and nonmetals

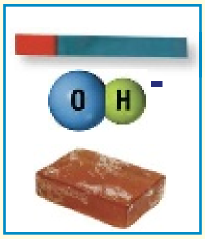
How does one substance become another?

salt a compound made of a metal and a nonmetal

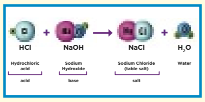
acid a substance that tastes sour and can be biting



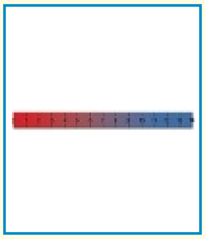
indicator something that changes color in ways that let you identify a substance



base a substance that tastes bitter and turns litmus paper blue



neutralize to add an acid and base together so that each cancels out the effects of the other



pH scale a measure of the strength of an acid or a base

Lesson 1
Chemical Reactions

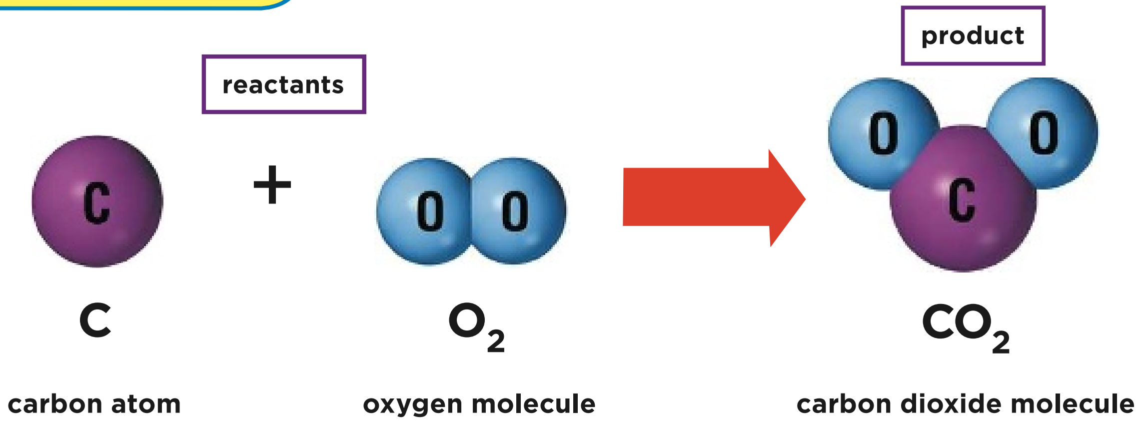
What are chemical changes?

Matter is going through *chemical changes* all around you. That is, substances are changing into other substances. Bread bakes. Iron rusts. Wood burns. Milk gets sour.

A chemical change in which you start with one substance (or more) and end up with a new substance (or more) is a **chemical reaction** (ree•AK•shuhn). The substances before the change are the **reactants** (ree•AK•tuhnts). The **products** are the new substances after the change.

What happens in a chemical reaction? The atoms and molecules in the reactants are rearranged. The rearranged particles form the products.

Carbon Dioxide



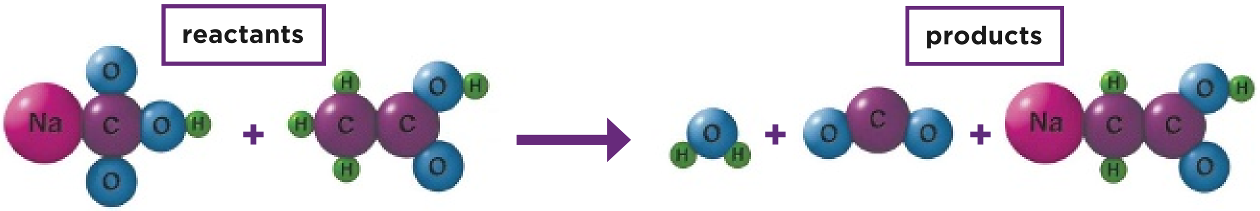
Reading Diagram

What happens to the carbon atom and the two atoms in the oxygen molecule?

Science in Motion Watch how atoms rearrange @ **www.macmillanmh.com**

This diagram shows a simple way to make carbon dioxide. Vinegar is added to baking soda. The products are water, bubbles of carbon dioxide, and a white powder (sodium acetate). See how the atoms rearrange themselves. There are just as many atoms of each kind before and after the reaction. So the total mass of the reactants equals the total mass of the products.

Formation of Carbon Dioxide



$NaHCO_3$	$HC_2H_3O_2$	H_2O	CO_2	$NaC_2H_3O_2$
sodium bicarbonate (baking soda)	**acetic acid (vinegar)**	**water**	**carbon dioxide**	**sodium acetate**

Here are two reactions in nature. In photosynthesis, green plants use sunlight and two reactants to produce food (a sugar).

water + carbon dioxide ⟶ sugar + oxygen

Plants and animals (and other living things) use that sugar to get energy in a chemical reaction called respiration.

