What are some ways to describe matter?

Do these images look like they have been digitally enhanced? They haven't been. This ghostly looking material is called silica aerogel. Compared with any other solid of the same size and shape, it is extremely light. That is why it almost appears to float above this person's fingers. A cube of silica aerogel measuring 1 cm on each side is about the same size as a mini-marshmallow but is 30 times lighter.

Silica aerogel has some unique properties. Despite seeming so fragile, it has an amazing ability to insulate against heat. Even a thin piece can protect a delicate flower from the full heat of a laboratory burner. Its applications range from common consumer products such as paint thickener to out-of-this-world uses such as insulation for spacesuits.
CONCEPT 1

Matter can be described by its physical properties.

Activity
Observing Properties
Choose an object in the classroom. Write down as many of its properties as you can. Then trade your description with a partner and see if you can identify the object. Afterwards, reflect on which properties helped to make the object more or less difficult to identify.

Physical Properties

All matter has different characteristics that can be used to describe it. A physical property of matter is a characteristic that can be observed or measured without changing its chemical identity (the type of matter that it is).

Qualitative Physical Properties

These berries, all B.C. crops, each have distinct colours, flavours, and odours due to a variety of substances in each fruit.

This gold ring was made by Haisla artist Barry Wilson. Gold is popular for jewellery because it is lustrous (shiny) and malleable (easy to shape). Diamond is prized for its sparkle and hardness.

Texture is a physical property that describes how the surface of a substance feels. This sandpaper has a rough texture.

Oxygen is a gas at room temperature. The state of a substance—gas, liquid, or solid—is a physical property.
Figure 2.5 shows examples of physical properties of matter. *Qualitative physical properties* can be described and compared using words, such as “red,” “sweet-smelling,” or “shiny.” You do not need to use an instrument to make measurements when observing qualitative physical properties. However, many physical properties have numerical values associated with them. Those properties that can be measured and assigned a value are called *quantitative physical properties*.

*Figure 2.5* Matter can have a variety of physical properties.

**Quantitative Physical Properties**

The temperature at which a substance melts is called the melting point. The melting point of most chocolates is between 30°C and 32°C, which is less than normal human body temperature.

The boiling point is the temperature at which a liquid becomes a gas. The boiling point of water is 100°C.

Solubility is the amount of matter that dissolves in another kind of matter. The solubility of table salt in water is 0.4 g of salt in 1 mL of water.

Tlingit Haida master carver Nathan Jackson uses the difference in hardness between wood and steel in his work. Various hardness scales are used to associate a number with the hardness of a material.

Viscosity describes the rate at which a material flows. Molasses has a high viscosity, which means it flows very slowly. Depending on the type, molasses is 5000 to 10,000 times as viscous as water.
Mass and Volume

All matter has two things in common: mass and volume. Mass is the quantity of matter in a sample that is being measured. A balance is used to measure mass, and there are a variety of different types. Figure 2.6 shows two electronic digital balances in use. Some common units for measuring mass are the kilogram (kg), gram (g), and milligram (mg).

Volume is the amount of space that a material takes up. Most often, the volume of a solid is measured in cubic units, such as cubic metres (m³) or cubic centimetres (cm³). The volume of a gas or liquid is measured in litres (L). Small volumes are often recorded as millilitres (mL). The unit used to measure the volume of a solid is related to the unit of volume used to measure liquids and gases. One cubic centimetre is the same volume as one millilitre (1 cm³ = 1 mL).

Density—A Physical Property Related to Mass and Volume

Suppose you have two identical shopping bags. One is filled with loaves of bread and hotdog buns, and the other is filled with containers of juice and milk. Which would be easier to lift? Even though both bags are the same size, the second bag would be much heavier because it contains more mass in the same volume. This example describes a quantitative physical property called density.

Density is the mass of a material that occupies a certain volume. Common units of density are grams per cubic centimetre (g/cm³) for solids and grams per millilitre (g/mL) for liquids and gases. Figure 2.6 compares two items with different densities.

Figure 2.6 The grape and foam have the same mass but different volumes. Which substance has the greater density? Explain why.
Determining Density

You do not usually measure density directly. Instead, you measure the mass and volume of a sample and then calculate density using this equation:

\[
\text{Density Equation} \\
\text{density} = \frac{\text{mass}}{\text{volume}}
\]

For example, jet fuel is tested to ensure it meets certain standards. One standard is density. If a sample of jet fuel has a mass of 8.30 g and a volume of 10.3 mL, what is its density?

\[
\begin{align*}
\text{mass} &= 8.30 \text{ g} \\
\text{volume} &= 10.3 \text{ mL} \\
\text{density} &= \frac{\text{mass}}{\text{volume}} \\
&= \frac{8.30 \text{ g}}{10.3 \text{ mL}} \\
&= 0.806 \text{ g/mL}
\end{align*}
\]

The density of water is about 1 g/mL. Therefore, the density of the jet fuel is less than the density of water. Jet fuel and water do not mix, so when jet fuel is added to water, it forms a layer that floats on top of the water. Figure 2.7 shows how liquids with different densities can form layers in a container.

Activity

Finding Density

Your teacher will provide you and a partner with a set of cubes of different materials.

- Using a ruler, measure the volume of each cube. What units will you use?
- Measure the mass of each cube. What units will you use?
- Determine the density of each cube. Make sure to report it in the correct units.

Which material was the densest? Which material was the least dense?

Before you leave this page . . .

1. What is a physical property? Give three examples as part of your answer.
2. What is the difference between a qualitative property and a quantitative property?
Matter can be described by its chemical properties.

