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SCIENCE

STUDENT BOOK

8th Grade | Unit 3

Alpha Omega
PUBLICATIONS

SCIENCE 803

Structure of Matter Part 2

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Structure of Matter Part 2

Introduction

In Science LIFEPAC® 802 you learned something about the structure of matter and the different properties of various kinds of matter. Frequently when you put two kinds of matter together, a definite change occurs. These changes are sometimes simple and sometimes very complex. Although only 103 elements are known, these elements combine with each other to form thousands of compounds. Compounds combine to form still other compounds. The study of chemistry attempts to unfold the many ways matter changes as it combines. In this LIFEPAC you will learn about matter in change and about three common chemical compounds: acids, bases, and salts.

Are you matter? You surely are! You are made up of a variety of compounds which contain the elements carbon, hydrogen, oxygen, and nitrogen. Are you changing? The answer again is yes! Your body is in constant change, particularly as you pass through the teens. What about your spiritual growth? If you are a Christian are you growing? Do you have areas in your life you would like to have changed? Most people do. Since God's Word is the source of truth and life, why don't you do a spiritual experiment as you progress through this LIFEPAC. Read Joshua 1:8 once a day while you are working on this LIFEPAC and do what it says. First, repeat this prayer to your Heavenly Father right now.

Dear Heavenly Father, I thank you for your Word and for sending my Savior. Guide me as I read and say your Word each day. I believe I will be successful and prosperous. As I study about your great Creation in change, I believe your Spirit will reveal areas in my life that you would like to help me change. Thank you for doing this. In Jesus' Name,... Amen.

Objectives

Read these objectives. The objectives tell you what you will be able to do when you have successfully completed this LIFEPAC. When you have finished this LIFEPAC, you should be able to:

1. Define physical change.
2. List three examples of physical change.
3. Define chemical change.
4. Describe a way by which a liquid may be tested to see if it is acid, base, or neither.
5. State the differences among evaporation, condensation, dissolving, and distillation.
6. Define nuclear change.
7. List three kinds of radiation given off by radioactive matter.
8. Compare and contrast fission and fusion.
9. Name an instrument used to detect and study radiation.
10. State two properties of an acid.
11. Identify the chemical formula for several acids.
12. List three examples of an acid.
13. Name three common uses of acids.
14. Explain two properties of a base.
15. List three examples of a base.
16. Identify the chemical formula for several common bases.
17. Explain neutralization.
18. List four uses of salts.
19. Explain the difference between hard and soft water.

Survey the LIFEPAC. Ask yourself some questions about this study and write your questions here.

1. MATTER AND CHANGE

Change is all around us. The world is constantly changing. In winter, water changes from liquid to solid on lakes and streams. Clothes on the wash line change from wet to dry. Lead solder changes when heated. Silver tarnishes from shiny to black. Dead plants and animals change with decay. Your body grows and you change to larger clothes. A popsicle melts in the sun. All these examples describe changes in matter.

Matter changes in many different ways. Scientists put all changes in matter into three groups: physical changes, chemical changes, and nuclear changes. Describing physical, chemical, and nuclear changes is what this section is about. As you learn how matter changes, think about how you are changing. You are certainly growing physically. Are you growing spiritually? God wants us to grow and change spiritually as well as physically. Ephesians 4:15 states that we are to grow up in all aspects unto Him, who is the head, even Christ.

SECTION OBJECTIVES

Review these objectives. When you have completed this section, you should be able to:

1. Define physical change.
2. List three examples of physical change.
3. Define chemical change.
4. Describe a way by which a liquid may be tested to see if it is acid, base, or neither.
5. State the differences among evaporation, condensation, dissolving, and distillation.
6. Define nuclear change.
7. List three kinds of radiation given off by radioactive matter.
8. Compare and contrast fission and fusion.
9. Name an instrument used to detect and study radiation.

Vocabulary

Study these words to enhance your learning success in this section.

composition (kom’ pu zish’ un). The makeup of anything.

condensation (kon’ den sā’ shun). Act of changing a vapor to a liquid.

decompose (dē’ kum pōz’). To decay, rot.

dissolve (di zolv’). To become liquid by breaking up into parts.

distillation (dis’ tu lā’ shun) The process of separating the parts of a substance by heating.

electron (i lek’ tron). A small particle of an atom with a negative charge.

evaporation (i vap’ u rā’ shun). The act of changing a liquid of solid to a gas.

fission (fish’ un). The splitting that occurs when the nucleus of an atom absorbs a neutron.

fusion (fyü’ zhun). A melting together.

nuclear (nü' klē ur). Having to do with the nucleus of an atom.

oxidation (ok' su dā' shun). Process of combining an element with oxygen.

product (prod' ukt). The end result of a chemical reaction.

radioactive (rā' dē ō ak' tiv). Giving off radiant energy in the form of alpha particles, beta particles, or gamma rays.

soluble (sol' yu bul). Capable of being dissolved or made into a liquid.

subscript (sub' skript). Written underneath or below.

Note: *All vocabulary words in this LIFEPAC appear in* **boldface** *print the first time they are used. If you are not sure of the meaning when you are reading, study the definitions given.*

Pronunciation Key: h**a**t, **ā**ge, c**ã**re, f**ä**r; l**e**t, **ē**qual, t**ė**rm; **i**t, **ī**ce; h**o**t, **ō**pen, **ô**rder; **oi**l; **ou**t; c**u**p, p**u̇**t, r**ü**le; **ch**ild; lo**ng**; **th**in; /ŦH/ for **th**en; /zh/ for mea**s**ure; /u/ represents /a/ in **a**bout, /e/ in tak**e**n, /i/ in penc**i**l, /o/ in lem**o**n, and /u/ in circ**u**s.

PHYSICAL CHANGE

Have you had to cut up wood into small pieces for a fire? Cutting the larger pieces of wood into smaller ones changed the appearance of the original piece of wood. This kind of change is called a physical change. In this section you will study various ways changes occur and how heat is important in many of these changes.

