5.2 Properties of Matter

The special characteristics of pure substances that make each one unique are called properties. The properties of the element or compound are true for any amount of the material anywhere. So the properties of Canadian gold are identical to South American gold. The differences in properties help to identify pure substances and make the substances useful for different applications. All matter exhibits two types of properties. One type is physical.

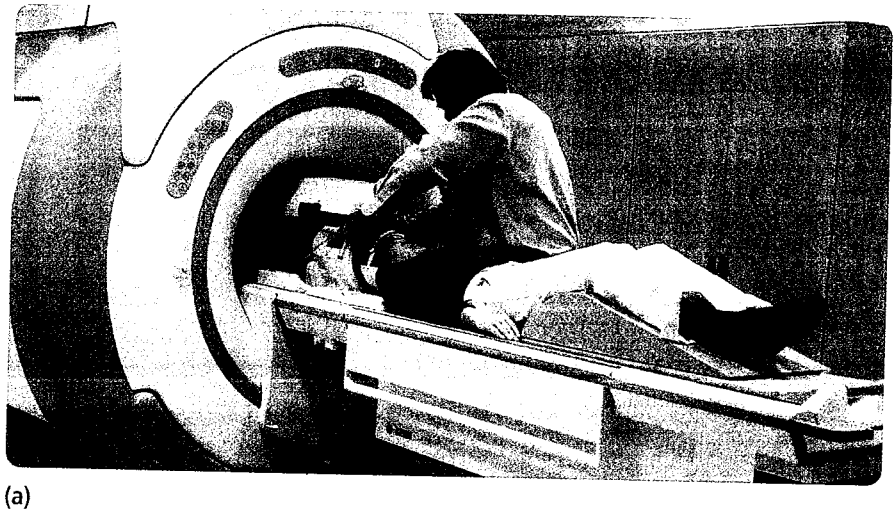
Physical Properties

The **physical properties** of matter are those you can observe with your senses, measure, or calculate. Although many physical properties (such as colour and hardness) of substances are directly observable, many are detected through an extension of the senses, for example with microscopes, X-rays, or magnetic resonance imaging (MRI) machines (Figure 1). Other properties, such as density or solubility, must be measured or calculated.

Did You KNOW

Cornstarch Footsteps

A physical property of cornstarch is the sound it makes when compressed. You may have heard it in the movies. Sound engineers use this property to imitate the sound of footsteps in snow!



(a)

(b)

Figure 1 (a) Using the magnetic properties of the body's tissues and radio waves, MRI machines produce the best possible images of the inside of the human body, without surgery. (b) This image shows the top of the spine and some of the nerves and muscles around the spine.

Examples of physical properties are the colour of a substance, the temperature at which it melts, and the amount that will dissolve in a litre of water. Table 1 lists only a few of the possible physical properties.

LEARNING TIP

Make connections to your prior knowledge. Ask yourself what you already know about the words in Table 1 from information you have learned in school, from your own reading, or by direct observation and experience.

Table 1 Physical Properties

colour	ductility	malleability	density	boiling point
melting point	conductivity	crystalline structure	brittleness	magnetism
solubility	viscosity	hardness	state	lustre

Important physical properties are those that help to identify an unknown pure substance or provide an application of it. The physical properties that are commonly used to identify substances are described below and on the next two pages.

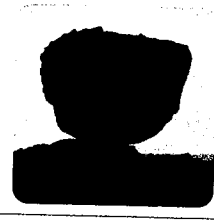
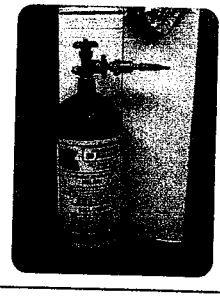
States of Matter

Most substances can exist in more than one physical state. When a substance changes its state, it does not change into another substance. For example, ice, water, and water vapour are all the same compound. The state of a substance at a certain temperature (usually room temperature) is considered a physical property that can be used to identify it. The three **states** in which matter can usually be found are solid, liquid, and gas (Table 2).

