Volume and Density

Objective:

- Define density.
- Use physical measurements to calculate density.
- Use density values to calculate mass or volume.

How do logs stay afloat?

Density

Density

A golf ball and a table tennis ball are about the same size. However, the golf ball is much heavier than the table tennis ball. Now imagine a similar size ball made out of lead. That would be very heavy indeed! What are we comparing? By comparing the mass of an object relative to its size, we are studying a property called **density.** Density is the ratio of the mass of an object to its volume.

A golf ball and a table tennis ball are about the same size. Which is heavier?

What are we comparing when when say one is heavier than the other?

Density of an object is a ratio of the mass of the object to the volume of the object

$$\text{Density} = \frac{\text{mass}}{\text{volume}}$$

Density is an intensive property. This means that the amount of the sample does not matter when you figure density. A swimming pool has the same density as a glass of water. 1.0 g/ml

The SI units of density are kilograms per cubic meter (kg/m^3), since the kg and the m are the SI units for mass and length respectively. In everyday usage in a laboratory, this unit is awkwardly large. Most solids and liquids have densities that are conveniently expressed in grams per cubic centimeter (g/cm^3). Since a cubic centimeter is equal to a milliliter, density units can also be expressed as g/mL. Gases are much less dense than solids and liquids, so their densities are often reported in g/L. Densities of some common substances at 20°C are listed in the Table 2.4

TABLE 2.4: **Densities of Some Common Substances**

Liquids and Solids	Density at 20°C (g/ml)	Gases	Density at 20°C (g/L)
Ethanol	0.79	Hydrogen	0.084
Ice (0°C)	0.917	Helium	0.166
Corn oil	0.922	Air	1.20
Water	0.998	Oxygen	1.33
Water (4°C)	1.000	Carbon dioxide	1.83
Corn syrup	1.36	Radon	9.23
Aluminum	2.70		
Copper	8.92		
Lead	11.35		
Mercury	13.6		
Gold	19.3		

An 18.2 g sample of zinc metal has a volume of 2.55 cm^3. Calculate the density of zinc.

Step 1: List the known quantities and plan the problem.

Known

- mass = 18.2 g
- volume = 2.55 cm^3

Unknown

- density = ? g/cm^3

Use the equation for density, $D = \frac{m}{V}$, to solve the problem.

Step 2: Calculate

$$D = \frac{m}{V} = \frac{18.2\ \text{g}}{2.55\ \text{cm}^3} = 7.14\ \text{g/cm}^3$$

Step 3: Think about your result.

If 1 cm^3 of zinc has a mass of about 7 grams, then 2 and a half cm^3 will have a mass about 2 and a half times as great. Metals are expected to have a density greater than that of water and zinc's density falls within the range of the other metals listed above

1. What is the mass of 2.49 cm^3 of aluminum?
2. What is the volume of 50.0 g of aluminum?

Step 1: List the known quantities and plan the problem.

Known

- density = 2.70 g/cm^3
- 1. volume = 2.49 cm^3
- 2. mass = 50.0 g

Unknown

- 1. mass = ? g
- 2. volume = ? cm^3

Use the equation for density, $D = \frac{m}{V}$, and dimensional analysis to solve each problem.

Step 2: Calculate

1. $2.49 \text{ cm}^3 \times \frac{2.70 \text{ g}}{1 \text{ cm}^3} = 6.72 \text{ g}$
2. $50.0 \text{ g} \times \frac{1 \text{ cm}^3}{2.70 \text{ g}} = 18.5 \text{ cm}^3$

A BTU, or British Thermal Unit, is as basic measure of thermal (heat) energy. BTUs are often used in the United States to "rate the heat output of fuels and appliances" (see wisegeek for more information). Human beings also put out hear.

Eighty-seven middle school students danced their hearts out at the middle school dance last night, each producing an unprecedented 3,000 BTUs of heat while listening to the amazing music of One Direction, Taylor Swift and M.C. Hammer (M.C. Who?). The dance was held in the multi-purpose room which is 110 feet long, 80 feet wide, and 35 feet tall. To the nearest thousandth, how many BTUs per cubic foot did they produce?

We are given the BTUs produced by each student so our first step is to find the total amount of heat:

$3000\ BTUs \times 87 = 261,000\ BTUs$ This is the mass portion of our density equation.

Next we need to find the volume of the multi-purpose room:

$110\ ft \times 80\ ft \times 35\ ft = 308,000\ ft^3$ This is the volume, or the total cubic feet of the room.

To find the BTUs per cubic foot, or density, you divide mass by the volume:

$\frac{mass}{volume} = \frac{261000}{308000}$ or $0.847\ BTUs/ft^3$