Change in the properties. A physical change is a change in the size and shape of a substance. Hardness, shape, mass, and density are physical properties, which may be involved in a physical change. Sodium metal can be cut with a knife because it is very soft. Hydrogen is a light gas. Chlorine is a green gas that is heavier than air. Sugar is sweet. These properties are physical. In a physical change, the kind of matter does not change. No new substance is formed. Therefore, a physical change is a change in the physical properties of a substance without a change in its chemical **composition**.

View 803 Physical & Chemical Change, from the Grade 8 SCIENCE EXPERIMENTS Video

Try this activity.

These supplies are needed:

- paper
- soda cracker
- lump of sugar
- stirring rod
- small glass of water

Follow these directions and answer the questions. Put a check mark in the box when each step is completed.

- ☐ 1. Place a lump of sugar in a glass of water.
- ☐ 2. Stir the water a few times.
- ☐ 3. Taste the water.
- ☐ 4. Now tear a piece of paper into several pieces.
- ☐ 5. Crumble a soda cracker over a sheet of paper.

1.1 What kind of change occurred in each case? Use complete sentences. ______________________________

____

1.2 How do you know the kind of change? ______________________________

____

Physical Change Experiment

Follow these directions.

1.3 List four physical properties of matter.

a. ____________________ b. ____________________

c. ____________________ d. ____________________

1.4 Write one example of a physical change. ____________________

Write true or false.

1.5 ____________ A physical change involves a change in composition.

1.6 ____________ A physical change creates a new substance.

1.7 ____________ A change in appearance is a part of a physical change.

Physical states. All substances exist as solid, liquid, or gas. Some substances exist as all three *phases*. When the liquid (water) freezes, it becomes the solid phase (ice). When the solid melts, it becomes a liquid. The liquid phase (water) escapes into the air in the form of the gaseous phase (water vapor). Water vapor in the air can change to liquid water inside a car and fog the windows. Each case is a physical *change of phase*.

A change in the phase of a substance is explained by the *kinetic theory*. The kinetic theory states that the particles of a substance are in motion. When heat is added to matter, the particles, atoms, or molecules move faster. If heat is removed, the particles in the substance slow down. In a change of phase, particles either separate or move closer together. They may become more attracted to each other or less.

Physical properties can change *without* a change of phase occurring.

Change within a phase. If you hold a copper wire in flame, the wire gets hot; but that isn't the only effect of heat. If you were to measure the copper wire before and after it was heated, you would have found that the heated wire is a little longer and thicker while it is hot. When a solid such as copper wire is heated, it *expands*. Different solids expand different amounts. Figure 1 shows how different solids expand when heated. Each of the rods expanded to a different length.

Liquids and gases also expand as they become warmer. Like solids, different liquids expand at different rates. In general, matter expands as it becomes warmer. Matter shrinks in size, or contracts, as it cools. However, water is an exception in that it expands as it cools from 4°C until it freezes. You might remember seeing a jar of liquid crack open as it froze. The jar cracked because the liquid expanded as it turned to ice.

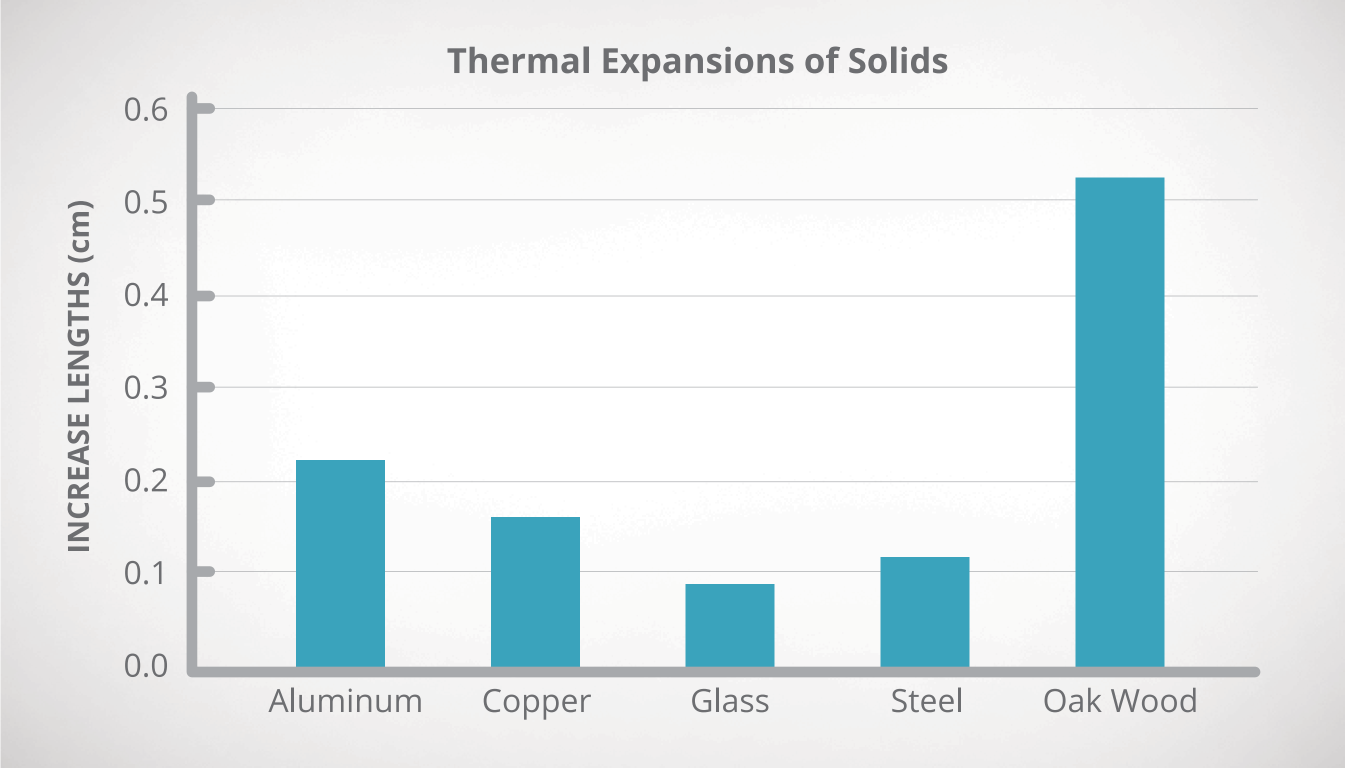


Figure 1 | Thermal Expansion of Solids

Look at Figure 1 and answer the following questions.

