New Jersey CCCS: 5.6.6.A.1, 5.6.8.B.1

Review 9

Elements, Compounds, and Mixtures

You and your pencil have a lot in common. Does that sound ridiculous? It may not be such a strange statement if you think about the elements that you and your pencil are made from. Pencil lead is made of the element carbon, and it turns out that your body is 18.5% carbon. The wood around the carbon in your pencil contains more carbon, along with hydrogen, nitrogen, calcium, potassium, and magnesium. It turns out that your body contains these exact same elements. However, most elements are not in their "pure" forms in the everyday world. Instead, most elements join up with each other to produce nearly all of the matter around us. This review will cover how combinations of elements produce different types of matter. It will also discuss some of the patterns that scientists have observed among the elements.

Physical and Chemical Properties

Matter has both physical and chemical properties. Physical properties include mass, volume, density, and so on. **Chemical properties** are the qualities of a substance that describe what will happen when the substance interacts with other substances. Just as matter can undergo physical changes, it can also undergo chemical changes. In a **chemical change**, a substance turns into one or more new substances that have different properties than the original substance or substances. If you have ever added vinegar to baking soda, you know what we're talking about. The baking soda and vinegar interact and change each other to form carbon dioxide (a gas) and salty water.

Words to Know

- atom
- atomic number
- chemical change
- chemical formula
- chemical properties
- chemical reaction
- compound
- concentration
- conservation of matter
- element
- endothermic
- exothermic
- indication
- metal
- metalloid
- mixture
- molecule
- noble gas
- nonmetal
- periodic table
- product
- proton
- reactant
- reactivity
- saturation
- solution

Is ice melting a physical or chemical change? Explain.

Chemical Reactions

In a **chemical reaction**, the original substances that change are called the **reactants**. In the example above, baking soda and vinegar are reactants. The new substances that form are called the **products**. Carbon dioxide and salt are the products of the reaction between baking soda and vinegar. When two or more substances chemically react, they usually give off an **indication**—some sign that a reaction is taking place. Indications that chemical reactions are taking place include color changes, the production of gas or light, and the formation of a solid substance from two or more liquids.

When you eat food, a chemical reaction takes place in your stomach. Identify some of the reactants and the products in this reaction.

Reactants: _____

Products: _____

Many chemical reactions either produce heat or absorb it. A chemical reaction that produces heat is called an **exothermic** reaction; a chemical reaction that absorbs heat is an **endothermic** reaction. In an exothermic reaction, energy is being transferred from the reactants to the surroundings. In an endothermic reaction, energy is being transferred from the surroundings into the reactants.

Most first-aid kits have chemical-filled packets that, when squeezed, grow very cold. Is the chemical reaction in such a packet endothermic or exothermic? Explain.

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Conservation of Matter

During both physical and chemical changes, there is no overall increase or decrease in the quantity of the matter that is changing. This is known as the law of **conservation of matter**. Suppose you add 5 g of baking soda to 10 g of vinegar. The chemical reaction between baking soda and vinegar produces a saltwater solution and carbon dioxide gas. The law of conservation of matter states that the total mass of the baking soda and vinegar must equal the mass of the saltwater solution and the carbon dioxide gas. Suppose you find the saltwater solution to have a mass of 14.5 g. Does this mean that mass has been destroyed during the reaction? No. It turns out that the remaining 0.5 g of mass floated away in the form of carbon dioxide.

As fuel is burned in an airplane, it seems to disappear from the tank, suggesting that matter is destroyed during the reaction. Explain why this is not true, and describe where the matter goes.

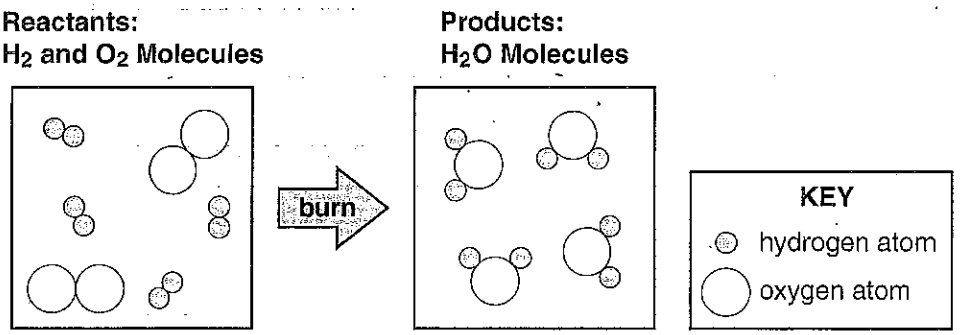
Compounds, Molecules, and Chemical Formulas

