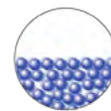


Chapter 2

Particles of Matter

THE MAIN IDEA



Matter is made of particles called atoms

- 2.1 [The Submicroscopic](#)
- 2.2 [Discovering the Atom](#)
- 2.3 [Mass and Volume](#)
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2.4 Density: Mass to Volume

The relationship between an object's mass and the amount of space it occupies is the object's density. **Density is a measure of compactness, of how tightly mass is squeezed into a given volume.** A block of lead has much more mass than does a same-sized block of aluminum. A reason for this is because each lead atom has more mass. The lead, having more mass per volume, is therefore more dense. We can think of density as the "lightness" or "heaviness" of objects of the same size, as **Figure 2.14** shows.

Density is the amount of mass contained in a sample divided by the volume of the sample:

$$\text{Density} = \text{Mass} / \text{Volume}$$

An object having a mass of 1 gram and a volume of 1 milliliter, for example, has a density of

$$\text{Density} = 1 \text{ g} / 1 \text{ mL} = 1 \text{ g/mL}$$

An object having a mass of 2 grams and a volume of 1 milliliter is denser; its density is

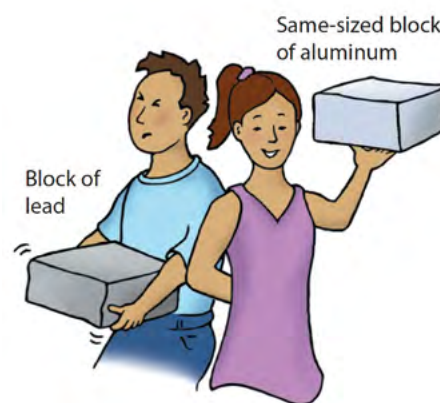
$$\text{Density} = 2 \text{ g} / 1 \text{ mL} = 2 \text{ g/mL}$$

Other units of mass and volume besides grams and milliliters may be used in calculating density. The densities of gases, for example, because they are so low, are often given in grams per liter. In all cases, however, the units are a unit of mass divided by a unit of volume.



READING CHECK

Density is a measure of what?



▲ Figure 2.14

The amount of mass in a block of lead far exceeds the amount of mass in a block of aluminum of the same size. Hence, the lead block weighs much more and is more difficult to lift.

TABLE 2.1 Densities of Some Solids, Liquids, and Gases

SUBSTANCE	DENSITY (G/ML)	DENSITY (G/L)
Solids		
osmium	22.5	22,500
gold	19.3	19,300
lead	11.3	11,300
copper	8.92	8920
iron	7.86	7860
zinc	7.14	7140
aluminum	2.70	2700
ice	0.92	920
Liquids		
mercury	13.6	13,600
seawater	1.03	1030
fresh water at 4°C	1.00	1000
ethyl alcohol	0.81	810
Gases*		
oxygen at 0°C	0.00143	1.43
dry air		
0°C	0.00129	1.29
20°C	0.00121	1.21
helium at 0°C	0.000178	0.178

*All values at sea-level atmospheric pressure.

The densities of some substances are given in **Table 2.1**. Which would be more difficult to pick up: a liter of water or a liter of mercury? Note how water has a density of 1.000 g/mL at 4°C. Why do we specify the temperature? As discussed in Section 2.6, the volume of a material changes with temperature. A change in temperature, therefore, can also result in a change in density, even though the mass of the object stays the same.

Gas densities are much more affected by temperature as well as pressure than are the densities of solids and liquids. With an increase in pressure, gas molecules are squeezed closer together. This makes for less volume (but

CONCEPT CHECK

Which occupies a greater volume: 1 kilogram of lead or 1 kilogram of aluminum?

CHECK YOUR ANSWER

The aluminum. Think of it this way. Because lead is so dense, you need only a little bit in order to have 1 kilogram. Aluminum, by contrast, is far less dense, so 1 kilogram of aluminum occupies much more volume than the same mass of lead.



< **Figure 2.15**

The hot air inside these hot air balloons is less dense than the surrounding colder air, which is why the balloons rise.

the same mass) and therefore greater density. The density of the air inside a diver's breathing tank, for example, is much greater than the density of air at normal atmospheric pressure. With an increase in temperature, gas molecules move faster and thus have a tendency to push outward, thereby occupying a greater volume. Thus, hot air is less dense than cold air, which is why hot air rises and the balloons in **Figure 2.15** can take passengers for breathtaking rides.

CONCEPT CHECK

1. Which has greater density: 1 gram of water or 10 grams of water?
2. Which has greater density: 1 gram of lead or 10 grams of aluminum?

CHECK YOUR ANSWER

1. The density is the same for any amount of water. Whereas 1 gram of water occupies a volume of 1 milliliter, 10 grams occupies a volume of 10 milliliters. The ratio 1 gram/1 milliliter is the same as the ratio 10 grams/10 milliliters.
2. The lead. Density is mass per volume, and this ratio is greater for any amount of lead than for any amount of aluminum.