CHAPTER 2: The Properties of Matter

SECTION 2: Physical Properties

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- What are physical properties of matter?
- What is density?
- What is a physical change?
- What makes objects float or sink?

What Are Physical Properties of Matter?

We use one or more of our senses to identify an object. The properties we are sensing are the physical properties of the object. A physical property of matter can be detected and measured without making a new substance. If a new substance is made, a chemical property was measured. Chemical properties will be covered in the next section.

There are many physical properties that can help you identify an object. Some physical properties are color, odor, texture, and shape. How could you identify a fruit as an apple? You would probably first look at its color and shape. Its odor and certainly its taste may confirm that the fruit is an apple.

Other physical properties of an object include its strength, flexibility, ability to conduct electricity, and magnetism. Some important examples of the physical properties of matter can be seen in the table below.

<table>
<thead>
<tr>
<th>Physical Property</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermal conductivity</td>
<td>How heat moves through a substance</td>
</tr>
<tr>
<td>Ductility</td>
<td>The ability of substance to be pulled into wire</td>
</tr>
<tr>
<td>State</td>
<td>The physical form of matter (solid, liquid, or gas)</td>
</tr>
<tr>
<td>Malleability</td>
<td>The ability of a substance to be rolled into a shape</td>
</tr>
<tr>
<td>Solubility</td>
<td>The ability of a substance to dissolve</td>
</tr>
<tr>
<td>Density</td>
<td>How compact a substance is</td>
</tr>
<tr>
<td>Compressibility</td>
<td>The ability to be squeezed or pressed together</td>
</tr>
</tbody>
</table>

CRITICAL THINKING

2. Applying Concepts

You are given two balls that are made from the same rubber. They are also the same size and color. One is hollow and one is solid. Give three physical properties that could be used to identify the ball that is solid.

STUDY TIP

Ask Questions

Read this section silently. In your science notebook, write questions that you have about this section. Underline all words you do not understand.
DENSITY

Density is a physical property of matter that describes how its mass and volume are related. **Density** is the amount of matter in a given volume. A golf ball and ping pong ball have similar volumes, so they occupy about the same amount of space. But since the golf ball has more mass, it has a greater density than the ping pong ball does. Take a look at the figure below.

A formula is used to find the density of an object. To find an object’s density \((D)\), you first measure its mass \((m)\) and volume \((V)\). Then use the formula below.

\[
D = \frac{m}{V}
\]

The units of density are a mass unit (kg or g) divided by a volume unit (L, mL, or cm\(^3\)). For example, a density unit could be grams per cubic centimeter (g/cm\(^3\)) for solids, and grams per millimeter (g/mL) for liquids. The density of a substance does not depend on how much of the substance you may have. One kilogram of iron has the same density as one gram of iron.

**How Is the Density Determined?**

When you are given a density problem, follow the following procedure:

**Step 1:** Write the density equation \(D = \frac{m}{V}\)

**Step 2:** Replace \(m\) and \(V\) with the measurements given in the problem.

Let’s try a problem. What is the density of mercury if 270 g of mercury has a volume of 20 mL?

\[
D = \frac{m}{V} = \frac{270 \text{ g}}{20 \text{ mL}} = 13.5 \text{ g/mL}
\]
USING DENSITY TO IDENTIFY SUBSTANCES

Density is a useful physical property. It can be used to help identify a substance. When measured at the same temperature and pressure, the density of a substance is always the same. The density of some common substances can be seen in the table below.

**Densities of Common Substances at 20°C and 1 atm**

<table>
<thead>
<tr>
<th>Substance</th>
<th>Density (g/cm³)</th>
<th>Substance</th>
<th>Density (g/cm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Helium (gas)</td>
<td>0.000166</td>
<td>Zinc (solid)</td>
<td>7.13</td>
</tr>
<tr>
<td>Oxygen (gas)</td>
<td>0.00133</td>
<td>Silver (solid)</td>
<td>10.5</td>
</tr>
<tr>
<td>Water (liquid)</td>
<td>1.00</td>
<td>Lead (solid)</td>
<td>11.4</td>
</tr>
<tr>
<td>Pyrite (solid)</td>
<td>5.02</td>
<td>Mercury (liquid)</td>
<td>13.5</td>
</tr>
</tbody>
</table>

**DENSITY OF SOLIDS**

Would you rather carry around 1 kg of lead or 1 kg of feathers? They both have the same mass. But you know that they are very different. Lead is denser than feathers. It has about the same volume as a stick of butter. The feathers would be about the size of a pillow. This difference in volume makes the lead easier to carry.