1.8 Which item expanded the least? ________________

1.9 Which item expanded the most? ________________

1.10 What approximate length did the oak wood expand to? ________________

1.11 What approximate length did the glass expand to? ________________

Write true or false.

1.12 ____________ When heated, most matter expands.

1.13 ____________ When matter other than water cools, it contracts.

1.14 ____________ Contract means to get larger.

1.15 ____________ Liquids and gases also expand as they become warmer.

1.16 ____________ Most solids expand at the same rate.

You will recall from Science LIFEPAC 802 that all matter has *mass* and takes up space. The amount of space a piece of matter takes up is its *volume*. The amount of mass in a certain volume is called the *density* of that matter. You can calculate density by dividing the volume into the mass

$$\left(D = \frac{m}{v}\right)$$

Heat is involved in many kinds of changes. When heat is removed, most substances get smaller (contract). A change in temperature causes a change in the density of matter. Adding or taking away heat causes a change in the size of matter. However, adding or taking away heat does not add or take away matter, or change the mass.

An important point to know is that the density changes when heat is added or taken away. If a piece of matter contracts, the same amount of matter takes up less space. That is, a greater amount of mass is contained in a certain volume. So when a piece of matter contracts, its density becomes greater.

Complete these sentences.

1.17 Matter that becomes smaller when it cools is said to ________________ .

1.18 Expansion or contraction does *not* change the ________________ of that matter.

1.19 Expansion or contraction does change the ________________ of that matter.

1.20 The amount of matter present in an object is called its ________________ .

1.21 The amount of mass divided by volume is the ________________ of that object.

Explain this problem.

1.22 A certain man lived in North Dakota where summers are warm and winters are very cold. Every year about the same time he noticed that his front door began to squeak and became difficult to close. He would have to push and push until finally it would close.

a. Give an explanation of why the door was difficult to close. ____________________________

____

b. In what season did he have the most difficulty with his door? ____________________________

____

Solutions. Another kind of physical change takes place when two substances are mixed together. For example, when you mix sugar in water, you make a *solution*. In making a sugar-water solution, the molecules of sugar become separated from each other and become scattered among the water molecules. The sugar dissolves in the water. The physical property of being able to **dissolve** is called **solubility**. A substance which does not dissolve in a liquid is said to be insoluble.

Use a physical change to separate a mixture.

These supplies are needed:

- sugar
- water
- beaker
- stirring rod
- dish
- teaspoon

Follow these directions and answer the questions. Put a check mark in the box when each step is completed.

☐ 1. Place several teaspoons of sugar in a small beaker half full of water, and stir it until the water is clear.

☐ 2. Pour some of the solution into a dish. Set the dish on a shelf or windowsill. Observe the dish for a day or two. Record what you observe.

1.23 What happened to the sugar? ____

____

1.24 What physical change was used to separate the sugar from the water? ______________

____

1.25 Name another mixture that could be separated in this way. ____________________

____

Physical Change Experiment

Write true or false.

1.26 ____________ The physical property of being able to dissolve is called solubility.

1.27 ____________ The sugar-water mixture is a solution.

Change in phase: solid/liquid. You know that adding heat to ice causes the ice to melt. When ice melts, it changes into water. Heat also causes water to boil and change into steam. Cooling, or removing heat, causes steam to change back into water. Cooling can also cause water to change into ice. So adding and removing heat causes changes in the phase of water.

Ice melts at 0º C. This temperature is called the melting point of ice. Water freezes at 0º C (32º F). This temperature is called the *freezing point* of water. Different substances melt or freeze at different temperatures. However, for any one substance, the melting and freezing points are virtually the same temperature.

If enough heat is added to a liquid, the liquid begins to boil. Each kind of liquid boils at a different temperature. The temperature at which a liquid boils is its *boiling point*. Water boils at 100º C at sea level. Water and other liquids, however, do not boil at the same temperature everywhere. The boiling point depends on how hard the air is pushing down on the surface of the liquid. That is, the boiling point temperature depends on the air pressure. The lower the air pressure, the lower the boiling point. Water would boil below 100º C on a mountain due to the lower pressure and higher altitude. Mountain campers often require more time to cook food due to this change in air pressure.

View 803 Heat of Fusion, from the Grade 8 SCIENCE EXPERIMENTS Video

Try this investigation.

These supplies are needed:

- crushed ice
- string
- burner
- beaker
- wire gauze
- thermometer
- (time piece with a second hand)
- ring stand

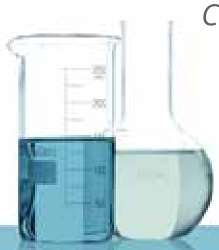
Heat of Fusion Experiment

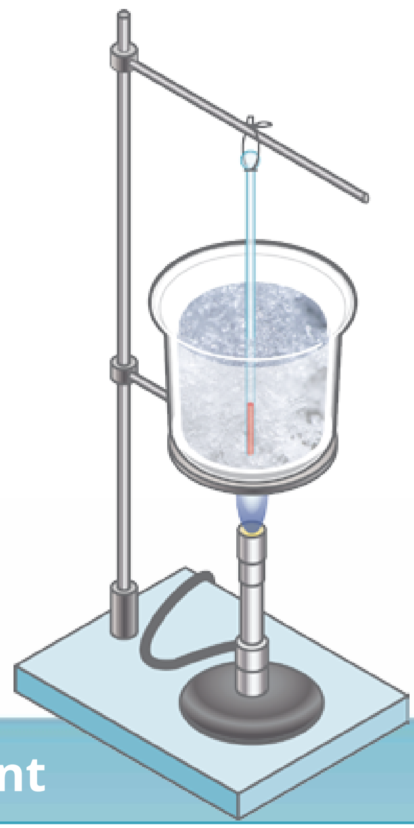
Follow these directions and answer the questions. Put a check mark in the box when each step is completed.

