

Properties of Matter2

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CHAPTER

1

Properties of Matter2

Learning Objectives

Lesson Objectives

- Define matter, mass, and volume.
- Identify physical properties of matter.
- List examples of chemical properties of matter.

Vocabulary

- chemical property
- density
- flammability
- mass
- matter
- physical property
- reactivity
- volume
- weight

Introduction

Here's a riddle for you to ponder: What do you and a tiny speck of dust in outer space have in common? Think you know the answer? Read on to find out.

What is Matter?

Both you and the speck of dust consist of atoms of matter. So does the ground beneath your feet. In fact, everything you can see and touch is made of matter. The only things that aren't matter are forms of energy, such as light and sound. Although forms of energy are not matter, the air and other substances they travel through are. So what is matter? **Matter** is defined as anything that has mass and volume.

Mass

Mass is the amount of matter in a substance or object. Mass is commonly measured with a balance. A simple mechanical balance is shown in **Figure 1.1**. It allows an object to be matched with other objects of known mass. SI units for mass are the kilogram, but for smaller masses grams are often used instead.

Mass versus Weight

The more matter an object contains, generally the more it weighs. However, weight is not the same thing as mass. **Weight** is a measure of the force of gravity pulling on an object. It is measured with a scale, like the kitchen-scale in **Figure 1.2**. The scale detects how forcefully objects in the pan are being pulled downward by the force of gravity.

**FIGURE 1.1**

This balance shows one way of measuring mass. When both sides of the balance are at the same level, it means that objects in the two pans have the same mass.

The SI unit for weight is the newton (N). The common English unit is the pound (lb). With Earth's gravity, a mass of 1 kg has a weight of 9.8 N (2.2 lb).

**FIGURE 1.2**

This kitchen scale measures weight. How does weight differ from mass?

Problem Solving

Problem: At Earth's gravity, what is the weight in newtons of an object with a mass of 10 kg?

Solution: At Earth's gravity, 1 kg has a weight of 9.8 N. Therefore, 10 kg has a weight of $(10 \times 9.8 \text{ N}) = 98 \text{ N}$.

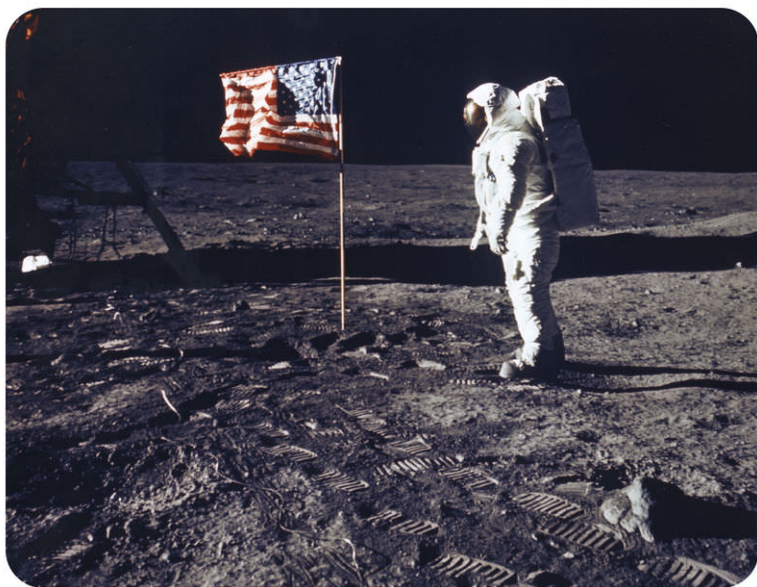
You Try It!

Problem: If you have a mass of 50 kg on Earth, what is your weight in newtons?

An object with more mass is pulled by gravity with greater force, so mass and weight are closely related. However, the weight of an object can change if the force of gravity changes, even while the mass of the object remains constant. Look at the photo of astronaut Edwin E. Aldrin Jr taken by fellow astronaut Neil Armstrong, the first human to walk on the moon, in **Figure 1.3**. An astronaut weighed less on the moon than he did on Earth because the moon's gravity is weaker than Earth's. The astronaut's mass, on the other hand, did not change. He still contained the same amount of matter on the moon as he did on Earth.

The amount of space matter takes up is its **volume**. How the volume of matter is measured depends on its state.

- The volume of liquids is measured with measuring containers. In the kitchen, liquid volume is usually measured with measuring cups or spoons. In the lab, liquid volume is measured with containers such as graduated cylinders. Units in the metric system for liquid volume include liters (L) and milliliters (mL).
- The volume of gases depends on the volume of their container. That's because gases expand to fill whatever space is available to them. For example, as you drink water from a bottle, air rushes in to take the place of the water. An "empty" liter bottle actually holds a liter of air. How could you find the volume of air in an "empty" room?

