

Changes in Matter

Changes in the state of matter, such as boiling or melting, are examples of physical changes. **Physical changes** alter the form of a substance, but not its identity. Even when you boil away a pan of water, the water is still present as water vapor. Other examples of physical changes include crushing a soda can, tearing a piece of paper, and mixing sugar into iced tea or breakfast cereal. Separating the parts of a substance, such as filtering orange juice to remove the pulp, is also a physical change. In each of these examples, the form or appearance of the substances changed, but the substances themselves remained.

In **chemical changes**, however, one or more substances combine or break apart to form new substances. Heating table sugar and changing it into caramel is one example of a chemical change. When this process is complete, the original sugar particles no longer exist. Burning wood is another example of a chemical change. When wood burns, it combines with oxygen in the air to produce the glowing gases that you recognize as fire. This process changes the wood into ash and gases that are no longer wood.

The ability of a substance to undergo a specific chemical change is another example of a characteristic property. This property is called the **chemical activity** of the substance.

Figure 3 Unlike a physical change, a chemical change alters the identity of a substance. In a forest fire, wood is changed into gases and other substances. In a test tube, caramel can be produced by heating sugar. *Observing* How can you tell that new substances were formed in both photos?

Changes in Matter

Chemistry is not just the study of kinds of matter, but also of how matter changes. Clouds bringing water to your garden, a plant seed, gasoline in a lawn mower engine, a book of matches—all of these are examples of matter. All of them are useful. They are useful as a result of the changes they undergo.

Physical Change Not all changes produce different material. A change that alters the form or appearance of a material but does not make the material into another substance is called a **physical change**.

When you think about water in its different forms, you are thinking about physical changes. When it is cooled in a freezer or at the cold regions of Earth, liquid water becomes solid ice. You can change ice to liquid water by leaving an ice cube on your kitchen counter. If it is heated on your stove or by the energy of the sun, liquid water becomes an invisible gas called water vapor. When water vapor becomes liquid again, it returns to the ground as rain. These are all physical changes. Water is still the same substance in all three forms. It is still made of two parts hydrogen and one part oxygen (H_2O).

Chemical Change A change in matter that produces new substances is called a **chemical change**. The new substances are made of the same elements as the original substance, but now in different combinations. Elements and compounds rearrange to make new materials. Elements may combine to make compounds, compounds may be broken down into elements, or compounds may change into other compounds.

Think about elements and compounds as if they were letters and words. Every word is made of specific letters in a certain combination. Likewise, every compound is made of specific elements in a certain combination. A physical change is like printing the same word in a different style of type:

stampedes → *stampedes*

A chemical change, or **chemical reaction**, is like scrambling the letters of a word to make new words:

stampedes → **made + steps**



Figure 3 Matter commonly exists in three different forms, or states. **Interpreting Photographs** Name two states of water shown in this photograph. Which state of water is invisible?

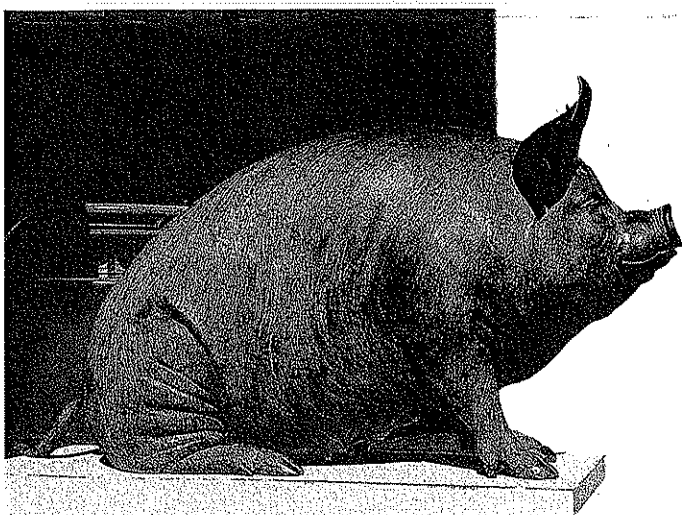


Figure 4 Over time, the surface of a polished bronze statue darkens as it reacts with oxygen in air.

You have seen the results of many chemical reactions. Rusting turns the strong iron metal of a car body into iron oxide, a compound you can easily knock a hole through. When wood burns, the compounds that make up the wood combine with oxygen in the air to make carbon dioxide and water.

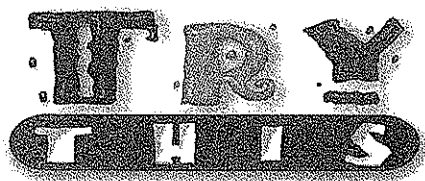
Checkpoint How is a physical change different from a chemical change?

Observing Chemical Reactions

Imagine you are toasting marshmallows over a campfire. You can use your senses to detect chemical changes. You see the burning logs change from a hard solid to a soft pile of ash. You can hear popping and hissing sounds as gases produced by the reaction cause the wood to expand. You can smell the smoke. You can feel the heat energy released. You can even taste the results of one chemical change. A soft, white marshmallow right out of the bag doesn't taste at all like one that is toasted by a reaction of sugar with oxygen.

