Pearson

E.5: Density

An old riddle asks, "Which weighs more, a ton of bricks or a ton of feathers?" The answer, of course, is neither—they both weigh the same (1 ton). If you answered bricks, you confused weight with density. The **density (*d*)** of a substance is the ratio of its mass (m) to its volume (V):

$$\text{density} = \frac{\text{mass}}{\text{volume}} \quad \text{or} \quad d = \frac{m}{V}$$

Density is a characteristic physical property of a substance. The density of a substance also depends on its temperature. Density is an example of an **intensive property**, one that is *independent* of the amount of the substance. The density of aluminum, for example, is the same whether we have a gram or a kilogram. We can use intensive properties to identify substances because these properties depend only on the type of substance, not on the amount of it. For example, in Table E.4 we can see that pure gold has a density of 19.3 g/cm^3. One way to determine whether a substance is pure gold is to measure its density and compare it to 19.3 g/cm^3. Mass, in contrast, is an **extensive property**, one that depends on the amount of the substance. If we know only the mass of a sample of gold, that information alone will not allow us to identify it as gold.

Table E.4 The Density of Some Common Substances at 20 °C

Substance	Density (g/cm^3)
Charcoal (from oak)	0.57
Ethanol	0.789
Ice	0.917 (at 0 °C)
Water	1.00 (at 4 °C)
Sugar (sucrose)	1.58
Table salt (sodium chloride)	2.16
Glass	2.6
Aluminum	2.70
Titanium	4.51
Iron	7.86
Copper	8.96
Lead	11.4
Mercury	13.55
Gold	19.3
Platinum	21.4

The units of density are those of mass divided by volume. Although the SI-derived unit for density is kg/m^3, we most often express the density of liquids and solids in g/cm^3 or g/mL. (Remember that cm^3 and mL are equivalent units: $1\ \text{cm}^3 = 1\ \text{mL}$.) Aluminum is one of the least dense structural metals with a density of 2.7 g/cm^3, while platinum is one of the densest metals with a density of 21.4 g/cm^3.

We calculate the density of a substance by dividing the mass of a given amount of the substance by its volume. For example, suppose a small nugget we suspect to be gold has a mass of 22.5 g and a volume of $2.38\ \text{cm}^3$. To find its density, we divide the mass by the volume:

$$d = \frac{m}{V} = \frac{22.5\ \text{g}}{2.38\ \text{cm}^3} = 9.45\ \text{g/cm}^3$$

In this case, the density reveals that the nugget is not pure gold.

Example E.5 Calculating Density

A man receives a ring from his fiancée, who tells him that it is made out of platinum. Before the wedding, he notices that the ring feels a little light for its size and decides to measure its density. He places the ring on a balance and finds that it has a mass of 3.15 g. He then finds that the ring displaces $0.233\ \text{cm}^3$ of water. Is the ring made of platinum? Assume that the measurements occurred at 20 °C. (*Note*: The volume of irregularly shaped objects is often measured by the displacement of water. In this method, the object is placed in water, and the change in volume of the water is measured. The increase in the total volume represents the volume of water *displaced* by the object and is equal to the volume of the object.)

Set up the problem by writing the important information that is *given* as well as the information that you are asked to *find*. In this case, you are to find the density of the ring and compare it to that of platinum.

Note: This standardized way of setting up problems is discussed in detail in Section E.8.

GIVEN: $m = 3.15\ \text{g}$
$V = 0.233\ \text{cm}^3$

FIND: density in g/cm^3

Next, write down the equation that defines density.

EQUATION: $d = \frac{m}{V}$

Solve the problem by substituting the correct values of mass and volume into the expression for density.

SOLUTION $d = \frac{m}{V} = \frac{3.15\ \text{g}}{0.233\ \text{cm}^3} = 13.5\ \text{g/cm}^3$

The density of the ring is much too low to be platinum (platinum density is $21.4\ \text{g/cm}^3$). Therefore, the ring is a fake.

FOR PRACTICE E.5

The fiancée in Example E.5 is shocked that the ring is fake and returns it. She buys a new ring that has a volume of $0.212\ \text{cm}^3$. If the new ring is indeed pure platinum, what is its mass?

FOR MORE PRACTICE E.5

A metal cube has an edge length of 11.4 mm and a mass of 6.67 g. Calculate the density of the metal and refer to Table E.4 to determine the likely identity of the metal.

Conceptual Connection E.2 Density

Interactive