- ☐ 1. Pack the beaker full of crushed ice. Suspend a thermometer in the ice so the bulb of the thermometer does not touch the bottom of the beaker throughout the experiment.
- ☐ 2. Record the temperature of the contents in the beaker at the start and every *fifteen seconds.*
- ☐ 3. Warm the beaker with heat source. Stir gently. Be careful not to let the thermometer touch the beaker.
- ☐ 4. Record the phase or phases in the beaker each time the temperature is recorded. Use additional paper if necessary.
- ☐ 5. Record several temperatures as the water begins to boil.

time every 15 seconds	temp	phases
0		
15		
30		
45		
1:00		
1:15		
1:30		
1:45		
2:00		
2:15		
2:30		
2:45		
3:00		

Chart continues on the next page.





Heat of Fusion Experiment

1.28 What was the temperature of the ice before you added heat? ________

1.29 What was the temperature as the ice melted? ________

1.30 At what temperature did the water begin to boil? ________

1.31 Did the temperature of the water continue to rise as the water boiled or did it remain the same? ________

1.32 If the temperature did not change while heat was being added, what was happening to the ice or the water at that time?

____

____

____

____

____

1.33 What do you think the heat was used for if not to raise the temperature?

____

____

____

____

____

____

time every 15 seconds	temp	phases
3:15		
3:30		
3:45		
4:00		
4:15		
4:30		
4:45		
5:00		
5:15		
5:30		
5:45		
6:00		
6:15		
6:30		
6:45		
7:00		
7:15		
7:30		
7:45		
8:00		
8:15		
8:30		
8:45		
9:00		
9:15		
9:30		
9:45		
10:00		

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Heat of Fusion Experiment

Write true or false.

1.34 ____________ Water freezes at 100º Celsius.

Change in phase: liquid/gas. If you were to place a pan of water in the open sun, the water would eventually disappear. Why? The liquid water changes into water vapor, a gas. This change from a liquid to a gas is called **evaporation**. Since the molecules of the liquid are in constant motion, they continually bump into each other. As a result of these collisions, the molecules on the surface of the liquid are constantly gaining enough energy to escape. The escaping molecules form a vapor; that is, they change into the gaseous state.

The change from a gas to a liquid is known as **condensation**. Rain is an example of water vapor changing into a liquid, then falling to the earth. Condensation and evaporation take part in another process called **distillation**. Distillation is the process of heating a liquid or solid to form a gas, then condensing the gas to form a liquid. Purified water is made this way. The product is free of dissolved minerals because they are left behind when the water evaporates.

Complete these sentences.

1.35 Most substances exist as a a. _____________ , b. ____________ , or c. _____________ .

1.36 The idea that the particles of a substance are constantly in motion is called the

__________________ .

1.37 The change of a gas into a liquid is called ___________________________ .

1.38 The change of liquid into a gas is called _____________________________ .

1.39 The physical change that involves both evaporation and condensation is called

___________________________ .

Write true or false.

1.40 ____________ Boiling causes a physical change.

1.41 ____________ Rain is an example of evaporation.

1.42 ____________ The molecules of a liquid must be heated to be in motion.

Phase boundaries. For every substance a special relationship exists between the amount of heat added (or taken away) and the temperature change produced. This relationship is called *heat capacity*. Heat capacity is the amount of heat that is needed to raise the temperature of one gram of a substance one Celsius degree. Heat capacity is also called *specific heat*. The specific heat of several substances is given in Figure 2.

Substance	Specific Heat
Water	1.0
Ice	0.5
Glass	0.16
Silver	0.06

Figure 2 | Specific Heats

Ice is different from water at 0º C. Suppose you take one gram of ice at -50º C, slowly heat it, and record its temperature while it is being heated. Suppose also that you record the amount of heat used. The experiment continues until the ice melts and the water boils. You would find that twenty-five calories are required to raise one gram of ice from -50º C to 0º C. Therefore, the specific heat of ice is about one-half calorie per gram for each Celsius degree. Then at 0º C, 80 calories of heat are added without causing a change in temperature. During this process, the one gram of ice at 0º C melts and becomes one gram of water at 0º C. Take note that *the ice changed to water with no change in the temperature.* The 80 calories is the "hidden heat" and is called the *latent heat of fusion*. (*Latent* means *hidden*.) Water has a relatively large heat of fusion. Then the water reaches 100º C after 100 more calories are added. You find that 540 calories of heat are needed to convert the water to steam at 100º C. This *hidden heat* associated with boiling is called the *latent heat of vaporization.* The latent heat of vaporization of water is one of the highest known.

View 803 Calorimetry, from the Grade 8 SCIENCE EXPERIMENTS Video

Try this investigation.

These supplies are needed:

- two beakers
- stirring rod
- ice
- thermometer
- heat source
- time piece with a second hand
- cloth or styrofoam cup
- water
- balance

Follow these directions and answer the question. Put a check mark in the box when each step is completed.

☐ 1. Measure out into a beaker 100 grams of ice at 0º C.

☐ 2. Insulate the beaker as well as possible. You may use a cloth or a styrofoam cup.

☐ 3. In another beaker, bring 100 grams of water to the *boiling point. Remember to weigh the beaker first to determine its weight before you add water.*

☐ 4. Now pour the water over the ice.

☐ 5. Stir briskly with a stirring rod until all the ice is melted.

☐ 6. Measure and record the temperature every five seconds from the time you pour the water until a constant temperature is reached.