sugar + oxygen ⟶ water + carbon dioxide

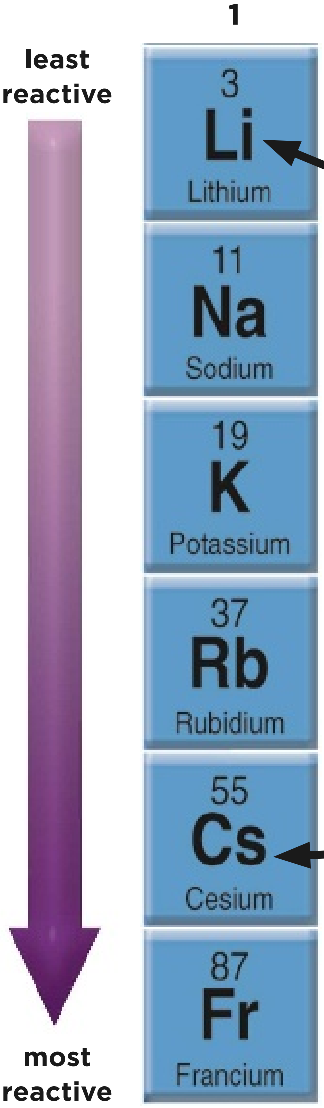
Quick Check

1. How are these last two chemical reactions alike? Different?

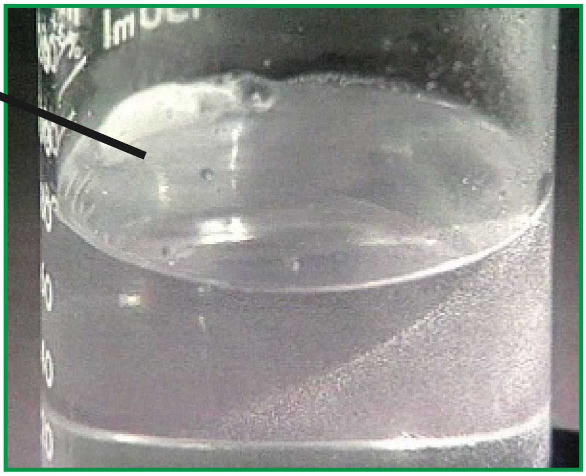
Which elements are most likely to change?

An iron fence is likely to rust unless you protect it. Iron is more reactive (ree•AK•tiv) than many other elements. **Reactive** means how easily a substance takes part in a chemical reaction.

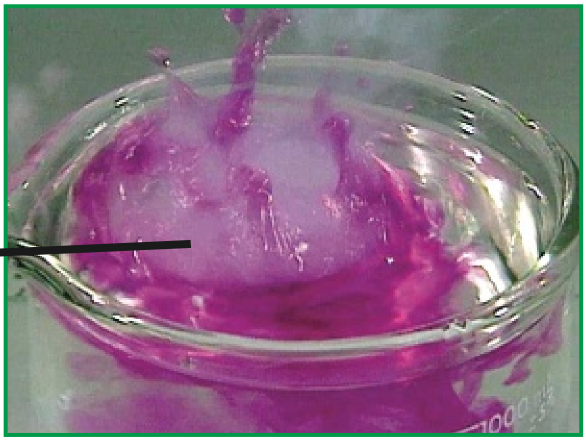
To tell how reactive a metal is, look at any column of metals in the periodic table. Metals become *more* reactive as you go *down* a group. The most reactive metals are the alkali (AL•kuh•ligh) metals, column 1. The most reactive metal of them is francium, (Fr).



▲ The alkali metals



◀ Lithium is at the top of this group and is the least reactive. When it is added to water, it takes 30.4 seconds to fizz and bubble.



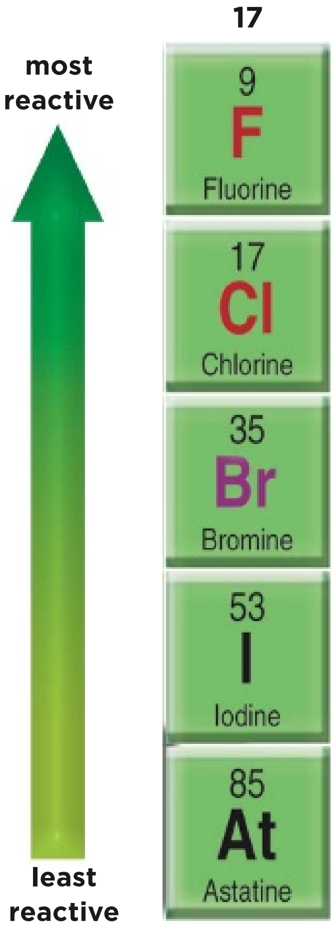
◀ Cesium is near the bottom of this group and is very reactive. When it is added to water, it fizzes wildly and sets off a brightly burning flame in 7.1 seconds.

Nonmetals

Nonmetals are reactive in an opposite way. Find any column of the periodic table that has nonmetals. The most reactive nonmetal is at the top of the column. Nonmetals become *less* reactive as you go *down* a column.

For example, oxygen is at the top of column 16. It is a reactive gas that combines with many metals.

The most reactive nonmetals are in column 17, the halogens. The most reactive of them are the two gases at the top, fluorine (Fl) and chlorine (Cl). For example, when chlorine combines with the metal sodium, the two elements disappear in a flash of light. They have formed table salt.



▲ The halogens

Quick Check

Write *more* or *less* in each blank.

2. Potassium is ______________________ reactive than lithium.

3. Fluorine is ______________________ reactive than bromine.

4. Metals are ______________________ reactive as you go up a group.

5. Nonmetals are ______________________ reactive as you go up a group.

Signs of a Chemical Change

Forms a solid	Forms a gas	Temperature changes
Two solutions (liquids) are mixed. They form a solid.	An antacid tablet in water produces bubbles of a gas, carbon dioxide.	When you slap these bags, substances inside the bags react. Heat is released and the temperature goes up.
		

What are the signs of a chemical change?

Chemical changes are going on all around. You can look for some signs that tell you a chemical change is happening.

- **Forms a solid** Sometimes when two solutions are mixed together, a chemical reaction takes place. The liquids form a solid. The solid does not dissolve.
- **Forms a gas** When two substances are mixed together, you might see bubbles of gas. The gas is the product of a chemical reaction. For example, put an antacid tablet into water. The reaction on page 181 takes place and bubbles of carbon dioxide are produced.

