We define the density of a substance to be the mass of the substance divided by the volume the substance occupies.

\[
\text{Density} = \frac{\text{Mass}}{\text{Volume}}
\]

The density of an element or a compound is an physical property of the substance. Measurement of physical properties does not change the composition of the substance. If we measure a greater mass of the substance, we also find a greater volume; but the ratio of the mass to the volume remains constant. The density depends on the temperature, because changes in the temperature cause a change in the volume. In chemistry, the densities of solids and liquids normally are expressed in units of g/cm\(^3\), while gas densities are reported in g/L.

There are three terms in the density expression. If you know two of the terms, you can find the third. Another way of visualizing the density is to think of it as a conversion factor. For example, the density of copper (Cu) is 8.92 g/cm\(^3\), so we could write 1 cm\(^3\) Cu = 8.92 g Cu.

Finding the density from the mass and volume:

Obviously, you can find the density of a substance when you know the mass and the volume of that mass. The volume could be measured directly or by displacement of a liquid. For instance, 37.81 g of a metal is placed in a graduated cylinder containing 50. cm\(^3\) of water. After adding the metal the volume in the cylinder reads 54 cm\(^3\). What is the density of metal?

We know the mass of the metal. We do not know the volume of the metal, but the volume can be found from the difference in the levels of the liquid. The volume of the metal is 54 cm\(^3\) - 50. cm\(^3\) = 4 cm\(^3\). Thus, the density is 37.81 g/4 cm\(^3\) = 9.45 g/cm\(^3\).
Finding the mass from the density and volume

Sometimes we want to know the mass of a given volume of a liquid. We will consider examples of this in the chapter on amounts of substances in chemical reactions. Let’s determine the mass of 250. mL of toluene, which has a density of 0.8669 g/mL. By the way, 1 mL = 1 cm³.

Viewing this problem as a unit conversion problem is permissible because the mass and volume are proportional to each other. Our unknown is the mass and the known is the volume. The density is the conversion factor because it relates the mass and the volume of the substance.

\[ ? \text{ m (g)} = 250. \text{ mL} \times \frac{0.8669 \text{ g}}{1 \text{ mL}} = 217 \text{ g} \]

Finding the volume from the density and mass

Occasionally it is more convenient to measure the volume of a substance rather than its mass. What volume of acetone contains 8.00 g of acetone? The density of acetone is 0.792 g/cm³. Once again we can view this problem as a unit conversion. The desired quantity is the volume, and the given quantity is the mass. The conversion factor is obtained by inverting the density. We need to know the volume per mass, because we know that we have 8.00 g.

\[ ? \text{ V (cm}^3\text{)} = 8.00 \text{ g} \times \frac{1 \text{ cm}^3}{0.792 \text{ g}} = 10.2 \text{ cm}^3 \]
EXAMPLE A block of iron weighs 36.8 g and has a volume of 4.68 cm$^3$. What is the density of the iron block?

Density is defined as the mass per unit volume. The density is

$$\text{Density} = \frac{16.8 \text{ g}}{4.68 \text{ cm}^3} = 7.86 \text{ g/cm}^3$$
PROBLEM 1 The mass of 35.88 cm³ of nickel is 319 g at 25°C. What is the density of nickel?

A) 0.899 g/cm³  B) 8.90 g/cm³  C) 0.112 g/cm³  D) 7.24 g/cm³

PROBLEM 2 A plastic part weighing 5.618 g was added to a graduated cylinder containing 13.2 cm³ of water. After adding the part, the water level was at 19.2 cm³. Find the density of the part.

A) 0.270 g/cm³  B) 2.71 g/cm³  C) 1.26 g/cm³  D) 1.4 g/cm³

PROBLEM 3 A sample of a pure metal weighs 32.17 g and a volume of 4.42 cm³. This is a sample of which metal? The densities are in parenthesis.

A) Copper (8.92 g/cm³)  B) Tin (7.28 g/cm³)  C) Aluminum (2.70 g/cm³)  D) Lead (11.3 g/cm³)

PROBLEM 4 How many pounds of water would fill a 20.0 gal tank? The density of water is 8.34 lb/gal.

A) 167 lb  B) 240 lb  C) 41.7 lb  D) 129 lb

PROBLEM 5 How many lb of isooctane (a component of gasoline) occupies 15.0 gal? Density of isooctane = 0.6919 g/cm³. Other useful conversion factors:

1 lb = 453.6 g  1 L = 1000 cm³  1 gal = 3.784 L

A) 86.6 lb  B) 125 lb  C) 181 lb  D) 26.0 lb

PROBLEM 6 How many gal of water weigh 135 lb?

A) 1.23x10³ gal  B) 22.1 gal  C) 16.2 gal  D) 8.58 gal

PROBLEM 7 How many mL of water will supply 5.94 g of ethanol (or ethyl alcohol)? Density of ethanol = 0.7899 g/mL

A) 4.69 mL  B) 10.7 mL  C) 3.24 mL  D) 7.53 mL

PROBLEM 8 The dimensions of a water bed are 8 ft x 7 ft x 0.75 ft. If the bed were filled completely with water, how many pounds of water would be in the bed?

Density = 62.4 lb/ft³

A) 983 lb  B) 2.62x10³ lb  C) 237 lb  D) 896 lb

PROBLEM 9 What volume of mercury in cm³ contains 5.00 lb of mercury?

Density of mercury = 13.6 g/cm³. 1 lb = 453.6 g

A) 6.67 cm³  B) 3.08x10² cm³  C) 167 cm³  D) 33.8 cm³

PROBLEM 10 The specific gravity of acetone is 0.7899. What is the density of acetone in lbs/gal? Density of water = 8.34 lb/gal.

A) 4.69 mL  B) 10.7 mL  C) 3.24 mL  D) 7.53 mL