Calorimetry Experiment

1.43 Why didn't the boiling water at 100° C raise the ice from 0° C to boiling also? Explain your results. ____________

____

____

____

____

____

____

____

____

____

____

____

time in seconds	temp	time in seconds	temp
0		80	
5		85	
10		90	
15		95	
20		100	
25		105	
30		110	
35		115	
40		120	
45		125	
50		130	
55		135	
60		140	
65		145	
70		150	
75		155	

TEACHER CHECK ____________ ____________
initials date

Calorimetry Experiment

Fill in the blanks.

1.44 The heat required to convert water to steam is called the ______________________________

____

1.45 The heat required to convert ice to water is called the ______________________________

____

1.46 The heat needed to raise one gram of a substance one Celsius degree is called ____________

____

CHEMICAL CHANGE

If you chop a large piece of wood into smaller pieces, the wood is obviously changed in appearance. Yet this change is only a physical change because each of the smaller pieces of wood is exactly the same kind of matter as the larger piece of wood. Other kinds of changes can be made that change the appearance and composition of the matter. In this section you will study about some of these chemical changes and their examples.

Chemical properties. The properties of a substance tell how it reacts with other substances. Some substances combine with oxygen and burn. Other substances react with other materials to produce gases or metals. The chemical properties of a substance always describe how it unites with other substances. Changes in chemical properties are called *chemical changes*. In a chemical change, new substances are produced. The souring of milk, the burning of a log, and the rusting of iron are chemical changes. A comparison of physical and chemical changes is given in Figure 3.

Have you ever seen a flashbulb used? The bright light from a flashbulb is the result of a chemical change. If you were to look at a flashbulb before and after it was used, you would see that the fine metal wire in the bulb before has changed to a white powder after. The fine wire inside most flashbulbs is magnesium metal. This type of flashbulb is filled with oxygen. When the flashbulb is used, the magnesium (Mg) combines with the oxygen (O) and forms a white powder called magnesium oxide (MgO). This reaction of magnesium (Mg) and oxygen (O) to form magnesium oxide (MgO) is an example of a chemical change. Heat and light are also produced.

$$2\ Mg + O_2 \rightarrow MgO + heat + light$$

If you burn pieces of wood, definite and permanent changes occur. Burning causes the wood to change into ashes, water vapor, and other gases. The molecules of the ashes, water vapor, and other gases are different from those of the wood. Thus when wood is burned, the kind of molecules in the wood is changed. This change is also a chemical change. Chemical changes usually involve the release of heat, light, water, or electricity. Energy is either absorbed or given off during a chemical change. If energy is given off, the reaction is called *exothermic*. If heat or some other energy is taken in during the reaction, it is called *endothermic.*

Chemical Change

1. Heat, light, or some other form of energy is lost or gained.
2. Original substances are changed to other substances.
3. Can be used to **decompose** or form compounds.

Physical Change

1. Little or no energy lost or gained.
2. Original substances remain. However, appearance may change.
3. Can be used to separate mixtures

Figure 3 | Chemical and Physical Changes

View 803 Chemical Change, from the Grade 8 SCIENCE EXPERIMENTS Video

Try this investigation.

These supplies are needed:

- plaster of Paris
- two glasses or cups
- water
- two thermometers
- two stirrers
- flour

Follow these directions and answer the questions. Put a check mark in the box when each step is completed. The production of heat is often a sign of a chemical reaction. A thermometer can measure the heat given off in a reaction.

☐ 1. Fill a cup with plaster of Paris.

☐ 2. Fill another cup with flour.

☐ 3. Take the temperature of both cups. Record it in the chart.

☐ 4. Add half a cup of water to each container and stir. Record the temperature of each mixture after ten minutes.

Measurements	Flour	Plaster of Paris
Temperature (before adding water)		
Temperature (after adding water)		

1.47 In which cup did the greatest increase of temperature occur? ______________________

____

1.48 In which cup did a chemical reaction take place? ______________________

1.49 How do you know? ____

TEACHER CHECK ____________ initials ____________ date

Chemical Change Experiment

Answer this question in one or two sentences.

1.50 How does a chemical change differ from a physical change? ________________________________

____

____

____

Answer true or false.

1.51 __________ A reaction that releases energy is called *endothermic*.

1.52 __________ Burning involves a chemical change.

1.53 __________ Physical change involves a change in composition.

1.54 __________ Little or no energy is lost or gained in a physical change.

1.55 __________ Snow melting is a physical change.

Complete these sentences.

1.56 How a substance unites with another substance is its ______________________________ .

1.57 The change in molecules is called a ______________________________ .

1.58 A piece of matter that is changed only in form or shape undergoes a

______________________________ .

Molecular structure. Water is made up of the elements oxygen and hydrogen. At most temperatures oxygen and hydrogen are gases. What happens to the atoms of these gases when water is formed?

One way to answer this question is to say that the oxygen atoms and hydrogen atoms join together to form water molecules. However, in the gaseous state both oxygen and hydrogen molecules combine to form water molecules. Figure 4 shows how this combination happens.

Each atom is shown as a circle. Each circle is labeled with a chemical symbol; *H* for hydrogen and *O* for oxygen. Molecules are shown as two or more circles together. This represents a chemical change because the molecules are different from the original molecules, thus there is a change in composition. If you count correctly, you find that the numbers and kinds of atoms present before and after are the same. Only the molecules change in most kinds of reactions.

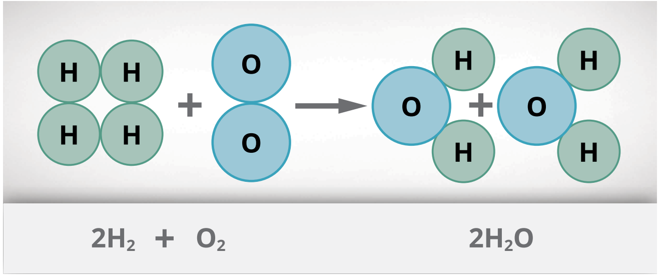

Figure 4 | A Chemical Change

Write the best answer on each blank.

