Learning Objectives

- To separate physical from chemical properties and changes

All matter has physical and chemical properties. **Physical properties** are characteristics that scientists can measure without changing the composition of the sample under study, such as mass, color, and volume (the amount of space occupied by a sample). **Chemical properties** describe the characteristic ability of a substance to react to form new substances; they include its flammability and susceptibility to corrosion. All samples of a pure substance have the same chemical and physical properties. For example, pure copper is always a reddish-brown solid (a physical property) and always dissolves in dilute nitric acid to produce a blue solution and a brown gas (a chemical property).

Physical properties can be extensive or intensive. **Extensive properties** vary with the amount of the substance and include mass, weight, and volume. **Intensive properties**, in contrast, do not depend on the amount of the substance; they include color, melting point, boiling point, electrical conductivity, and physical state at a given temperature. For example, elemental sulfur is a yellow crystalline solid that does not conduct electricity and has a melting point of 115.2°C, no matter what amount is examined (Figure \(\PageIndex{1}\)). Scientists commonly measure intensive properties to determine a substance’s identity, whereas extensive properties convey information about the amount of the substance in a sample.

![Sulfur crystals and sulfur powder](image)

Figure \(\PageIndex{1}\): The Difference between Extensive and Intensive Properties of Matter. Because they differ in size, the two samples of sulfur have different extensive properties, such as mass and volume. In contrast, their intensive properties, including color, melting point, and electrical conductivity, are identical.

Although mass and volume are both extensive properties, their ratio is an important intensive property called **density** \(\rho\). Density is defined as mass per unit volume and is usually expressed in grams per cubic centimeter \(\text{g/cm}^3\). As mass increases in a given volume, density also increases. For example, lead, with its greater mass, has a far greater density than the same volume of air, just as a brick has a greater density than the same volume of Styrofoam. At a given temperature and pressure, the density of a pure substance is a constant:

\[
\text{density} = \frac{\text{mass}}{\text{volume}} \quad \text{\textcopyright } \rho = \frac{m}{v} \quad \text{\textcopyright}\text{label1.2.1}\]

Pure water, for example, has a density of 0.998 g/cm\(^3\) at 25°C. The average densities of some common substances are in Table \(\PageIndex{1}\). Notice that corn oil has a lower mass to volume ratio than water. This means that when added to water, corn oil will “float.”

<table>
<thead>
<tr>
<th>Substance</th>
<th>Density at 25°C (g/cm(^3))</th>
</tr>
</thead>
<tbody>
<tr>
<td>blood</td>
<td>1.035</td>
</tr>
<tr>
<td>body fat</td>
<td>0.918</td>
</tr>
</tbody>
</table>

Table \(\PageIndex{1}\): Densities of Common Substances
## Substance and Density at 25°C (g/cm³)

<table>
<thead>
<tr>
<th>Substance</th>
<th>Density at 25°C (g/cm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>whole milk</td>
<td>1.030</td>
</tr>
<tr>
<td>corn oil</td>
<td>0.922</td>
</tr>
<tr>
<td>mayonnaise</td>
<td>0.910</td>
</tr>
<tr>
<td>honey</td>
<td>1.420</td>
</tr>
</tbody>
</table>

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### Physical Property and Change

Change in which the matter's physical appearance is altered, but composition remains unchanged, e.g., a change in state of matter. The three main states of matter are: Solid, Liquid, Gas.

- Solid is distinguished by a fixed structure. Its shape and volume do not change. In a solid, atoms are tightly packed together in a fixed arrangement.
- Liquid is distinguished by its malleable shape (is able to form into the shape of its container), but constant volume. In a liquid, atoms are close together but not in a fixed arrangement.
- Gas is made up of atoms that are separate. However, unlike solid & liquid, a gas has no fixed shape and volume.

**Example 
\(\PageIndex{1}\): Physical Change**

When liquid water (\(H_2O\)) freezes into a solid state (ice), it appears changed; However, this change is only physical as the the composition of the constituent molecules is the same: 11.19% hydrogen and 88.81% oxygen by mass.

*Figure \(\PageIndex{2}\): Ice Melting is a physical change*
Chemical Properties and Change

- **Chemical Property is** Any characteristic that gives a sample of matter the ability/ inability to undergo a change that alters its composition. Examples: Alkali metals react with water; Paper's ability to burn.

- **Chemical Change is a** Change in which one or more kinds of matter are transformed to new kinds of matter with altered compositions (or Chemical Reaction).

Example \(\PageIndex{2}\): Chemical Change

The combustion of magnesium metal is a chemical change (Magnesium + Oxygen → Magnesium Oxide):

\[
2 \text{Mg} + \text{O}_2 \rightarrow 2 \text{MgO}
\]

The rusting of iron is a chemical change (Iron + Oxygen → Iron Oxide/ Rust):

\[
4 \text{Fe} + 3\text{O}_2 \rightarrow 2 \text{Fe}_2\text{O}_3
\]

Using the components of composition and properties, we have the ability to distinguish one sample of matter from the others.

References


Contributors

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