Density

The density of a substance is the ratio of that substance's mass to its volume. The higher the density of a substance, the less space it takes to fill that space with some amount of the substance. For example, imagine you have 100 pounds of lead and 100 pounds of cotton balls. It would take a space with a much larger volume to accommodate 100 pounds of cotton balls than lead. This is because lead is much denser than cotton balls. To determine the density of a substance, divide the amount of that substance by the volume it takes to accommodate that amount. If you know the density, you can solve for the volume a certain mass will occupy or you can solve for the mass a certain volume will accommodate.

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}} \quad \text{or} \quad \text{Volume} = \frac{\text{Mass}}{\text{Density}} \quad \text{or} \quad \text{Mass} = \text{Volume} \times \text{Density}$$

Example 12: What is the density of 908 g of cadmium metal that occupies 105 mL?

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}} = \frac{908\ \text{g}}{105\ \text{mL}} = \mathbf{8.65\ g/mL}$$

The important thing is to first make sure you are dealing with the correct units before solving for density. Mass should be in grams, and volume should either be in mL or cm^3 since 1 mL = 1 cm^3. This means density should always be in g/mL or g/cm^3. You may have to do some basic unit converting first.

Example 13: What mass of Ne gas with a density of 0.00090 g/mL occupies a volume of 70 ounces?

Known relationships: 32 oz = 1 qt (quart), 1.0567 qt = 1 L, and 1 mL = 10^{-3} L (or 0.001 L)

$$70\ \text{oz} \times \frac{1\ \text{qt}}{32\ \text{oz}} \times \frac{1\ \text{L}}{1.0567\ \text{qt}} \times \frac{1\ \text{mL}}{10^{-3}\ \text{L}} = 2069.54\ \text{mL}$$

$$\text{Mass} = \text{Volume} \times \text{Density} = 2069.54\ \text{mL} \times 0.0009\ \text{g/mL} = \mathbf{2\ g\ Ne}$$

Sometimes density can be incorporated into other types of problems, for example, chemical quantity conversions. In Example 14, you must find the mass from the density and volume before the number of moles can be found.

Example 14: How many moles are there in a sample of titanium metal, density 4.54 g/mL, that can occupy a volume of 25.0 mL?

Known relationships: 1 mol = molar mass of Ti = 48 g

$$\text{Mass} = \text{Volume} \times \text{Density} = 4.54\ \text{g/mL} \times 25.0\ \text{mL} = 113.5\ \text{g}$$

$$113.5\ \text{g Ti} \times \frac{1\ \text{mol}}{48\ \text{g}} = \mathbf{2.36\ mol\ Ti}$$