**Activity**

**What's a Chemical Property?**
Which of these situations do you think describes a chemical property and why?
- The flesh of an apple turns brown when exposed to air.
- Copper wire can be bent to form a coil.

A chemical property describes the ability of matter to react with another substance to form one or more new substances with different properties. Chemical properties can only be observed when a substance chemically interacts, or reacts, with another substance. Some examples of chemical properties are shown in Figure 2.8.

**Figure 2.8** Chemical properties are only observed when substances chemically interact to form new substances—or when they fail to do so.

Before you leave this page . . .

1. What is the main difference between physical and chemical properties?
2. Explain why melting point is not a chemical property.
CONCEPT 3
Matter can be described based on physical and chemical changes.

Activity
What Changes Are Happening?
Your teacher will give you and a partner a test tube with water and part of an Alka-Seltzer® tablet. The tablet contains baking soda and citric acid. Make a list of the physical properties of the water and tablet. Predict what will happen when the tablet is added to the water. Add the tablet to the water and observe what happens. Which changes do you think are physical changes? Which are chemical changes? Explain.

Physical Changes
A physical change is a change that alters a substance without changing its chemical identity or composition. Crumpling a sheet of aluminum foil into a ball or folding a piece of paper into the shape of a bird are examples of physical changes. The crumpled ball of foil is still aluminum and the folded paper is still paper. Figure 2.9 shows a familiar physical change.

The freezing of water to form ice is also an example of a physical change—the frozen, solid water is still water. Substances can exist in gas, liquid, or solid forms. These forms are called states. For example, you are most familiar with gold in its solid state. But gold can exist as a liquid or even a gas. However, extreme conditions are needed to change gold into its gas state, because its boiling point is 2856°C, which is hotter than most furnaces can get.

When a substance changes from one state to another, the physical change is known as a change of state.

Chemical Changes
During a chemical change, or chemical reaction, one type of matter changes to produce one or more different types of matter. The matter that is produced has a different identity and different properties from the original matter. The substances that take part in a chemical change are called the reactants. The substances that are formed by the chemical change are called the products.

Figure 2.10 shows some physical and chemical changes involved in preparing food.
Chemical change: As food decomposes, its texture, appearance, and smell change. New substances are being formed as chemical changes take place.

Physical change: To make tea, water is heated in a pot or kettle until it boils. A boiling liquid is in the process of changing from a liquid to a gas, which is a change of state.

Chemical change: The colour, texture, and smell of bread change when you toast it. These changes are all evidence of new substances forming.

Physical change: When ice is placed in a room-temperature liquid such as orange juice, it absorbs some of the energy from the liquid and begins to melt. Eventually all the ice will become water that is mixed with the orange juice.

Chemical change: If not kept dry, cast iron frying pans rust over time as the iron reacts with the oxygen in air in the presence of water. The brown, flaky rust has very different properties from the strong, black cast iron.

Chemical and physical changes: When bacon cooks, the colour and texture of the bacon change—evidence of chemical change. The solid fat melts and becomes liquid, which is a physical change.

Figure 2.10 Even a simple task like preparing a meal involves many physical and chemical changes. What are some other chemical or physical changes that take place in a kitchen? List one of each not shown in the illustration.
Law of Conservation of Mass

Early scientists experimented with chemical changes by heating, burning, and mixing matter. These studies included measuring the masses of substances before and after chemical changes had occurred.

French scientist Antoine Lavoisier (1743–1794) and his wife Marie-Anne carried out many chemical reactions, measuring the mass of substances before (the reactants) and after (the products). Figure 2.11 shows an example of one of these experiments. Over and over again, the Lavoisiers observed that mass did not change when a chemical reaction took place. The mass of the reactants was always equal to the mass of the products. This observation was summarized as the law of conservation of mass. According to this scientific law, mass is neither created nor destroyed during a chemical reaction—it is conserved.

The Law of Conservation of Mass

mass of reactants = mass of products

In any chemical reaction, the total mass of the products is the same as the total mass of the reactants.

Figure 2.11 Lavoisier sealed a powdery, red-coloured chemical called mercury(II) oxide in a container. After intense heating, the red powder was changed to silvery liquid mercury and oxygen gas. The mass after the reaction was the same as the mass before the reaction.

Before you leave this page . . .

1. What is the main difference between a physical change and a chemical change?
2. State the law of conservation of mass in your own words.
3. In Lavoisier’s experiments, why was it important that the container be sealed? Explain your answer.
CONCEPT 4

Matter can be classified based on how it responds to physical and chemical changes.

Matter can be classified based on how it can be separated or broken down using physical and chemical changes. As you can see in Table 2.1, matter can be either a mixture or a pure substance. A pure substance can be either a compound or an element. The rest of the unit will focus on pure substances and the models and theories that help explain their properties and changes.

Table 2.1 Classifying Matter Based on Physical and Chemical Changes

<table>
<thead>
<tr>
<th>Type of Matter</th>
<th>Description</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mixtures</td>
<td>Can be separated into parts by physical changes.</td>
<td>A mixture of iron filings and sand can be separated using a magnet.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>A solution of salt and water can be separated by allowing the water to evaporate.</td>
</tr>
<tr>
<td>Pure substances</td>
<td>Compounds: Can be broken down into two or more elements by chemical changes but not physical changes.</td>
<td>Passing an electric current through water produces the elements hydrogen and oxygen.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>These lights contain neon gas, an element.</td>
</tr>
</tbody>
</table>

Before you leave this page...

1. Classify each of the following as a mixture or a pure substance.
   a) oxygen  b) lemonade  c) mercury(II) oxide