1.59 All molecules are made up of ________________ .
a. hydrogen b. minerals c. atoms d. gas

1.60 In chemical changes the numbers and kinds of ________________ always change.
a. atoms b. molecules c. elements

1.61 A water molecule contains ________________ hydrogen atoms.
a. one b. two c. three

1.62 A molecule of oxygen gas contains two ________________ .
a. atoms b. molecules c. elements

1.63 A molecule of water contains one atom of ________________ .
a. hydrogen b. chlorine c. oxygen

Make a diagram.

1.64 In the following space draw a water molecule and label the parts.

Chemical reactions. Burning and rusting are two common chemical reactions. In chemical reactions new, different substances are formed. Heat and light may also be given off.

When iron rusts, the iron reacts with oxygen to form iron oxide. The mass of the oxide is equal to the combined mass of the iron and oxygen. Mass is neither lost nor gained in the reaction. In ordinary chemical changes, *no matter is lost*. The mass of all the substances before a reaction equals the mass of all the substances after the reaction. This principle is called the *Law of Conservation of Mass* and is a basic principle in studying chemical reactions.

The Law of Conservation of Mass can easily be seen when describing a chemical reaction by use of an equation. A word equation tells you what substances are involved in the reaction and the names of the newly formed substances. A word equation does *not* tell you how much of each substance is involved in the reaction. For example, the chemical change involved in a flashbulb is represented by the following reaction:

- magnesium + oxygen → magnesium oxide

The arrow (→) means *yields* or *makes.* The word equation above would then read, “magnesium plus oxygen yields magnesium oxide.”

However, it is helpful to know how much of each substance is involved in a chemical reaction. The substances always combine in the same proportions for a reaction to be completed. In the reaction of magnesium and oxygen, atoms of magnesium combine with atoms of oxygen to make molecules of magnesium oxide. A chemical equation is like a word equation except that numbers and symbols are used in place of words. The chemical equation for the reaction between magnesium (Mg) and oxygen (O) is this:

reactants → product

$$Mg + O_2 \rightarrow 2\ MgO$$

The number before a symbol shows the number of molecules or atoms that take part in the chemical change. A symbol represents one atom of the element. Thus in this equation, two *atoms* of magnesium (2 Mg) unite with one *molecule* of oxygen (O_2). Notice that when no **subscript** appears below the element, an atom is involved. The number 2 below the symbol (O_2) means that two atoms make up that molecule. A symbol without a number in front of it means *one*. The substances which unite are called reactants. The substances which are produced are called **products**.

Another example of a chemical reaction is rusting.

$$4\ Fe + 3\ O_2 \rightarrow 2\ Fe_2O_3$$

This chemical equation tells that four atoms of iron (Fe) combine with three molecules of oxygen (O_2). This equation also shows you the ratio of atoms and molecules that combine. Be sure to notice that the three molecules of oxygen ($3\ O_2$) amount to six atoms (3 × 2) and the total number of iron atoms is four (4 × 1). Therefore the total number of atoms of reactants is ten. Since mass is neither lost nor gained, ten atoms must appear in the product (two iron atoms + three oxygen atoms times 2 = ten). The product of this reaction is iron oxide (rust). When the number and kind of atoms on the left side of the arrow equal the number and kind of the right side, the equation is said to be *balanced*.

Complete these activities.

1.65 Write the word equation for two chemical changes given in this section.

a. ______________________________

b. ______________________________

1.66 Write the chemical equation for the preceding reactions.

a. ______________________________

b. ______________________________

Match the items correctly.

1.67 ________ reactants

1.68 ________ yields or makes

1.69 ________ plus

1.70 ________ product

1.71 ________ Fe_2O_3

a. +

b. substances that combine

c. iron oxide

d. →

e. magnesium oxide

f. new substance

Complete these exercises.

Given the reaction: $2\ Mg + O_2 \rightarrow 2\ MgO$

1.72 Count the number of atoms in the reactants. __________

1.73 Count the number of atoms in the product. _________

1.74 The idea that atoms are neither gained not lost during a reaction is called the Law of

____ .

Count the atoms in each formula.

1.75 ____________ 2 Fe

1.76 ____________ O_2

1.77 ____________ $2\ Al_3O_2$

1.78 ____________ $4\ O_2$

1.79 ____________ 5 C

1.80 ____________ H_2SO_4

Oxidation processes. A chemical change in which an element or compound unites with oxygen is called **oxidation**. Rusting is an example of slow oxidation. The flash in a flashbulb is rapid oxidation. Burning also is rapid oxidation. Burning is a chemical change in which the atoms of a substance rapidly combine with atoms of oxygen to form new substances. Heat is always given off in the oxidation process.

Sometimes a fire starts because of a buildup of heat from slow chemical changes. A slow buildup of heat from oil in rags may occur as the oil is oxidized by oxygen. The slow oxidation of the oily rags eventually results in a rapid oxidation if the rags burst into flames. Because the fire is started without any apparent help, it is called *spontaneous combustion*.

When a candle is lit, the chemical change produces water vapor (H_2O), carbon dioxide (CO_2), and carbon monoxide (CO). Black carbon is another by-product of a burning candle.

Study and follow these important safety rules.

1. Follow directions carefully.
2. Do *not* mix anything without instructions.
3. Do *not* taste anything unless told to do so.
4. Place chemicals and investigation materials in a safe place.
5. Check with your teacher to see if chemist's goggles are needed for eye protection.

Important Safety Rules

Try this investigation.

These supplies are needed:

- small candle
- jar or beaker
- matches
- flat candle base or watch
- glass

Follow these directions and answer the questions. Put a check mark in the box when each step is completed.

- ☐ 1. Place a small candle in a watch glass and light it.
- ☐ 2. Turn the beaker upside down over the candle.
- ☐ 3. Notice the drops of water and black material on the inner surface of the jar.

