2.3: Density, Proportion and Dimensional Analysis

In the previous section, we have learned about the states of matter. The physical state of a substance at under a defined set of conditions (like temperature and pressure) is an **intensive property** of a substance. An intensive property is defined as a property that is inherent to the substance and is not dependent on the sample size. **Density**, the mass-to-volume ratio of a substance, is another example of an intensive property.

If you picked up equal sized samples of aluminum and gold, you would immediately notice that one was much heavier than the other. The atomic mass of gold is over seven times greater than the atomic mass of aluminum, so although the two samples are the same size, the lump of gold is significantly more massive than the equally sized lump of aluminum. We can say that gold is more *dense* than aluminum.

Making this a quantitative measurement, one cubic centimeter of gold has a mass of 19.3 grams (remember that a cubic centimeter is the volume of a cube that is exactly one cm on each side, and it has the units of cm^3. We defined density as the mass-to-volume ratio of a substance. For gold, the mass is 19.3 grams and the volume is 1 cm^3. The mass-to-volume ratio of gold is and the density (*d*) of gold is written as d = 19.3 g/cm^3.

Returning to our block of aluminum;experimentally, one cubic centimeter of aluminum has a mass of 2.70 grams. The mass-to-volume ratio of aluminum is , and the density of aluminum is therefore 2.70 g/cm^3, about 7 times *less* than that of gold.

Density is a physical property that can be measured for all substances, solids, liquids and gasses. For solids and liquids, density is often reported using the units of g/cm^3. Densities of gasses, which are significantly lower than the densities of solids and liquids, are often given using units grams/liter (g/L, remembering from SI and Metric Units" data-cke-saved-href="/Bookshelves/Introductory_Chemistry/Book:_Introductory_Chemistry_Online_(Young)/01:_Measurements_and_Atomic_Structure/1.4:_SI_and_Metric_Units" href="/Bookshelves/Introductory_Chemistry/Book:_Introductory_Chemistry_Online_(Young)/01:_Measurements_and_Atomic_Structure/1.4:_SI_and_Metric_Units" data-quail-id="28">Section 1.4 that a liter is defined as 1000 cm^3).

The definition of density that we used previously was *the mass-to-volume ratio of a substance*. This is also stated as “mass *per* unit volume”. The word *per* in this context implies that a mathematical relationship exists between mass and volume. In this case, the relationship is the ratio of mass-to-volume. Whenever two factors can be related by a *ratio* or fraction we can use *unit analysis* to solve problems relating those factors. For density, the ratio is mass-to-volume. If a sample of iron has a mass of 23.4 grams and a volume of 3.00 cm^3, the density of iron can be calculated as:

$$d = \frac{mass}{volume}$$

$$d = \frac{23.4 g}{3.00 cm^3} = 7.80\ g/cm^3$$

In this calculation, our two experimental numbers are 23.4 and 3.00. Each of these numbers has *three significant figures* (remember, the trailing zeros in 3.00 are significant because the number has a decimal point). Our answer must therefore *also* be accurate to three significant figures, or 7.80.