Releases light	**Color changes**	**Forms tarnish**
Burning a candle releases heat and light.	When bleach whitens a stain, a chemical reaction is taking place.	Tarnish, such as on this silver spoon, forms when metals react with oxygen or sulfur.
		

Reading Photos

The photos show different signs of a chemical change.

Energy and Color

- **Releases energy** You may see or feel energy given off in a chemical reaction. The energy may be heat, light, or both. For example, burning wood releases heat and light.
- **Color changes** If bleach is poured on a stain, the stain turns white. If a drop of reddish iodine is put on a potato, the red turns black. These color changes indicate a chemical change.
- **Forms tarnish** Metals may turn rusty, black, or green when they react with oxygen or sulfur. The changed color is tarnish.

Quick Check

Fill in three facts to explain the summary.

6. ______________________

____

____

7. ______________________

____

____

8. ______________________

____

____

Summary: You can look for signs of a chemical change.

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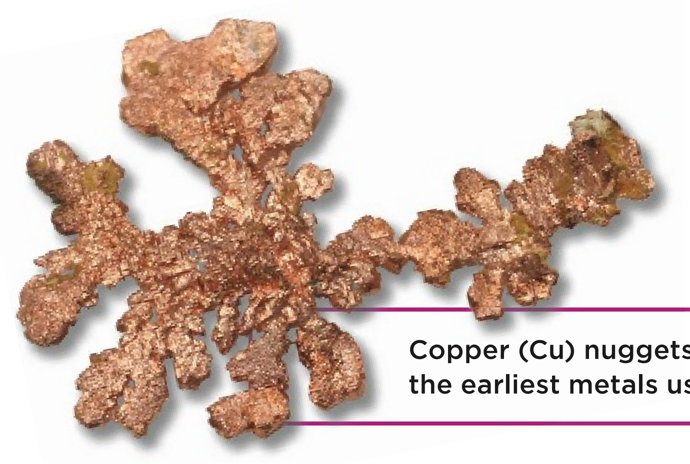
What are metals?

About three-fourths (75%) of all the elements are metals. Copper (Cu), silver (Ag), iron (Fe), aluminum (Al), zinc (Zn), and lead (Pb) are some common metals. What are metals like?

A **metal** is substance that is a good conductor of heat and electricity. A **conductor** allows heat and electricity to flow through easily. In addition, you can often tell metals by their shine when they are polished.

Metals melt at different temperatures. Their melting points make some metals very useful. For example, mercury melts at a very low temperature, –39°C (–38.2°F). So, mercury is a liquid at room temperature. Mercury is used in one kind of barometer. It is the silvery liquid that rises or falls when air pressure changes.



Copper (Cu) nuggets like these may be the earliest metals used by humans.

Mercury (Hg) is a liquid metal at room temperature. However, spilled mercury is dangerous and should not be touched.

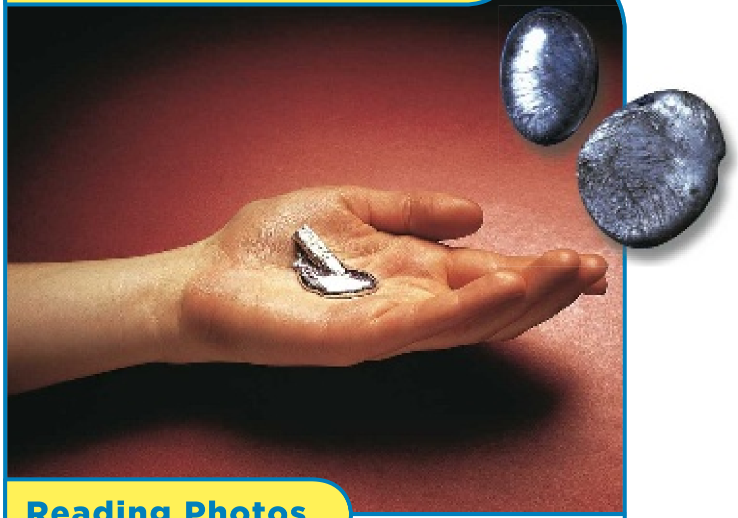
Useful Melting Points

When mercury is warmed, it expands evenly. When it cools, mercury shrinks (contracts) evenly. Because of this property, mercury is used in most thermometers to show temperature changes.

However, the metal gallium (Ga) melts at 30°C (86°F). It stays a liquid up to a very high temperature. It boils at 2403°C (4357°F). So gallium is used in thermometers that measure high temperatures.

Metals with very high melting points are useful because they stay solid at high temperatures. Titanium has a melting point of 1668°C (3034°F). It is also strong and lightweight. So it is used to make aircraft and spacecraft. Beryllium, with an almost as high melting point, is used for wheel brakes of the space shuttle.

Melting Point of Gallium



Reading Photos

Gallium melts at the mildly warm temperature of your hand. So it is not useful to make spoons.

Quick Check

Match the metal with the description.