**FIGURE 1.3**

If the astronaut weighed 175 pounds on Earth, he would have weighed only 29 pounds on the moon. If his mass on Earth was 80 kg, what would his mass have been on the moon?

- The volume of regularly shaped solids can be calculated from their dimensions. For example, the volume of a rectangular solid is the product of its length, width, and height ($l \times w \times h$). For solids that have irregular shapes, the displacement method is used to measure volume. You can see how it works in **Figure 1.4** and in the video below. The SI unit for solid volumes is cubic meters (m^3). However, cubic centimeters (cm^3) are often used for smaller volume measurements.

http://www.youtube.com/watch?v=q9L52maq_vA

Physical Properties of Matter

Matter has many properties. Some are physical properties. **Physical properties** of matter are properties that can be measured or observed without matter changing to a different substance. For example, whether a given substance normally exists as a solid, liquid, or gas is a physical property. Consider water. It is a liquid at room temperature, but if it freezes and changes to ice, it is still water. Generally, physical properties are things you can see, hear, smell, or feel with your senses.

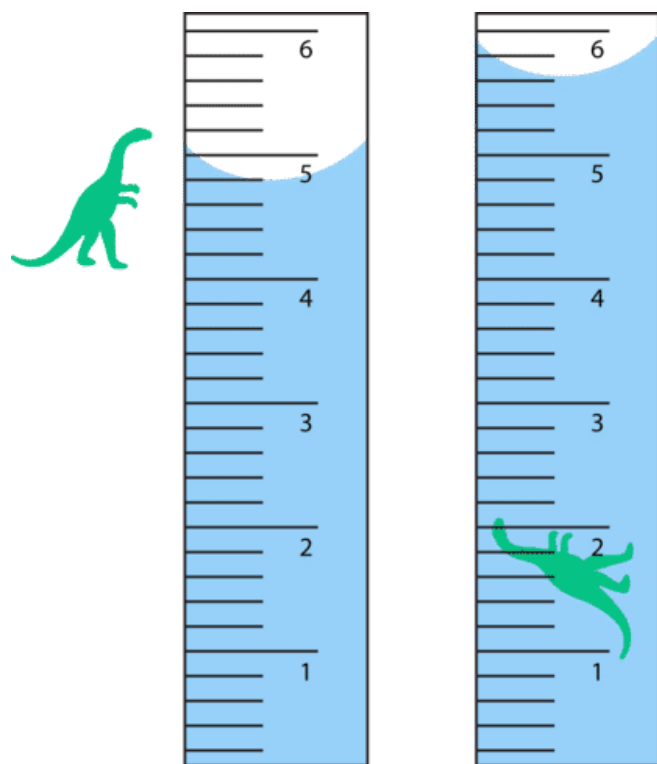
Examples of Physical Properties

Physical properties include the state of matter and its color and odor. For example, oxygen is a colorless, odorless gas. Chlorine is a greenish gas with a strong, sharp odor. Other physical properties include hardness, freezing and boiling points, the ability to dissolve in other substances, and the ability to conduct heat or electricity. These properties are demonstrated in **Figure 1.5**. Can you think of other physical properties?

Density

Density is an important physical property of matter. It reflects how closely packed the particles of matter are. Density is calculated from the amount of mass in a given volume of matter, using the formula:

$$\text{Density } (D) = \frac{\text{Mass } (M)}{\text{Volume } (V)}$$



Displacement Method for Finding Volume

1. Add water to a measuring container such as a graduated cylinder. Record the volume of the water.
2. Place the object in the water in the graduated cylinder. Measure the volume of the water with the object in it.
3. Subtract the first volume from the second volume. The difference represents the volume of the object.

FIGURE 1.4

The displacement method is used to find the volume of an irregularly shaped solid object. It measures the amount of water that the object displaces, or moves out of the way. What is the volume of the toy dinosaur in mL?

Problem Solving

Problem: What is the density of a substance that has a mass of 20 g and a volume of 10 mL?

Solution: $D = 20 \text{ g}/10 \text{ mL} = 2.0 \text{ g/mL}$

You Try It!

Problem: An object has a mass of 180 kg and a volume of 90 m^3 . What is its density?

To better understand density, think about a bowling ball and a volleyball. The bowling ball feels heavy. It is solid all the way through. It contains a lot of tightly packed particles of matter. In contrast, the volleyball feels light. It is full of air. It contains fewer, more widely spaced particles of matter. Both balls have about the same volume, but the bowling ball has a much greater mass. Its matter is denser.