LEARNING TIP

As you study Table 2, ask yourself, "What does this show? How does it relate to what I already know about the three states of matter?"

Table 2 Examples of a Solid, a Liquid, and a Gas

Rock is a solid at room temperature. Solid matter can be picked up and carried around without being in a special container.	
Water is a liquid at room temperature. Liquids flow to the lowest level and can be poured. They must be in containers to be moved or stored. Liquids take the shape of the container they are in.	
Helium is a gas at room temperature. Gases take both the volume and shape of any container they are placed in. If a gas is not in a container, it will spread out indefinitely.	

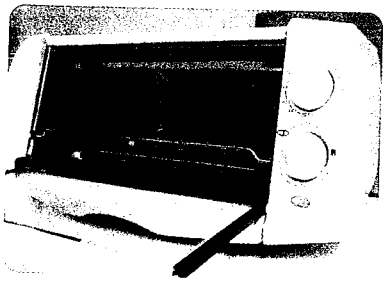


Figure 2 Nichrome is an alloy that has a melting point of 2550 °C. This melting point makes it useful for heating elements in toasters and ovens.

Melting Point and Boiling Point

The temperature at which a substance changes from one state to another is a property unique to that substance. The **melting point** of a substance is the temperature at which the substance changes from a solid to a liquid (Figure 2). The change of state from liquid to solid occurs at the same temperature as the melting point. The **boiling point** of a substance is the temperature at which a liquid rapidly changes to a gas. The change of state from gas to liquid occurs at the same temperature as the boiling point. Table 3 gives the melting and boiling points of some common substances.

Table 3 Melting and Boiling Points of Some Common Substances

Pure substance	Melting point (°C)	Boiling point (°C)
carbon (diamond)	3550	4830
chlorine	−101	−34
copper	1085	2580
gold	1065	2710
iron	1540	2890
magnesium	650	1120
mercury	−39	357
oxygen	−218	−183
sodium	98	890
sodium chloride (table salt)	808	1465
water	0	100

LEARNING TIP

Headings are visible organizers. Try turning these headings into questions, and read with the goal of answering your questions. Clarify the meanings of words in bold by examining Figures 3 to 7.

Malleability

Since their early discovery, metals have been important because they can be physically changed in shape. Metals that can be beaten into thin sheets are considered to be **malleable** (Figure 3).

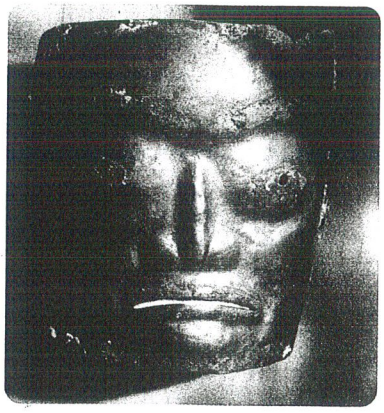


Figure 3 Most metals are malleable and can be hammered into different shapes. Some Aboriginal peoples of British Columbia have been using metal to make items like this mask for more than 2000 years.

Ductility

The softness of certain metals provides them with special properties. Some metals are **ductile**, meaning they can be "drawn" into wires. In other words, if you pull at opposite ends of some metal rods, they will become thinner and thinner until they form a wire (Figure 4).