9. ____ gallium **a.** used in barometers and thermometers

10. ____ mercury **b.** used to make spacecraft

11. ____ titanium **c.** melts in your hand

12. What do metals have in common? ______________________________

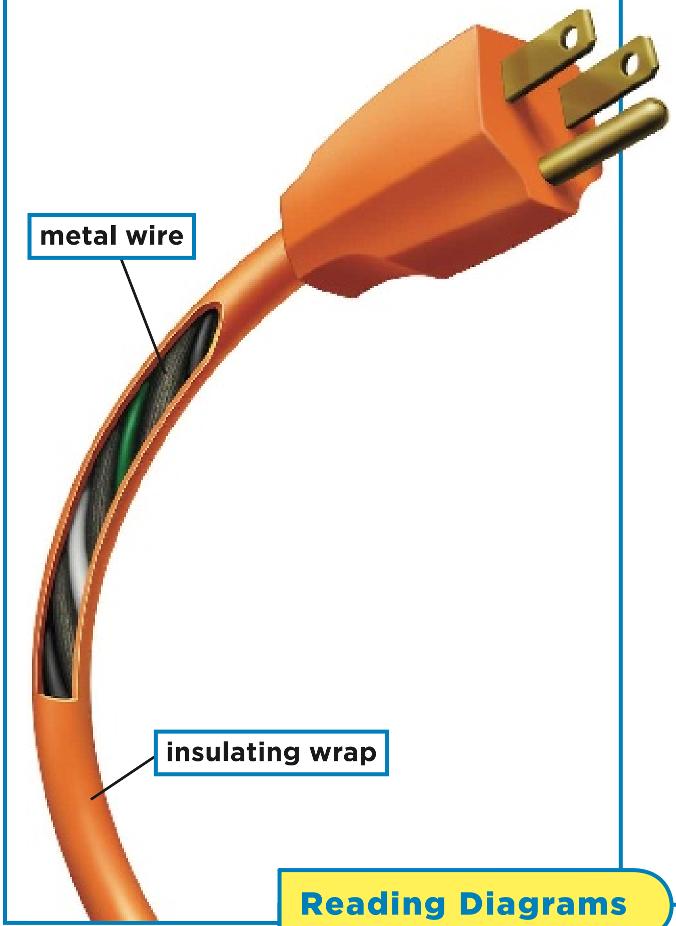
____

What do metals have in common?

Remember, metals are good conductors of electricity and heat. Nonmetals, on the other hand, are good insulators (IN•suh•lay•tuhrs). An **insulator** helps prevent the flow of heat and electricity. Wood and plastic are insulators.

- **Conducting electricity** Metals such as copper and aluminum are used to make electrical wires. These metals conduct electricity from power plants to towns and inside your home.
- **Conducting heat** Pots and pans are usually made of metals so that the heat can spread evenly through the cookware and into the food inside them. Handles and gloves are made of insulators such as wood or plastic. Car engines are made of metals. The metal conducts heat away so that the engines do not overheat.

Inside of Power Cord



Reading Diagrams

The metal wires are wrapped with an insulator (plastic or rubber). The insulator prevents electric shock if the cord is touched.

▲ The metal sodium (Na) is soft enough to cut with a knife. It is very reactive, so gloves are used when holding it.

Hard vs. Flexible

Glass and wood can break if you try to bend them. However, you can bend metal rods without breaking them. Many metals can be rolled or pounded into flat sheets without shattering. Gold can be pounded into thin sheets.

Some metals stretch into strands of wire when they are pulled. Copper and aluminum, for example, are made into wires. They can also be rolled like dough into sheets.

You may think iron is very hard. However, most metals can be dented. The deeper a dent is, the softer the metal. Chromium (Cr) is the hardest metal. Cesium (Cs) is the softest.

Pure copper, silver, and gold are soft. Jewelry made from these metals is often mixed with other metals to make a hard mixture of metals. The mixture does not scratch as easily as the pure metal.

✓ Quick Check

13. Circle the row that has three properties of metals:

used as insulators	breaks	snaps
used as conductors	drawn into wires	pounded flat
used as conductors	cracks when pulled	splinters

What are metal compounds?

What happens when iron rusts? Atoms of iron combine with atoms of a nonmetal, oxygen. The product, rust, is a compound—iron oxide.

When silver tarnishes, silver atoms combine with atoms of sulfur. The product, tarnish, is a compound called silver sulfide. When copper atoms combine with oxygen, tarnish is also formed—the compound copper oxide.

Rust and tarnish gradually "eat away" a metal. They weaken the metal so that it crumbles.

Reactive metals are the quickest to be "eaten away." The metal sodium reacts with oxygen so fast that they must be stored in oil to keep air out. In some cases, the compound that forms (such as aluminum oxide) coats the metal. The coating protects the metal.

Rust has turned a useful machine into a crumbling piece of junk.

Quick Check

14. What is rust? ______________________________

____

15. Why do metals need to be protected against rust and tarnish?

____

____

What are alloys?

People can improve the usefulness of some metals melting them and mixing other elements with them. The products, when cooled and harden, are solid mixtures called alloys (AL•oyz). An **alloy** is a mixture of two or more metals and nonmetals.

For example, mixing gold with copper, silver, or other metals can make it stronger. Iron is soft and weak until carbon and metals such as chromium and nickel are added to make a hard alloy, steel. These two metals also protect the steel from being "eaten away."

Brass is an alloy made of copper and zinc. Musical instruments made from brass, such as trumpets, have a bright sound quality. Bronze, a long lasting alloy, is made of copper and tin.

Medical tools are made of an alloy of tungsten. This alloy allows the tools to be razor sharp.

People who lived in the Bronze Age knew how make bronze. They used this alloy to make strong tools and weapons.

Quick Check

In each row, cross out a word that does not belong.