An **element** is a substance that cannot be broken down into simpler substances by physical or chemical means. An **atom** is the smallest unit of an element that has the chemical properties of that element. When two or more atoms combine to form a new substance, those atoms form a new substance called a **compound**. Each unit of the compound is called a **molecule**. The molecule has properties that are different from either of the original atoms. Two atoms of hydrogen and one atom of oxygen will combine to produce a single water molecule, H_2O. A **chemical formula** tells you the types and the numbers of atoms in a single molecule. Consider the molecules of oxygen that you breathe. Each molecule consists of two atoms of oxygen, so scientists represent a molecule of oxygen with the formula O_2. The letter says that the molecule contains oxygen atoms; the subscript says that the molecule has two of those atoms.

A molecule of hydrogen peroxide has one more oxygen atom than a molecule of water. What is the chemical formula of hydrogen peroxide?

Propane has the chemical formula C_3H_8. How many hydrogen and carbon atoms are in a molecule of propane?

When substances undergo a chemical change, the atoms in those substances are rearranged from one form into another. After the reaction, the total number of atoms and their mass is the same as the total number of atoms and their mass before the reaction. The following diagram represents this fact. The left box contains the reactants prior to a chemical reaction; the right box contains the products of that reaction.



How many hydrogen and oxygen atoms exist before the reaction? _____

How many hydrogen and oxygen atoms exist after the reaction? _____

The Periodic Table

Scientists have identified more than 100 different elements. Most materials on the Earth are made of just eight elements: oxygen, silicon, aluminum, iron, calcium, sodium, potassium, and magnesium. The **periodic table**, shown on the next page, organizes all the known elements by **atomic number**, which is the number of **protons** (a type of subatomic particle) that an atom contains. Elements in the same column have similar chemical properties. Look at column VI A of the periodic table. An atom of oxygen (O) has chemical properties similar to other atoms in column VI A—sulfur (S), selenium (Se), and so on.

What four elements have chemical properties most similar to those of fluorine in column VII A?

_____

Periodic Table of the Elements

IA	IIA	IIIB	IVB	VB	VIB	VIIB	VIIIB			IB	IIB	IIIA	IVA	VA	VIA	VIIA	VIIIA
1 H Hydrogen 1.0																	2 He Helium 4.0
3 Li Lithium 6.9	4 Be Beryllium 9.0											5 B Boron 10.8	6 C Carbon 12.0	7 N Nitrogen 14.0	8 O Oxygen 16.0	9 F Fluorine 19.0	10 Ne Neon 20.2
11 Na Sodium 23.0	12 Mg Magnesium 24.3						Transition elements					13 Al Aluminum 27.0	14 Si Silicon 28.1	15 P Phosphorus 31.0	16 S Sulfur 32.1	17 Cl Chlorine 35.5	18 Ar Argon 40.0
19 K Potassium 39.1	20 Ca Calcium 40.1	21 Sc Scandium 45.0	22 Ti Titanium 47.9	23 V Vanadium 50.9	24 Cr Chromium 52.0	25 Mn Manganese 54.9	26 Fe Iron 55.8	27 Co Cobalt 58.9	28 Ni Nickel 58.7	29 Cu Copper 63.5	30 Zn Zinc 65.4	31 Ga Gallium 69.7	32 Ge Germanium 72.6	33 As Arsenic 74.9	34 Se Selenium 79.0	35 Br Bromine 79.9	36 Kr Krypton 83.8
37 Rb Rubidium 85.5	38 Sr Strontium 87.6	39 Y Yttrium 88.9	40 Zr Zirconium 91.2	41 Nb Niobium 92.9	42 Mo Molybdenum 95.9	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	57 La Lanthanum 138.9	72 Hf Hafnium 178.5	73 Ta Tantalum 180.9	74 W Tungsten 183.9	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)	89 Ac Actinium (227)	104 Rf Ruther-fordium (257)	105 Db Dubnium (262)	106 Sg Seaborgium (263)	107 Bh Bohrium (262)	108 Hs Hassium (265)	109 Mt Meitnerium (266)	110 Uun Ununnilium (272)	111 Uuu Unununium (272)	112 UUb Ununbium (277)						

58 Ce Cerium 140.1	59 Pr Praseo-dymium 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	71 Lu Lutetium 175.0
90 Th Thorium 232.0	91 Pa Protactinium (231)	92 U Uranium (238)	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)	103 Lr Lawrencium (262)