Oxidation Experiment

1.81 What can explain the presence of the water and black material? ____________________

____

____

____

1.82 Why does the candle stop burning? ____

____

TEACHER CHECK ____________ initials ____________ date

Oxidation Experiment

How did you do on answering the questions? If they were a little difficult, read this explanation carefully. In the experiment, new substances are formed during the burning, or rapid oxidation, of the candle. The chemical change produced water (H_2O), carbon dioxide (CO_2), carbon monoxide (CO) and soot. When the water vapor touched the cool wall of the jar, it condensed on the inner surface and small drops of water were formed. The black material is soot or incomplete burning of carbon (C). Oxygen is necessary for oxidation, so when it was used up, the flame went out.

Fill in the blanks.

1.83 A chemical change in which an element or compound combines with oxygen is called

______________ .

1.84 Black soot is made up of the element ______________ .

1.85 The water vapor resulted in drops of water on the jar by the process of ______________ .

1.86 Burning is a ______________ change.

1.87 The oxidation process always gives off ______________ .

NUCLEAR CHANGE

A third type of change involves a change in the nucleus of the atom. This type of change is called a **nuclear** change. The sun is an example of nuclear change.

The sun is our primary source of energy. The sun is 93 million miles away, yet a tremendous amount of its heat energy warms our planet Earth.

Scientists have known that the amount of heat given off by the sun could not result from the simple burning of fuel. Therefore, the kind of change taking place in the sun is not *physical* nor *chemical*, but *nuclear*. A nuclear change can cause a change in the *kinds of atoms* present. In this section you will study two different nuclear changes and the particles they produce.

Nuclear Fission. Atoms have a tremendous amount of energy locked within their nuclei. If nuclear energy can be released, it can be used in many ways. Nuclear **fission** is one way nuclear energy may be released. Fission means to *divide*. In nuclear fission, the nucleus of certain elements splits into two nuclei. Nuclear fission is nuclear change. Matter that gives off atomic particles or energy is said to be **radioactive**. When a uranium 235 atom is bombarded by neutrons, it splits into two nuclei. The *daughter nuclei* are about equal in size.

Uranium fission results in a *chain reaction*. First, a uranium nucleus is split by a neutron. The splitting releases two other neutrons. The two neutrons are captured by two more nuclei, which split. The fission of nuclei and the emission of neutrons continue throughout the sample if enough uranium is present. Otherwise, the neutrons do not escape and strike more nuclei.

A neutron that travels over ten centimeters without hitting a nucleus will be slowed down too much to split another nucleus.

During fission, an extremely small mass is changed to energy. The energy is given off as *gamma radiation*. The term *radiation* is applied to energy or to high-speed particles given off

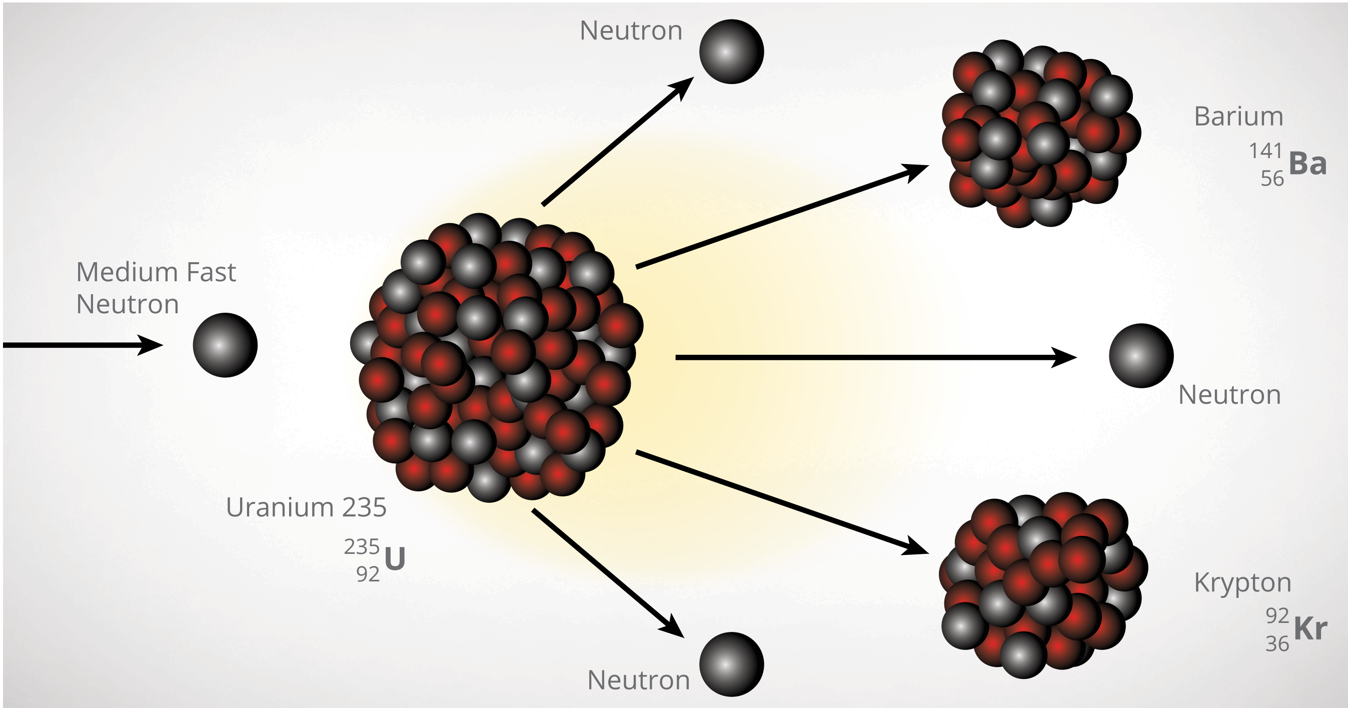

Figure 5 | Fission

in a nuclear reaction. Early in their study, scientists thought that all radiation was energy. They therefore called three types of radiation *alpha rays, beta rays*, and *gamma rays.* Research has revealed that alpha "rays" are really fast-moving helium nuclei, each made of two protons and two neutrons. Beta "rays" are **electrons** emitted from atomic nuclei, and gamma rays are a very high energy form of light waves. The three forms of radiation range from high penetration gamma rays to relatively low energy alpha particles. A geiger counter detects radiation.