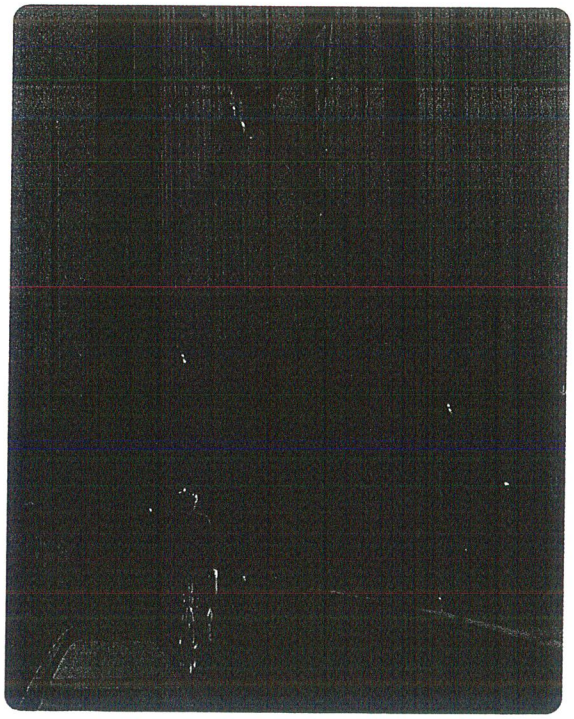


Figure 4 The ductility of some metals and the development of technology that can draw steel into wires make suspension bridges, like the Lions Gate Bridge in Vancouver, possible.

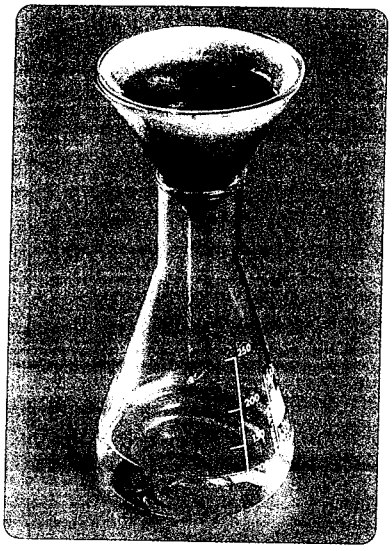


Figure 5 Some substances can be separated from mixtures because of differences in solubility. The brown substance in the photo can be filtered out of the water because the substance is not soluble in water.

Solubility

The degree to which a substance will dissolve in a given amount of another substance, usually water, is called **solubility** (Figure 5). The ability to dissolve or not dissolve in other liquids is a physical property. Salt, for example, is quite soluble in water, but not in gasoline.

Conductivity

The ability of a material to conduct electricity or heat is called **conductivity**. Electrical conductivity is a necessary property for wiring in our very electrical world (Figure 6). Non-conductivity is an important property for materials that are used to contain and protect against electrical flow.

Figure 6 Electrical conductivity makes our electrical world possible.

Density

What we often describe as the "heaviness" of a substance is really the density of the substance. **Density** is the mass per unit volume of a substance. It is a constant property of a substance no matter how much of the substance is present (Figure 7). There is no device to measure density—it can only be calculated. The following formula can be used: $\text{density} = \frac{\text{mass}}{\text{volume}}$.

Density is usually expressed in g/cm^3.

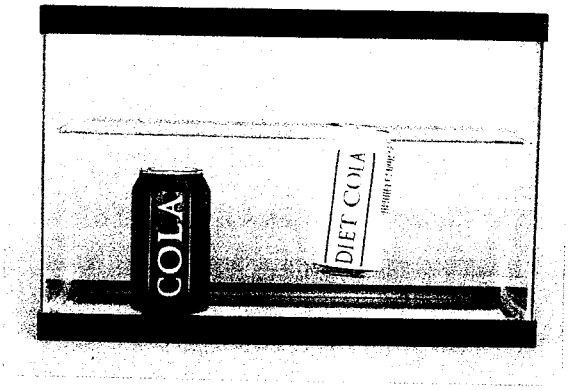


Figure 7 Why might the density of a diet pop be less than the density of a regular pop?

For example, if a piece of aluminum with a mass of 20 g has a volume of 7.4 cm^3, its density can be calculated as follows:

$$\text{density} = \frac{\text{mass}}{\text{volume}} = \frac{20\ \text{g}}{7.4\ \text{cm}^3} = 2.7\ \text{g/cm}^3$$

Density can also be expressed in g/mL. The millilitre is defined as the liquid equivalent of a cubic centimetre. For example, if glycerol in a container has a mass of 1500 g and a volume of 1190 mL, its density can be calculated using the same formula:

$$\text{density} = \frac{\text{mass}}{\text{volume}} = \frac{1500\ \text{g}}{1190\ \text{mL}}$$

$$= 1.26\ \text{g/mL or } 1.26\ \text{g/cm}^3$$

TRY THIS: Is It Gold?