KQED: Aerogel

It looks like frozen smoke, and it's the lightest solid material on the planet. Aerogel insulates space suits, makes tennis rackets stronger and could be used one day to clean up oil spills. Lawrence Livermore National Laboratory scientist Alex Gash shows us some remarkable properties of this truly unique substance. For more information on aerogel, see <http://science.kqed.org/quest/video/quest-lab-aerogel/>.



Diamond



Talc

Hardness

Diamond is the hardest mineral. It is so hard that it is used in drill bits. Talc is the softest mineral. It is so soft that you can crumble it with your fingers.



Antifreeze



Water

Freezing & Boiling Points

Antifreeze has a higher boiling point and lower freezing point than water. It is used in a car's cooling system to keep the cooling fluid in a liquid state. If plain water were used instead, it might boil in hot weather and freeze in cold weather.

FIGURE 1.5

These are just a few of the physical properties of matter.



Aluminum vs. Wood



Copper vs. Plastic

Ability to Conduct Heat or Electricity

Aluminum is a good conductor of heat; wood is not. That's why this pot is made of aluminum and the spoon is made of wood. Copper is a good conductor of electricity; plastic is not. That's why the wires inside this cable are made of copper and the outside covering is made of plastic.



Sand



Sugar

Ability to Dissolve in Other Substances

This white sand may look like sugar. But it doesn't dissolve in water as sugar does.



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Click image to the left or use the URL below.

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Chemical Properties of Matter

Some properties of matter can be measured or observed only when matter undergoes a change to become an entirely different substance. These properties are called **chemical properties**. They include flammability and reactivity.

Flammability

Flammability is the ability of matter to burn. Wood is flammable; iron is not. When wood burns, it changes to ashes, carbon dioxide, water vapor, and other gases. After burning, it is no longer wood.

Reactivity

Reactivity is the ability of matter to combine chemically with other substances. For example, iron is highly reactive with oxygen. When it combines with oxygen, it forms the reddish powder called rust (see **Figure 1.6**). Rust is not iron but an entirely different substance that consists of both iron and oxygen.



FIGURE 1.6

The iron in these steel chains has started to rust.

Lesson Summary

- Matter is anything that has mass and volume. Mass is the amount of matter in a substance. Volume is the amount of space matter takes up.
- Matter has both physical and chemical properties. Physical properties can be measured or observed without matter changing to a different substance.
- Chemical properties of matter can be measured or observed only when matter undergoes a change to become an entirely different substance.

Lesson Review Questions

Recall

1. Define matter.
2. How does mass differ from weight?
3. Describe the displacement method for measuring the volume of an object.
4. Identify two physical properties and two chemical properties of matter.

Apply Concepts

5. Create a table comparing and contrasting physical properties of tap water and table salt.
6. Apply the concept of density to explain why oil floats on water.

Think Critically

7. Some kinds of matter are attracted to a magnet. Is this a physical or chemical property of matter? How do you know?

Points to Consider

The physical and chemical properties of substances can be used to identify them. That's because different kinds of matter have different properties.

- What property could you use to tell the difference between iron and aluminum?

- How could you tell whether a liquid is honey or vinegar?

Vocabulary

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5. Diamond: Steve Jurvetson; Talc: Courtesy of the US Geological Survey and the Mineral Information Institute; Antifreeze: Flickr:dno1967; Water: José Manuel Suárez; Pot: Phil and Pam Gradwell (to be) (Flickr: Phil and Pam); Wire: Scott Ehardt; Sand: Jakub Michankow; Sugar: Robert Lopez and Steven Terrebonne. **Diamond:** <http://www.flickr.com/photos/jurvetson/156830367/>; **Talc:** http://commons.wikimedia.org/wiki/File:Talc_block.jpg; **Antifreeze:** <http://commons.wikimedia.org/wiki/File:Antifreeze.jpg>; **Water:** http://commons.wikimedia.org/wiki/File:Water_drop_001.jpg; **Pot:** <http://www.flickr.com/photos/philandpam/2131629044/>; **Wire:** http://commons.wikimedia.org/wiki/File:Stranded_lamp_wire.jpg; **Sand:** <http://www.flickr.com/photos/glowform/5859259137/>; **Sugar:** [CK-12 Foundation](#) . Diamond: CC BY 2.0; Talc: Public Domain; Antifreeze: CC BY 2.0; Water: CC BY 2.0; Pot: CC BY 2.0; Wire: Public Domain; Sand: CC BY 2.0; Sugar: CC BY-NC 3.0
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