16. bronze oxygen copper tin

17. sulfur brass copper zinc

18. steel iron chlorine chromium

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Lesson 3
Salts

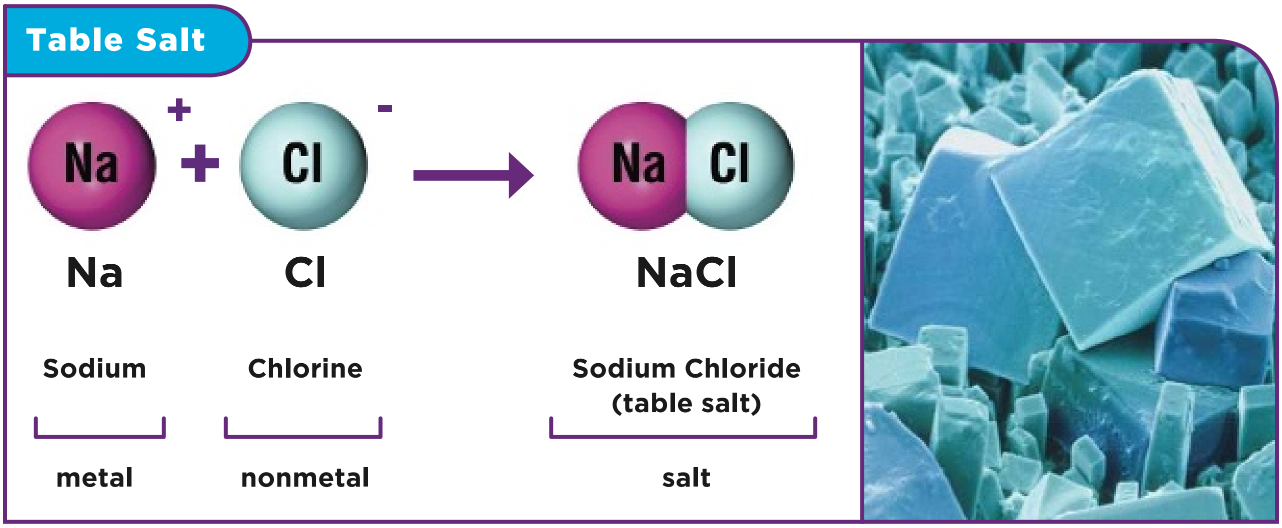
What is a salt?

You sprinkle it on food. It looks like little grains. What is it? It's table salt. There are actually many kinds of salt. Table salt is just one kind of salt. It is a compound called sodium chloride.

A **salt** is any compound made of a metal and a nonmetal. In sodium chloride, sodium is the metal and chlorine is the nonmetal.

The particles that make up salt are lined up in orderly rows. This orderly arrangement gives salts a boxlike shape and makes them hard. It's hard to melt salts. They have high melting points. Table salt melts at 801°C (1,474°F)!

Table Salt



▲ Table salt is made of a metal (Na) and a nonmetal (Cl). Up close, you can see its boxlike salt grains.

Making Salts

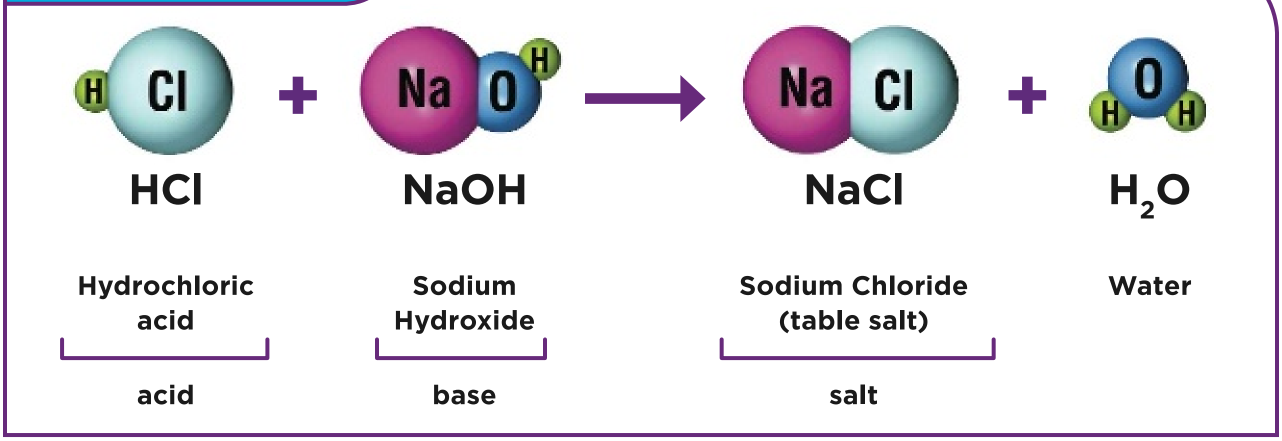
One way to make salts is to mix two compounds called an acid (A•sed) and a base. See that the acid in the diagram has chlorine (Cl) in it. The base has sodium (Na). When the two compounds react, the Na and Cl join to became NaCl (salt).

When salts are dissolved in water the metal particles and nonmetal particles break apart. They have electric charges (+ and –):

$$\mathbf{NaCl\ (in\ water)} \longrightarrow \mathbf{Na^+ + Cl^-}$$

These charged particles carry electricity through water. So a mixture of salt and water can be a good conductor. However, some salts do not dissolve well in water. They do not make good conductors when added to water.

Formation of Salt



Quick Check

Cross out the item that does not belong in each row.

19. metal Na Cl sodium

20. nonmetal Na Cl chlorine

21. To make a good conductor, a salt must ______________________

____

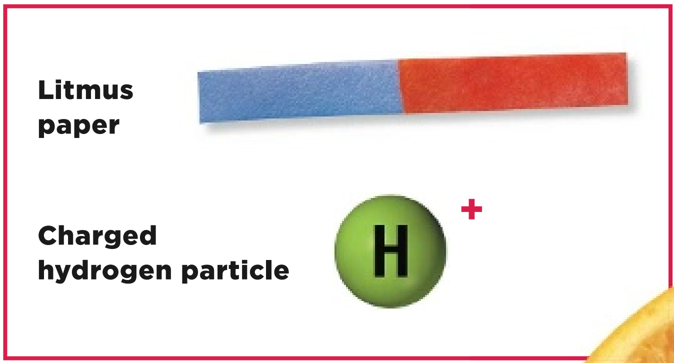
What are acids and bases?

An orange tastes sour. Squeeze a drop of orange juice on litmus (LIT•muhs) paper. Lemon juice makes the paper turn red.