You can detect many chemical reactions by observing changes in the properties of matter. Such changes result when new substances form. But how can you tell when a new substance is present? Sometimes a gas is produced, which you might see as bubbles in a liquid. Other times, a solid may appear when two solutions are mixed. A solid that forms from solution during a chemical reaction is called a **precipitate** (pree SIP uh tayt). Still other times, a color change or a change in other properties may tell you that a new substance has formed. Changes in energy also happen during reactions, usually indicated by temperature changes. You will learn more about energy and chemical changes in Section 3.

All of these kinds of evidence are good indicators of a chemical reaction. But they may not always be. Sometimes physical changes give similar results. Take, for example, the changes to water described earlier. When water boils, gas bubbles form. When water freezes, solid ice crystals appear. The properties of solid, liquid, and gaseous water differ also. Ice is a hard, sometimes milky white, brittle solid. Liquid water is clear and colorless. Some of the properties differ, but water vapor, ice, and liquid water all are made of hydrogen and oxygen in a 2 to 1 ratio. **The key characteristic of a chemical reaction is the production of new materials that are chemically different from the starting materials.**



Mostly Cloudy

ACTIVITY

How can you tell if a chemical reaction is taking place?

1. Put on your safety goggles and apron.
2. Pour about 5 mL of lime-water into a plastic cup.
3. Pour an equal amount of plain water into another plastic cup.
4. Add about 5 mL of carbonated water to each of the cups.

Inferring In which cup do you think a chemical reaction occurred? What evidence supports your inference?

White Substances Information

Ascorbic Acid

Ascorbic acid ($C_6H_8O_6$), better known as vitamin C, is essential in the human diet. All vertebrates (animals with backbones), except primates (including humans) and guinea pigs, make their own vitamin C. Guinea pigs and primates must get it from foods, like citrus fruit, tomatoes, and liver.

Vitamin C helps body tissues grow and heal. It helps make an important protein called collagen, which is found in bones, cartilage, soft tissues, and teeth. Without vitamin C, joints hurt and grow weak, gums bleed, and teeth loosen, making it very difficult and painful to eat. The final result is death. Pretty severe consequences for not eating enough vitamin C!

The connection between these symptoms, called scurvy, and vitamin C was unknown until the late 1700s. A British naval doctor, James Lind (1716–1794), observed that eating citrus fruits cured scurvy. From that time on, sailors were required to drink lime or lemon juice to prevent scurvy.

You may have heard that a massive dose of vitamin C can prevent the common cold. According to medical studies, however, this isn't true. There are definite health benefits associated with vitamin C, but cold prevention is not one of them.

Calcium Carbonate

Calcium carbonate ($CaCO_3$) is a common mineral found in sedimentary rock, such as chalk, limestone, and marble. Carbonate rocks account for about 4% of the mass of Earth's crust. Calcium carbonate is also important in ocean ecosystems. Snails, oysters, and clams make their shells out of it. And when you see a coral reef, you are looking at the calcium carbonate skeletons of millions of tiny animals called corals.

Calcium carbonate is an inexpensive source of calcium used in the calcium pills that people take to strengthen bones. It is also used in antacids to relieve acid indigestion after a big meal. Calcium carbonate neutralizes excess hydrochloric acid found in our stomachs.

And don't forget the chalkboard. Chalk is used in classrooms around the world. Writing chalk is usually made of calcium carbonate.

Calcium Chloride

Calcium chloride (CaCl_2) is a salt, but not the same salt you use to flavor foods. Calcium chloride has two useful properties. When it dissolves, it releases heat. This makes calcium chloride particularly good for melting ice on roads and sidewalks. And as the salt dissolves in the melted ice, it lowers the freezing point of water so it will not freeze again. Calcium chloride has another side benefit as road salt. It does not damage plants growing at the sides of roads nearly as much as other salts.

Calcium chloride is also hygroscopic. That means it absorbs water. Because it soaks up water so efficiently, it is used to dry air and other gases. It is also spread on dirt roads. The calcium chloride absorbs water, which holds down the dust.

Calcium chloride is added to concrete to make it set up faster and cure harder. It is used as a food additive (pickles particularly) to add a salty taste without increasing the sodium content of the food. This is important for people who are on low-sodium diets and cannot eat regular salt, which is sodium chloride.

Citric Acid

Citric acid ($\text{C}_6\text{H}_8\text{O}_7$) is found naturally in almost all plants and in many animal tissues and fluids. It is important in animal metabolism. You usually think of citric acid when you think of citrus fruits like lemons, oranges, tangerines, or grapefruits. But citric acid is also found in strawberries, apples, peaches, and even brown rice, soybeans, and wheat.

Most of the citric acid used in the United States finds its way into food. It is used to preserve foods, like jams and jellies. It is also used to give texture to processed cheese. Because citric acid, like all acids, has a sharp, sour taste, it is added to candies and soft drinks to give them a sour zing. Because of its taste, citric acid is sometimes referred to as "sour salt." When you pop a sour candy in your mouth and feel your cheeks pucker and get that momentary ache in your jaw, you are having a citric acid moment.