Skill Focus: conducting, measuring, recording, analyzing, interpreting data

Materials: a small piece of gold jewellery, scale, graduated cylinder, water

1. Measure the mass of the piece of jewellery.
2. Add enough water to the graduated cylinder to immerse the jewellery completely. Measure and record the volume of the water alone.
3. Add the jewellery to the graduated cylinder and completely immerse it. Measure and record the new volume.
4. Calculate and record the density of the jewellery and compare it with the data in Table 4.

Table 4

Gold (karat)	Density (g/cm^3)
10K	11.4
14K	13.1
18K	15.5
24K	19.3

A. Does the density of the jewellery match any of the different karats of gold? Which one?

B. What does it mean if the density of the jewellery doesn't match any of densities in Table 4?

C. Some jewellery is gold plated, meaning that it has a layer of gold over a cheaper metal. Would you be able to detect the difference using the density of the jewellery? Explain.

Chemical Properties

The second type of properties that can be used to identify substances are chemical properties. A **chemical property** describes the behaviour of a substance as it changes into a new substance. Chemical properties are often used to group substances based on several common reactions. Chemical properties include whether one substance will react with another substance, the rate of reaction of these substances, the amount of heat produced by the reaction, and in what proportion the substances react. The chemical properties that are commonly used to identify substances are described on the next page.

Did You KNOW

From Failure to Success

3M Post-It Notes have changed the way many people communicate, yet their invention came about by looking at apparent failure in a different way. The semi-sticky glue used on the notes was developed by a scientist who was trying to improve the adhesives used on tape. It was a failure as a glue, but with a little thought and a change in perception, this "poor" property became the foundation for a new communication device. What may often be perceived as a failure may often be an opportunity to learn something new.

Flammability

One of the first chemical properties ever observed was that some materials burn. **Flammability** is the rapid reaction of some substances with oxygen, resulting in the release of a great deal of energy. (The terms flammable, inflammable, and combustible all mean that a substance will burn.) Flammability can be a very useful property, supplying the heat for our homes and the energy to move our cars, but it can also be dangerous, causing fires and explosions (Figure 8). The chemical property of non-flammability is equally important for keeping our world safe from fire. Water and carbon dioxide are not only non-flammable, but they are also able to cool and smother fires.

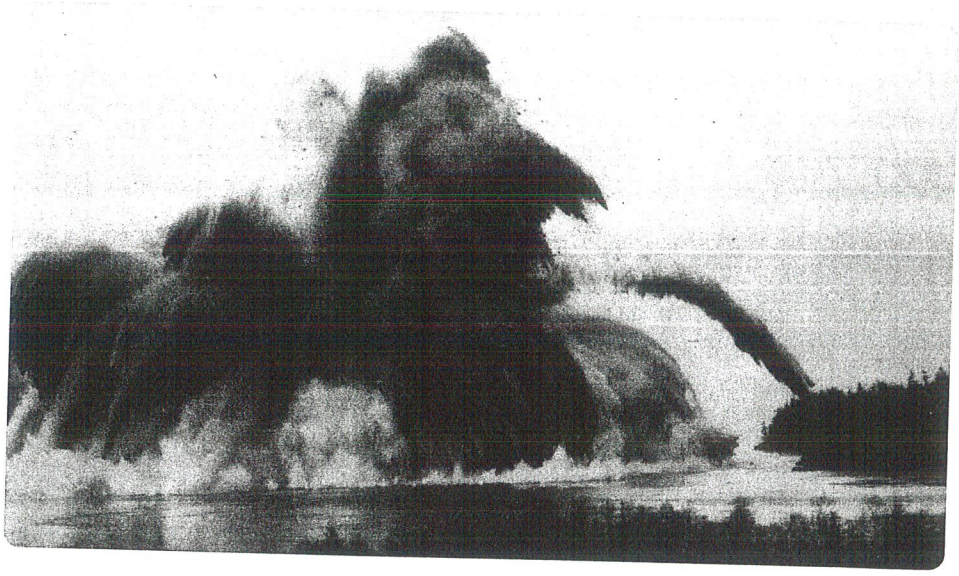


Figure 8 Ripple Rock in the Seymour Narrows just north of Campbell River was destroyed in 1958 when 125 000 kg of an ammonium nitrate explosive created one of the greatest non-nuclear explosions.