**DENSITY, FLOATING, AND SINKING**

If you know the density of a substance, you can tell if it will float or sink. If the density of an object is lower than the density of water, the object will float. Cork, many types of wood, and some plastics are less dense than water. This is why they will float.

If the density of an object is greater than the density of water, it will sink when submerged. Rock and many types of metal are denser than water, so they sink.

The figure below shows a can of diet soda and a can of regular soda in a tank of water. You can see that their densities are different.

In a tank of water, a can of diet soda floats, and a can of regular soda sinks.

**READING CHECK**

6. Describe Under what conditions is the density of a substance always the same?

7. Identify You are given a solid found in the table above. The density is about 7 g/cm³. Which solid is it?

8. Describe When will an object sink in water?

9. Applying Concepts Which can of soda is less dense than water? Explain
LIQUID LAYERS

Take a look at the following figure. It shows different kinds of liquids in a graduated cylinder. Each of the liquids (maple syrup, water, and corn oil) has a different density. When these three items are carefully poured into the cylinder, they will form three different layers. What do you think causes them to look that way?

This happens because their densities are different. The layer with the highest density is on the bottom, and the layer with the lowest density is on the top.

![Diagram of liquid layers in a graduated cylinder]

What Is a Physical Change?

Any change that affects the physical properties of a substance is a physical change. Imagine that a piece of silver is pounded into a heart-shaped charm. This is a physical change because only the shape of the silver has changed. The piece of silver is still silver. Take a look at the figure below to see some other examples of physical changes.

Examples of Physical Change

A change from a solid to a liquid is a physical change. All changes of state are physical changes.

![Examples of physical changes]
EXAMPLES OF PHYSICAL CHANGES

When a substance changes from a solid to a liquid, it changes state. The three states of matter are solid, liquid, and gas. Any change to a different state of matter is a physical change. See the figure below.

Freezing water to make ice is a physical change. Heating water in a teapot makes steam. This is also a physical change.

Sugar seems to disappear or dissolve in water. However, if the water evaporates, the sugar reappears. Therefore, dissolving is a physical change.

REVERSIBILITY OF PHYSICAL CHANGES

The figure above shows arrows with two heads. This means that each change can be reversed. For example, a solid can change into a liquid, then back into a solid.

Physical changes are often easy to undo. Suppose that some solid gold is melted and then poured into a bear-shaped mold. When it cools, the gold solidifies, and a bear-shaped charm is formed. These are physical changes because only the state and shape of the gold has changed. The gold charm is still gold.

MATTER AND PHYSICAL CHANGES

Physical changes do not change the identity of matter. All of the examples that you have read about are examples of a physical change. Physical changes can often be easily reversed, and the identity of the substance itself never changes.
Section 2 Review

SECTION VOCABULARY

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>density</td>
<td>the ratio of the mass of a substance to the volume of the substance</td>
</tr>
<tr>
<td>physical change</td>
<td>a change of matter from one form to another without a change in chemical properties</td>
</tr>
<tr>
<td>physical property</td>
<td>a characteristic of a substance that does not involve a chemical change, such as density, color, or hardness.</td>
</tr>
</tbody>
</table>

1. Describe Write, in words, how to calculate the density of a substance.

Interpreting Tables Use the table below to answer questions 2 and 3.

<table>
<thead>
<tr>
<th>Substance</th>
<th>Density (g/cm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>wood (oak)</td>
<td>0.85</td>
</tr>
<tr>
<td>water</td>
<td>1.00</td>
</tr>
<tr>
<td>ice cube</td>
<td>0.93</td>
</tr>
<tr>
<td>aluminum</td>
<td>2.7</td>
</tr>
<tr>
<td>lead</td>
<td>11.3</td>
</tr>
<tr>
<td>gold</td>
<td>19.3</td>
</tr>
<tr>
<td>ethanol</td>
<td>0.94</td>
</tr>
<tr>
<td>methanol</td>
<td>0.79</td>
</tr>
</tbody>
</table>

2. Identify Will any substance float in methanol? Why?

3. Identify Which substance would have a mass of 135 g when it has a volume of 50 cm³? Show your work.

4. Identify Two balls have the same mass, but one has a larger volume than the other. Which ball has the larger density?

5. Explain When water freezes, its density gets lower. The change in density is different than that of most substances. Most substances get denser when they become solid. When a certain mass of water freezes, what property of water changes, causing its density to get lower? How does this property change?