Litmus paper is an indicator (IN•duh•kay•duhr). An **indicator** changes color in ways to help you tell what a substance is. The red color indicates that orange juice is an acid. An **acid** is a substance that tastes sour and turns litmus paper red. **Be careful:** Never taste unfamiliar substances to tell if they are acids.

Other acids are lemon juice and vinegar. The formula for any acid starts with **H** (hydrogen). For example, hydrochloric acid is **H**Cl. When you mix an acid and water, hydrogen particles are formed. The hydrogen particles have an electric charge. They conduct electricity through water.

$$\textbf{acid + water} \longrightarrow \mathbf{H^+}$$



Citrus fruits (such as oranges and lemons) contain an acid. ▶

Bases

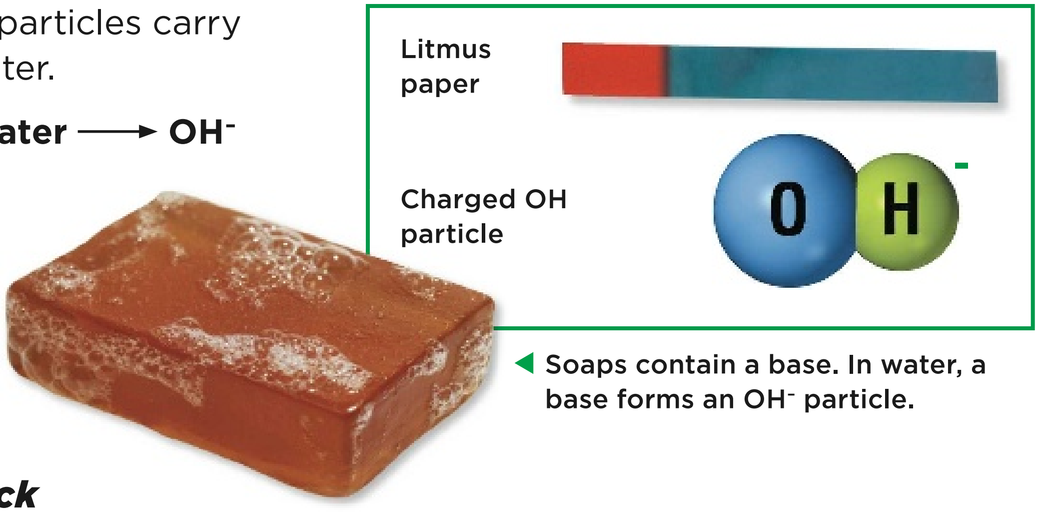
Soap and ammonia cleaner contain bases. A **base** is a substance that tastes bitter and turns litmus paper blue. Bases feel slippery, like soap. **Be careful:** Never taste or feel unfamiliar substances to tell if they are bases.

The formula for a base ends in **OH** (oygen + hydrogen). When a base is added to water, a charged particle is formed from the **OH**. These charged particles carry electricity in water.

$$\text{base} + \text{water} \longrightarrow OH^-$$

When an acid is mixed with a base, they form a salt. The acid supplies the nonmetal part of the salt. The base supplies the metal part.

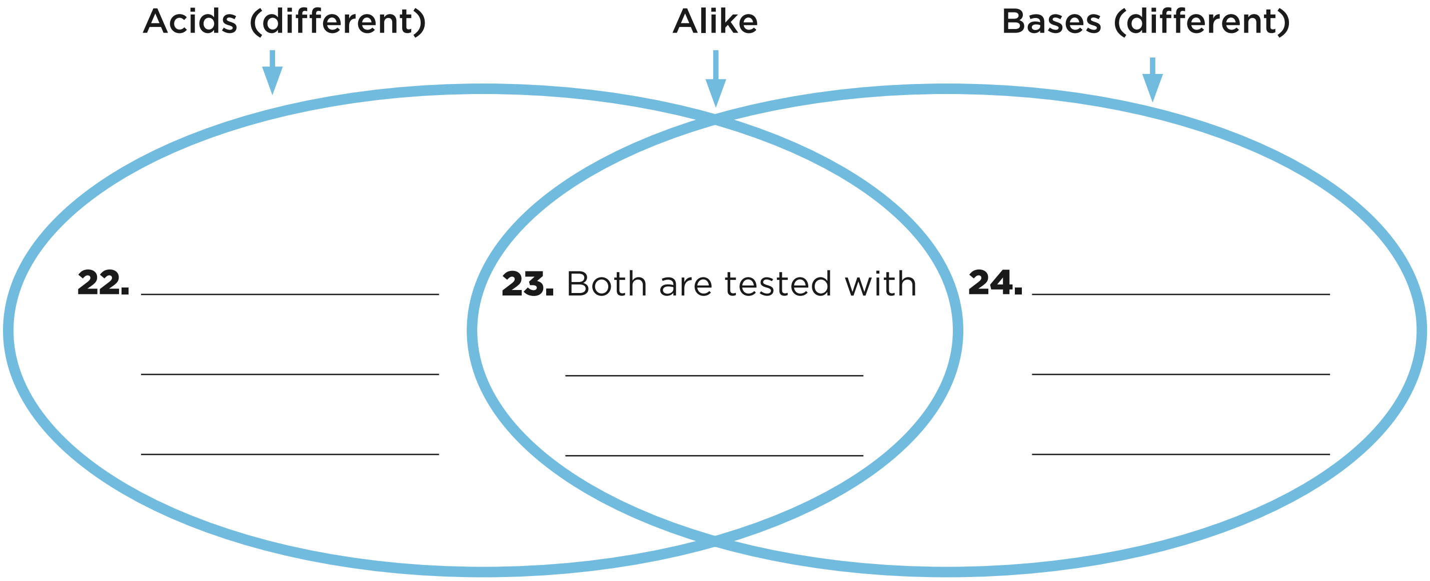
Acids and bases neutralize (NEW•truh•lyze) each other. **Neutralize** means "to cancel each other out." That is, the salt that is produced is not an acid or a base.