Magnesium Sulfate

Ahhh, soak those sore feet in a nice warm bath of Epsom salts. People have soothed their sore feet in naturally occurring magnesium sulfate (MgSO_4) mineral springs for centuries.

Perhaps the most famous magnesium sulfate spring is located in Epsom, England. Hence the name Epsom salts. In the early 1600s, a farmer noticed that his thirsty cattle would not drink at a certain spring. He tasted the water. It was very bitter and unsuitable for drinking. But the magnesium sulfate salts were found to be relaxing and medicinal. This discovery led to the creation of the famous Epsom Spa and the first patent for medicine in England in 1698.

Today magnesium sulfate is sold in drugstores as a soaking agent for bruised, tired feet. It is also an effective laxative, providing relief from constipation. It is not too difficult to find other places where magnesium sulfate is used. It is found in fertilizers as a source of magnesium, in detergents and soaps, and in stainless steel flatware as a filler in hollow handles. It is even added to purified water to give it some taste.

Sodium Bicarbonate

Did you ever see a model volcano erupt? The "lava" was probably produced by mixing sodium bicarbonate (NaHCO_3) and vinegar. Sodium bicarbonate's common name is baking soda. It is added to baked goods like biscuits to make them light and fluffy. When sodium bicarbonate reacts with acid, carbon dioxide gas forms. That gas makes the foam in the model volcano and causes the biscuit dough to rise.

Sodium bicarbonate is an ingredient in many brands of toothpaste. Why is it helpful? The bacteria that grow in your mouth give off acid as a waste product. That acid eats away at the outer layer of your teeth and causes them to decay. A toothpaste with sodium bicarbonate neutralizes the acid. In fact, sodium bicarbonate is so good at fighting tooth decay that some people use it alone to brush their teeth.

Sodium bicarbonate is also good for indigestion caused by excess stomach acid. That is why it is in many over-the-counter antacids. *Antacid* literally means "against acid." Sodium bicarbonate effectively neutralizes that extra acid, forming neutral products: carbon dioxide gas, table salt, and water.

Sodium Carbonate

Sodium carbonate (Na_2CO_3), known as washing soda or soda ash, is found naturally as trona ore in only a few parts of the world. The largest deposit of trona is in Wyoming.

Hundreds of years ago, soda ash was recovered from the ash from burned seaweed. In the 1700s, sodium carbonate, recovered from seaweed ashes, was used to make glass and soap.

Today a chemical process called the Solvay process can be used to make synthetic sodium carbonate. However, this process produces a number of hazardous wastes. The preferred method of obtaining sodium carbonate is still mining and refining it from natural ore.

Sodium carbonate is important in glassmaking. To make glass, you need to melt sand (silicon dioxide). Sand melts at 1700°C . But if you add sodium carbonate to the sand, it lowers the melting temperature, making it more cost effective to produce glass.

Glass production is the largest use for sodium carbonate, but sodium carbonate has many other uses. It is used in manufacturing detergents and soaps, making paper, and treating wastewater.

Sodium Chloride

Sodium chloride (NaCl), the salt you put on food, is so important that it has played a role in the development of civilization. Salt has led to war, has served as money, and is still considered a universal symbol of hospitality. Why is salt so important? Our bodies cannot make it but must have it. Without sodium and chlorine, our bodies cannot function properly.

Sodium is essential for muscle movement, heartbeat regulation, and nerve function. Chlorine is in stomach acid, making digestion possible. It also controls the movement of water into and out of cells.

Salt is an excellent preservative, used to keep meat, fish, and vegetables from spoiling. Food that has been salted and cured can remain edible for months. Pickling foods, like cucumbers (pickles), is another method of food preservation. Food is first soaked in brine (salt water), followed by vinegar. Before refrigerators, salt was the most important preservative.

Today sodium chloride is used for much more than preserving foods. The salt industry claims that salt has more than 14,000 uses! Most of the salt used in the United States goes to make other substances, like chlorine, sodium carbonate, and hydrochloric acid.

SUCROSE

Sucrose ($C_{12}H_{22}O_{11}$), best known as the refined white sugar used to sweeten foods, comes from plants. The two most important source plants are sugarcane and sugar beets.

About 70% of the sugar produced in the world is extracted from sugarcane, a very tall grass that looks like bamboo. It is grown in tropical regions around the world. The rest comes from sugar beets. Sugar beets are grown in northern, cooler climates and are roots. They look like fat, white carrots.

So why is sugar so important? It tastes good and is a source of energy in the human diet. There are 16 food calories of energy in every teaspoon of sucrose. So, if you are like most Americans, you eat 45 pounds of sugar per year! That's nine 5-pound bags, or about 2 ounces of sugar per day. That means that you eat almost 200 food calories per day of pure sucrose. That may be a bit much, but your body breaks down the sucrose into glucose that cells use as their most important fuel source. Sugar, in moderation, is an important part of our diet.

Sugar also has other uses. It is used in large quantities as a preservative in jams and jellies and is a food source for yeast in the making of bread.