39	Atomic number
Y	Symbol
Yttrium	Element
88.9	Atomic mass

Metals, Nonmetals, and Metalloids

Scientists put the elements on the periodic table into three main groups: metals, nonmetals, and metalloids. Most elements in the table are **metals**. Metals occupy the left side and the middle of the table. Most metals share a few properties: They conduct heat and electricity well, they are shiny, and all of them except mercury (Hg) are solid at room temperature. Many metals in the middle of the table, such as copper (Cu) and gold (Au), are malleable, which means that they can be pounded into thin sheets. Such metals also tend to be ductile, which means that they can be drawn into long wires.

Nearly all of the **nonmetals** are grouped on the right side of the periodic table. The nonmetals, unlike the metals, are poor conductors of heat and electricity. They have dull surfaces and cannot be pounded into sheets or drawn into wires. The nonmetals also vary greatly in their appearance. At room temperature, sulfur is a yellow crystal, helium is an invisible gas, and bromine is a red-brown liquid.

Between the metals and the nonmetals in the periodic table are a group of elements called the **metalloids**. In the periodic table on page 99, all of the metalloids are shaded. The metalloids have some properties of metals and some properties of nonmetals, but they are neither one nor the other. The metalloid silicon (Si) is a good example of this. Silicon looks like a metal, but it is brittle, which means that it is neither malleable nor ductile. Silicon conducts heat and electricity better than a nonmetal but not as well as a metal.

Use the periodic table to find the name of the element that goes with each symbol. Then state whether the element is a metal, a metalloid, or a nonmetal.

Ag: _____

P: _____

Li: _____

Te: _____

I: _____

Reactivity

The periodic table is also organized by **reactivity**, or an element's tendency to combine with other elements to form molecules. Elements in the middle columns of the table are not very reactive. Gold, for example, is often found in pure form because it rarely reacts with other elements. As you move away from the middle columns, the elements become more reactive. Lithium (Li), at the far left of the table, is an extremely reactive metal. If pure lithium is exposed to air, it quickly reacts with oxygen and turns dark. Fluorine (F) is so reactive that it took nearly 100 years for chemists to find a procedure that could isolate it in its pure form. The exception to this pattern of reactivity is the column farthest right on the periodic table. The elements in column VIII A, called the **noble gases**, almost never react with other elements to form molecules.

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Use the periodic table to name two metals other than lithium (Li) that probably tarnish quickly in air.

_____

Another useful pattern to know is that elements on the left side of the periodic table tend to react easily with elements on the right side of the table. The metals in column I A combine easily with the elements in column VII A to produce salts. For example, an atom of sodium (Na) will react with an atom of chlorine (Cl) to produce a molecule of sodium chloride, otherwise known as table salt.

Name two elements other than chlorine (Cl) that are likely to form molecules with sodium (Na).

_____

Yet another useful pattern to know is that nonmetals tend to form molecules with each other. Think of some common molecules: water (H_2O), atmospheric oxygen (O_2), and carbon dioxide (CO_2). All of these molecules form when atoms of nonmetals join with each other.

Examine the following chemical formulas. Identify the names of the elements in each molecule. Then, state whether these molecules are made of a metal and a nonmetal or of two nonmetals. (Refer to the periodic table on page 99.)

LiF: _____

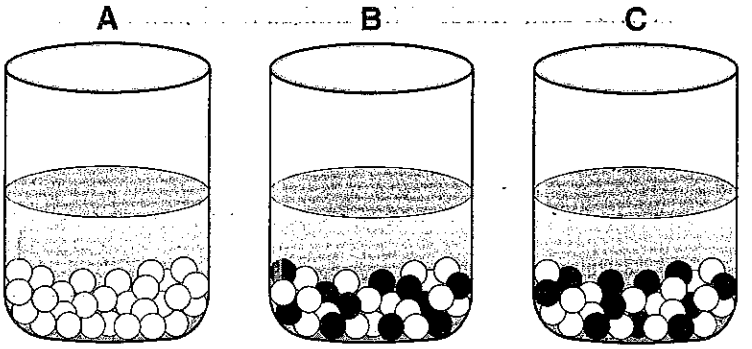
N_2: _____

MgI_2: _____

Cl_2: _____

Mixtures

A **mixture** is a combination of two or more substances in which the chemical properties of the substances do *not* change. When you make a mixture, the atoms of the different substances do not join up to form new molecules. Suppose you mix black pepper and iron filings in a bowl. The atoms do not combine to make a new substance: The pepper and the iron filings keep their distinct chemical properties. Because the atoms of pepper and iron do not combined into molecules, the types of matter in a mixture can be separated by physical means. You can separate the substances in salt water by evaporating the water, leaving behind clumps of solid salt. You can separate the substances in a mixture of black pepper and iron filings by using a magnet to pull out the iron filings. In contrast, the atoms in a molecule can only be separated by chemical means.