Soaps contain a base. In water, a base forms an OH^- particle.

Quick Check

Fill in the diagram. How are acids and bases alike? Different?



22. ______________________

____

____

23. Both are tested with

____

____

24. ______________________

____

____

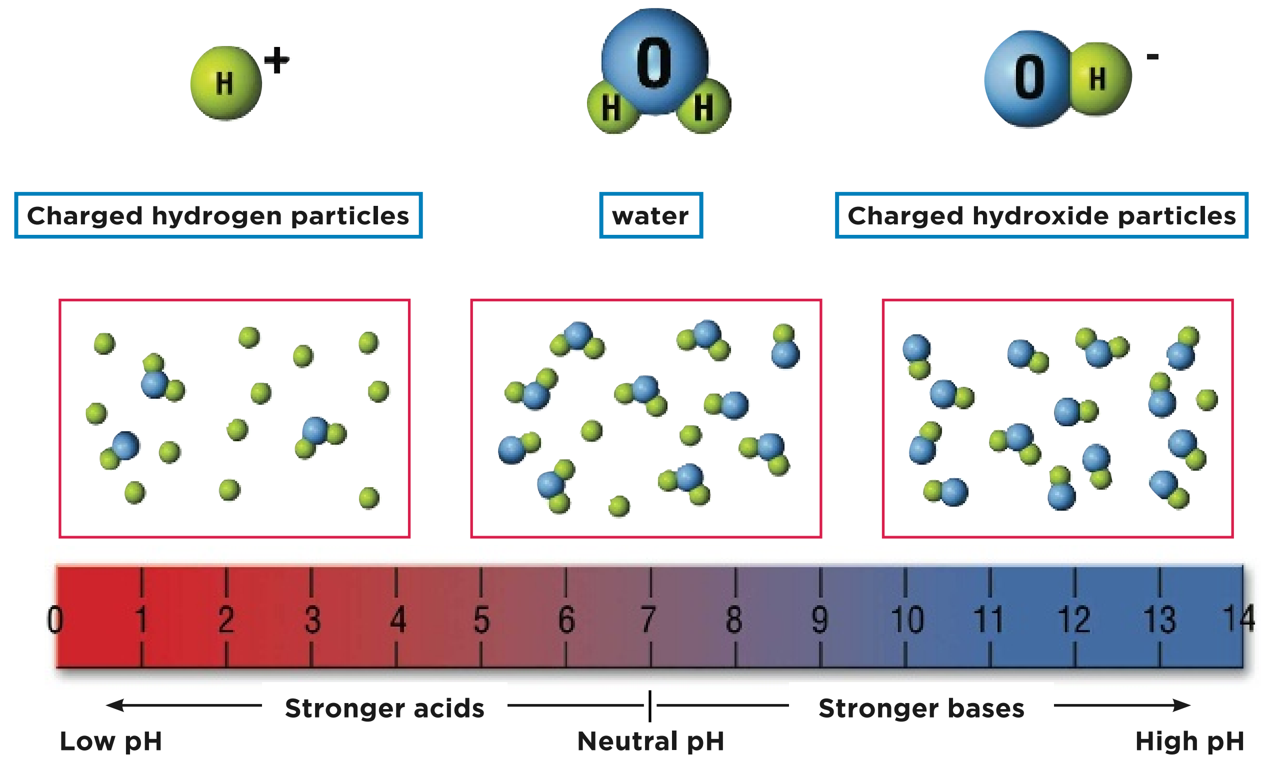
How strong are acids and bases?

Some acids are stronger than others. For example, a strong acid can wear away a hole in metal quickly. Vinegar on the other hand is a weak acid. It's weak enough for you to use on a salad with no effect.

Some bases are stronger than others. For example, lye is a strong base in drain cleaners. It can "eat away" a clog in a drain quickly.

The strength of acids and bases is measured on a **pH scale**. The scale runs from 0 (strong acid, weak base) to 14 (strong base, weak acid). A rating of 7, right in the middle, is neutral—neither acid nor base.

pH Scale of Charged Hydrogen Particles



Reading Diagrams

At low pH (acids), there are more H^+ than OH^-. At high pH (bases), there are more OH^- than H^+. At 7, there are equal numbers of both.

Reading the pH Scale

Strong acids form many charged hydrogen particles (**H^+**) when added to water. They have very few **OH^-** particles. For example, an acid with a pH of 0 or 1 forms many more **H^+** than an acid with a pH of 5 or 6.

Strong bases have very few **H^+** particles in water. They form, instead, many **OH^-** particles. Bases with a pH of 13 or 14 have many more **OH^-** particles than a base with a pH of 8 or 9.

Water has a pH of 7. It has about the same number of **H^+** and **OH^-** particles. Water is neutral. That is, it is neither an acid nor a base.

Scientists use meters to measuring the pH of water and soil. A pH near 0 (very acid) can be very harmful for living things in a lake or river. Most plants grow best when the soil has a pH over 7 (base) rather than under (acid).

Hydrangeas have blue flowers when grown in soil that has a pH under 7 (acid). They have pink flowers when the pH of the soil is above 7 (base). ▶

Quick Check

Write *acid* or *base* next to each description.

25. pH under 7 ______________________

26. More **H^+** particles than **OH^-** particles ______________________

27. pH over 7 ______________________

How do we use salts?

Salt was used as money in some ancient cultures. Why was it so valuable? In days when there were no freezers, salt kept foods from spoiling. Salts remove water from foods. Bacteria cannot survive in foods dried with salt. Fish has been packed in salt in many places for centuries.

