7.4: Concentration and Molarity

As described in the previous section, sodium chloride is quite soluble in water. At 25 ˚C (about room temperature), 359 grams of sodium chloride will dissolve in one liter of water. If you were to add more sodium chloride to the solution, it would not dissolve, because a given volume of water can only dissolve, disperse and stabilize a fixed amount of solute (the stuff that dissolves). This amount is different for every compound and it depends on the structure of the particular compound and how that structure interacts with the solvation shell. When a substance is dissolved in water to the point that no more will go into solution, we say the solution is **saturated**. For most compounds, heating the solution will allow more of the substance to dissolve, hence it is important to note the temperature when you are speaking of the solubility of a particular compound.

If we had a saturated solution of sodium chloride at 25 ˚C, we could quote the concentration as 359 grams/L, but because we know the molar mass of sodium chloride (58.44 grams/mole), we could also express our concentration as:

$$\left(\frac{(359\ g) \times \frac{1\ mole}{58.44\ g}}{1\ L} \right) = 6.14\ moles/L$$

In chemistry, the units of moles/L are called **molarity**, with the abbreviation M. Thus we could say that our saturated solution of sodium chloride was **6.14 molar**, or **6.14 M**.

The advantage of expressing concentrations in terms of molarity is that these solutions can now be used in chemical reactions of known stoichiometry because any volume of the solution corresponds directly to a known number of moles of a particular compound. For example, the molar mass of potassium bromide is 119.0 g/mole. If we dissolved 119.0 grams of KBr in 1.000 L of water, the concentration would be 1.000 mole/L, or 1.000 M. If we now took half o this solution (0.500 L) we know that we would also have 0.500 moles of KBr.

We can determine the concentration of a solution using the problem-solving algorithm we introduced back in Chapter 1. For example, if you wan to find the molarity of a solution containing 42.8 grams of KBr in 1.00 L of water, you would identify the *given* and 42.8 g, your *ratio* is the molar mass (119 g/mole) and you want to *find* molarity (or moles/L). Remembering to set the equation up so that the units of *given* appear in the denominator of the *ratio*, the number of moles is:

$$42.8\ g) \times \left(\frac{1\ mole}{119\ g} \right) = 0.360\ moles$$

and, the molarity is:

$$\left(\frac{0.360\ mole}{1.00\ L} \right) = 0.360\ moles/L\ or\ 0.360\ M$$

When you become comfortable with the simple two-step method, you can combine steps and simply divide your given mass by the given volume to get the result directly. Thus, if you had 1.73 grams of KBr in 0.0230 L of water, your concentration would be:

$$\left(\frac{(1.73\ g) \times \frac{1\ mole}{119\ g}}{0.0230\ L} \right) = 6.32\ moles/L\ or\ 0.632\ M$$

We can also solve these problems *backwards*, that is, convert molarity into mass. For example; determine the number of grams of KBr that are present in 72.5 mL of a 1.05 M solution of KBr. Here we are given a volume of 0.0725 L and our ratio is the molarity, or (1.05 moles/L). We first solve for moles,

$$0.0725\ L \times \left(\frac{1.05\ mole}{1.00\ L} \right) = 0.0761\ moles$$

and then convert to mass using:

$$0.0761\ moles \times \left(\frac{119\ grams}{1\ mole} \right) = 9.06\ grams\ of\ KBr$$

Exercise 7.4.1

A sample of 12.7 grams of sodium sulfate (Na_2SO_4) is dissolved in 672 mL of distilled water.

a. What is the molar concentration of sodium sulfate in the solution?
b. What is the concentration of sodium ion in the solution?

Exercise 7.4.1

Calculate the mass of sodium chloride required to make 125.0 mL of a 0.470 M NaCl solution. If you dissolve 5.8g of NaCl in water and then dilute to a total of 100.0 mL, what will be the molar concentration of the resulting sodium chloride solution?