Complete these statements.

1.88 The sun is our main source of ________________ .

1.89 The sun is ________________ million miles away from the earth.

1.90 Particles or energy given off in a nuclear reaction are called ________________ .

1.91 Matter that gives off atomic particles is said to be ________________ .

1.92 The type of radiation of highest energy is ________________ rays.

1.93 An alpha particle is made up of a. ________________ and b. ________________ .

Write the correct letter and answer in the blank.

1.94 A beta particle is the same as ________________ .
a. an electron b. a neutron c. a proton

1.95 A phase change involving whole atoms is called ________________ .
a. chemical b. physical c. nuclear

1.96 The process of a neutron splitting a nucleus into two parts is called ________________ .
a. fusion b. fission c. atomic

1.97 When one nucleus after another is split, a ________________ occurs.
a. double nucleus b. neutron split c. chain reaction

1.98 During the fission, a small amount of mass is changed to ________________ .
a. density b. energy c. weight

Nuclear Fusion. Nuclear **fusion** is the opposite of nuclear fission. *Fusion* means *to fuse or join together*. In nuclear fusion, two or more atomic nuclei unite to form a single, heavier nucleus. Thus, elements with small masses join together to form elements with larger masses. Hydrogen, deuterium, and tritium are raw materials commonly used for nuclear fusion.

deuterium + tritium → helium + *energy*

Temperatures in the millions of degrees must be reached for nuclear fusion to occur. Nuclear fusion is also called a *thermonuclear reaction*. *Thermo-* means *heat.* At the tremendous temperatures of thermonuclear reactions, atoms lose their electrons and no longer exist as atoms. This phase of matter is called the *plasma* phase. It consists of nuclei and free electrons. The plasma phase is different from solid, liquid, or gas phases.

At nuclear fusion temperatures, matter becomes plasma and charged nuclei are formed, which can be squeezed together and fused.

The sun sets the right conditions for nuclear fusion to occur. The sun has an internal temperature of ten to twenty million degrees. Through a complex series of nuclear changes, four hydrogen nuclei are fused into one helium nucleus. The sun is constantly losing hydrogen and gaining helium through nuclear fusion. The helium atom has a mass almost one percent less than the mass of the original four hydrogen atoms. This *mass defect* (deficiency) is equivalent to the energy produced.

Nuclear fusion occurs in the explosion of a hydrogen bomb. The reactions in a hydrogen bomb are similar to the reactions in the sun. The temperature inside an exploding hydrogen bomb is about 10 million degrees Celsius. An atomic bomb is used as a fuse to produce a temperature high enough to start nuclear fusion for a hydrogen bomb.

Write true or false.

1.99 ____________ Nuclear fusion is the opposite of nuclear fission.

1.100 ____________ In nuclear fission, high temperatures must be reached.

1.101 ____________ The plasma state is essentially a solid state.

1.102 ____________ Fusion means *splitting*.

1.103 ____________ *Thermo* means *heat*.

Match the letters with the correct answer.

1.104 ________ fusion

1.105 ________ fission

1.106 ________ atomic bomb

1.107 ________ plasma phase

1.108 ________ hydrogen

a. nuclei and free electrons

b. fuse for hydrogen bomb

c. splitting

d. raw material for fusion

e. carbon

f. nuclei unite

Review the material in this section in preparation for the Self Test. The Self Test will check your mastery of this particular section. The items missed on this Self Test will indicate specific areas where restudy is needed for mastery.

SELF TEST 1

Match these items (each answer, 2 points).

1.01	________	evaporation	a.	pertaining to the nucleus
1.02	________	reactants	b.	a reaction between a substance and oxygen
1.03	________	gamma rays	c.	radiation
1.04	________	rusting	d.	Celsius temperature scale
1.05	________	0° C	e.	freezing point of water
1.06	________	distillation	f.	to fuse or join together
1.07	________	oxidation	g.	involves evaporation and condensation
1.08	________	nuclear	h.	change from liquid to gas state
1.09	________	fission	i.	rapid oxidation
1.010	________	Centigrade	j.	splitting of the atom
1.011	________	burning	k.	the combining substances in a reaction
1.012	________	thermo-	l.	heat
			m.	slow oxidation

Write C if the change is chemical, and P if the change is physical (each answer, 2 points).

1.013 ____________ burning a match

1.014 ____________ melting ice

1.015 ____________ evaporating water

1.016 ____________ making pencil marks on paper

1.017 ____________ blowing up a balloon

1.018 ____________ baking a cake

1.019 ____________ making a chocolate milkshake

Define the terms (each answer, 5 points).

1.020 chemical change ____

____

____

____

1.021 physical change ____

____

____

____

1.022 chemical property ____

____

____

Make a list (each answer, 3 points).

1.023 List five physical properties of matter.

a. ____________________ b. ____________________

c. ____________________ d. ____________________

e. ____________________

1.024 List three kinds of radiation given off by radioactive substances.

a. ____________________ b. ____________________

c. ____________________

Define these terms (each answer, 5 points).

1.025 latent heat of fusion ______________________________

____

1.026 latent heat of vaporization ______________________________

____

1.027 kinetic theory ______________________________

____

Answer the questions on the basis of the chemical equation (each answer, 4 points).

$$4\ Fe + 3\ O_2 \rightarrow 2\ Fe_2O_3$$

1.028 Write the reactants.

a. ____________________ b. ____________________

1.029 How many *atoms* do the reactants represent? ____________________

1.030 How many atoms does the product represent? ____________________

1.031 Why are the number of atoms the same on each side of the arrow?

____

90/112 **SCORE** ____________ **TEACHER** ____________ ____________

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