Salt is used for seasoning. Small amounts of salt along with other flavorings give many meals a rich flavor. Salt is also used for curing meats and baking. It is used for canning foods and pickling foods.

Salt is also very useful in icy weather. If you spread salt onto ice, it dissolves into the ice and lowers the freezing point. The ice turns to slush or water and is easy to remove.

Mummies were dried in salt by ancient people of Egypt. A number of them have remained preserved for over 2,000 years.

Salt spreaders are hard at work to ease the removal of snow and ice from the road.

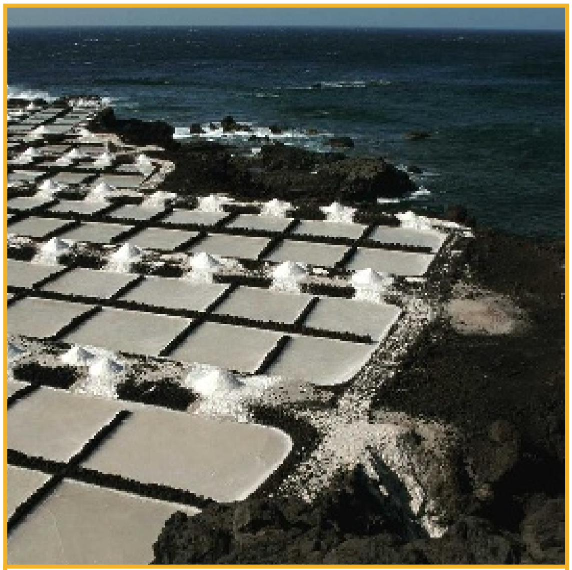
Getting Salt

Combining an acid and a base makes a salt. However, to meet our need for salt, we collect salt that is already made in nature.

Salt was formed early in Earth's history. It was dissolved by rain and ended up in the oceans. Today, there are as much as 3.5 kg (7.7 lb) of salt in every 100 kg (220 lb) of ocean water.

In many places today, ocean water is drawn into shallow pools. Exposed to the Sun, the water evaporates. The salt remains behind.

Early in Earth's history, salt remained behind when shallow inland seas dried up. Over time the salt was buried by sediments. We can get this salt by pumping water down into the salt. The water becomes salty. We collect the water and let it evaporate. The salt remains behind.



These sea side pools are used for getting salt.

Quick Check

Write *true* or *false* for each sentence. Correct any false statement.

28. Salt evaporates from ocean water. ______________________

29. Salt raises the freezing point of water. ______________________

30. Salt can preserve foods. ______________________

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Vocabulary Review

Changes in Matter

Choose the letter of the best answer.

1. Anything that lets heat and electricity flow through easily is a(n)

a. compound

b. insulator

c. reactant

d. conductor

2. A change in which substances before the change are different from those after the change is called a(n)

a. reactant

b. physical change

c. chemical reaction

d. indicator

3. When an acid is added to a base, the two substances can

a. form an acid

b. form a base

c. become more reactive

d. neutralize each other

4. A measure of the strength of an acid or a base is the

a. chemical change

b. pH scale

c. salt content

d. metal content

5. A substance before a chemical reaction happens is called a(n)

a. reactant

b. salt

c. metal

d. product

6. A substance that is formed by a chemical reaction is a(n)

a. product

b. conductor

c. insulator

d. indicator

7. Something that prevents heat, electricity, and even sound from moving through is a(n)

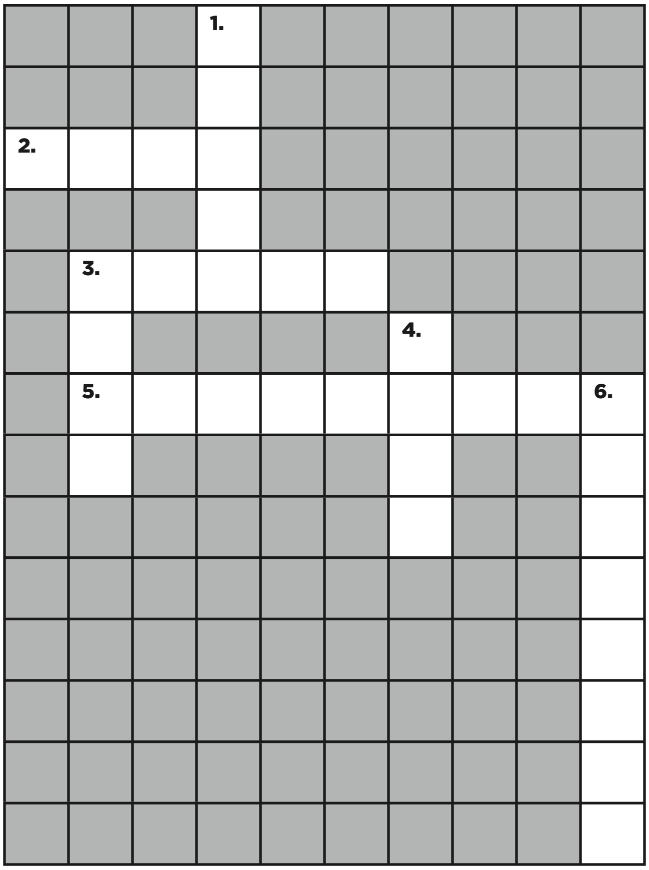
a. acid

b. conductor

c. reactant

d. insulator

Read each clue. Write the answers in the blanks to fill in the crossword puzzle.



Across

2. a compound made of a metal and a nonmetal

3. a mixture of two or more metals and nonmetals

5. something that changes color in ways that let you identify a substance

Down

1. a substance that lets heat and electricity pass through easily

3. a substance that tastes sour and can be biting

4. a substance that tastes bitter and turns litmus paper blue

6. how easily a substance takes part in a chemical reaction