LEARNING TIP

Check your understanding. Explain, in terms of corrosion, why cars rust.

Corrosion

Another chemical property also involves a reaction with oxygen, but at a much slower rate. **Corrosion** is the slow reaction of certain metals with oxygen to form metal oxides. This process is called oxidation. The iron hull of the *Titanic* is a good example of the change in the properties of iron as it becomes rust (iron oxide). Since the new substance, rust, does not have the same properties as iron, the ship is slowly disintegrating in the deep water (Figure 9).

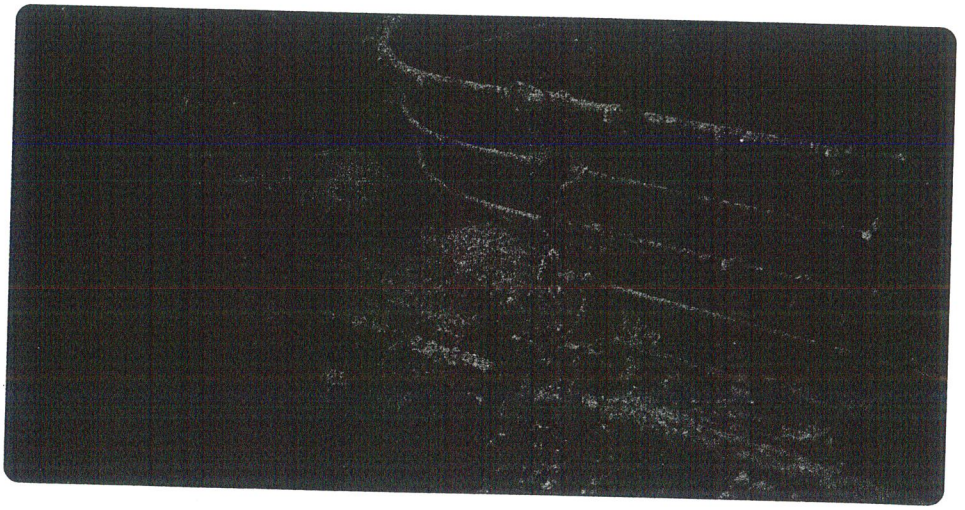


Figure 9 Corrosion is slowly destroying the *Titanic*.

Reactions with Acid

Some metals, such as zinc and magnesium, react with acid (a highly reactive liquid). Some minerals, such as limestone, also react with acid to form carbon dioxide gas. Limestone caves are created when groundwater that is weakly acidic chemically changes the limestone into carbon dioxide and soluble substances (Figure 10).

Figure 10 Beautiful caves are created by only a tiny flow of water and a little dissolved acid. This tour guide in the Home Lakes Caves on Vancouver Island is pointing to the calcium deposits on the cave walls.

TRY THIS: What's The Use?

Skills Focus: analyzing, inferring

We use different substances for different purposes based on their properties. The properties of substances are what make them important for us.

1. Examine Table 5 and identify the properties and possible uses that are missing.

A. The absence of a property is itself a property. For example, the absence of electrical conductivity is a good property for insulation around electrical wire. Choose three properties from the table. For each property, give an example of a situation in which the absence of the property would be an advantage.

B. Name five other substances that you are familiar with, and identify the property that makes them useful. Share your list with a partner.

Table 5

Substance	Property	Use
gasoline	ignites easily at low temperature	
diamond	is extremely hard	
graphite		pencil lead
stomach acid	chemically breaks down substances	
steel		wires of suspension bridges
plastic		covering on electrical wiring
cedar wood		Aboriginal canoe
nitroglycerin	burns extremely rapidly to form a gas	
gold		jewellery