Contents
- water
- glass marbles

Contents
- water
- glass marbles
- iron marbles

Contents
- salt water
- glass marbles
- iron marbles

The picture above shows three mixtures. For each mixture, describe a process for separating out the parts.

Mixture A: _____

_____

_____

Mixture B: _____

_____

_____

Mixture C: _____

_____

_____

Recall from Review 8 that a **solution** is a mixture in which one substance dissolves into another substance. Solutions can come in different **concentrations**. Suppose you have three beakers, each with 100 g of water. You put 1 g of salt into the first beaker, 5 g of salt into the second beaker, and 10 g of salt into the third beaker. All three beakers hold solutions of salt water, but each solution has a different ratio of salt to water.

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A science teacher puts out three samples of ammonia in water. All three samples are the same volume. One sample has a faint odor, the second sample has a strong odor, and the third sample has an overwhelming odor. Explain why the difference in odors tells you that ammonia in water is a mixture.

When no more of a material can be dissolved in a solution, the solution has reached its **saturation** point. For example, 100 g of water at room temperature can dissolve about 36 g of table salt (NaCl). If you put 37 g of table salt into a solution, about 1 g of salt crystals will simply sit at the bottom of the water and be unable to dissolve.

Keys to Keep

- **In a chemical change, two or more substances turn into new substances with different chemical properties than the original substances.**
- **The periodic table organizes the elements by their chemical properties.**
- **A chemical formula indicates the type and the number of atoms in a molecule.**
- **Elements in the same column of the periodic table have similar chemical properties.**
- **An element can be classified as a metal, a nonmetal, or a metalloid.**
- **You can use the periodic table to predict how elements will react with each other.**
- **The components of mixtures can be separated by physical means.**
- **Mixtures can come in different concentrations.**

NJ ASK Practice

1. Which of the following correctly compares the elements on the right side of the periodic table with the elements on the left side of the periodic table?

   A. The elements on the right side are generally denser than the elements on the left side.
   B. The elements on the left side are better conductors of electricity than the elements on the right side.
   C. The elements on the right side are better conductors of thermal energy than the elements on the left side.
   D. The elements on the left side have lower melting points than the elements on the right side.

2. Which of the following is a property of fluorine (F), a nonmetal?

   A. It is a good conductor of electricity and heat.
   B. It is a gas at room temperature and pressure.
   C. It can be drawn into wires.
   D. It is shiny.

3. Which element is **least** likely to combine with another element to form a molecule?

   A. chlorine (Cl), a halogen.
   B. iron (Fe), a metal
   C. neon (Ne), a noble gas
   D. silicon (Si), a metalloid

4. A certain molecule has a ratio of one atom of element X for every two atoms of element Y. Suppose a sample of element X and a sample of element Y react to form exactly 1 kg of XY_2, with no reactants left over. Which of the following could be the amounts of X and Y in the reaction?

   A. 150 g of X and 300 g of Y
   B. 200 g of X and 800 g of Y
   C. 300 g of X and 600 g of Y
   D. 400 g of X and 800 g of Y

5. Which of the following is an example of a chemical change?

   A. a chunk of metal being hammered until it is flat
   B. a piece of chalk being crushed into a powder
   C. a solid rock melting into magma
   D. an iron bridge turning brownish-red over the years

6. Which equipment will best separate a mixture of sand and sugar?

   A. filter paper, water, and beakers
   B. magnet and hydrochloric acid
   C. graduated cylinder and gram balance
   D. microscope, slide, and cover slip

7. Five molecules of methane contain five carbon atoms and 20 hydrogen atoms. What is the chemical formula of methane?

   A. CH_4
   B. C_2H_8
   C. C_4H_{16}
   D. C_5H_{20}

8. Dr. Halite combined sodium metal with chlorine gas to make sodium chloride (table salt). The chemical reaction used up all of the metal and all of the gas. If Dr. Halite made 116 g of table salt and started with 68 g of chlorine gas, then how many grams of sodium metal did he start with? Describe the law of nature that supports your answer.