7.6: Dilution of Concentrated Solutions

In the laboratory, a chemist will often prepare solutions of known concentration beginning with a standard stock solution. A stock solution is generally concentrated and, of course, the molar concentration of the solute must be known. To perform a reaction, a measured amount of this stock solution will be withdrawn and added to another reactant, or will be diluted into a larger volume for some other use. The calculations involved in these dilutions are trivial and simply involve calculating the number of moles transferred and dividing this by the final volume. For example, 15.0 mL of a stock solution of 1.00 M hydrochloric acid (HCl) is withdrawn and diluted into 75 mL of distilled water; what is the final concentration of hydrochloric acid?

First, the number of moles of HCl is calculated from the volume added and the concentration of the stock solution:

$$0.0150L \times \left(\frac{1.00\,moles}{1\,L}\right) = 0.0150\,moles\,HCl$$

We have diluted this number of moles into (15.0 + 75.0) = 90.0 mL, therefore the final concentration of HCl is given by:

$$\left(\frac{0.0150\,moles\,HCl}{0.0900\,L}\right) = (0.167\,moles\,HCl/L)\;or\;0.167\,M$$

An even simpler way to approach these problems is to multiply the initial concentration of the stock solution by the *ratio* of the aliquot (the amount withdrawn from the stock solution) to the final volume, using the equation below:

$$(stock\;concentration) \times \left(\frac{volume\;of\;the\;aliquot}{final\;volume}\right) = final\;concentration$$

Using this method on the previous problem,

$$(1.00\,M) \times \left(\frac{15.0\,ml}{90.0\,ml}\right) = 0.167\,M$$

Note that we did not have to convert our volumes (15.0 and 90.0 mL) into L when we use this approach because the units of volume cancel in the equation. If the units that are given for the aliquot and the final volume are different, a metric conversion ratio may be required. For example, 10.0 µL of a 1.76 M solution of HNO_3 (nitric acid) are diluted into 10.0 mL of distilled water; what is the final concentration of nitric acid?

In this problem, we need to convert µL and mL into a common unit. We can do this using the ratios,

$$\left(\frac{10^{-6}L}{1\mu L}\right)\;and\;\left(\frac{10^{-3}L}{1\,mL}\right)$$

We need to multiply each of our volumes by the appropriate factor to get our volumes in terms of liters, and then simply multiply by the initial concentration. Thus,

$$1.76\,M \times \left\{\frac{10.0\mu L\left(\frac{10^{-6}L}{1\mu L}\right)}{10.0\,mL\left(\frac{10^{-3}L}{1\,mL}\right)}\right\} = 1.76 \times 10^{-3}M$$

The final volume in this problem is actually (1.00×10^{-2} L) + (1.00×10^{-5} L) = 1.001×10^{-2} L, but because our calculation is only accurate to three significant figures, the volume of the aliquot is not significant and the final volume has been rounded.

The standard method we have used here can also be adapted to the type of problem in which you need to find the volume of a stock solution that must be diluted to a certain volume in order to produce a solution of a given concentration. For example, what volume of 0.029 M $CaCl_2$ must be diluted to exactly 0.500 L in order to give a solution that is 50.0 µM?

In order to solve this problem in the simplest of terms, we should re-examine the above equation:

$$(stock\;concentration) \times \left(\frac{volume\;of\;the\;aliquot}{final\;volume}\right) = final\;concentration$$

This equation can be re-written as:

$$\left(\frac{volume\ of\ the\ aliquot}{final\ volume}\right)=\left(\frac{final\ concentration}{stock\ concentration}\right)$$

Or

$$\left(\frac{V}{V_f}\right)=\left(\frac{C_f}{C_i}\right)$$

where C_i and C_f are the *stock* and *final* concentrations, respectively, V is the volume of the aliquot and V_f is the final volume of the solution. Stated another way, this is simply a set of ratios; *aliquot* to *final volume*, and *final concentration* to *initial concentration* (operationally, these ratios will always be "*small value/larger value*"). Working with this set of ratios, we can directly solve this type of problem as follows:

First, we need to convert our final concentration (50.0 μM) into M, to match the units of our stock solution. The metric multiplier for μ is 10^{-6}, making our final concentration 50.0×10^{-6} M, or more properly, 5.00×10^{-5} M. Our equation is therefore:

$$\left(\frac{V}{0.500L}\right)=\left(\frac{5.00\times10^{-5}M}{0.029M}\right)$$

$$V=\left(\frac{5.00\times10^{-5}M}{0.029M}\right)\times0.500L$$

The volume of the aliquot, V, is 8.62×10^{-4} L, or using the conversion factor

$$\left(\frac{10^3mL}{1L}\right)$$

the required volume is 0.86 mL (there are only two significant figures in the concentration of the stock solution, 0.029 M).

Dilution problems can be solved directly using the above equation, or, as you become more comfortable with the math, using the initial and final ratios like we did in this problem (remember, the numbers in the two ratios are "*smaller/larger*").

? Exercise 7.6.1

1. A 1.50 mL aliquot of a 0.177 M solution of sulfuric acid (H_2SO_4) is diluted into 10.0 mL of distilled water, to give solution **A**. A 10.0 mL aliquot of **A** is then diluted into 50.0 mL of distilled water, to give solution **B**. Finally, 10.0 mL of **B** is diluted into 900.0 mL of distilled water to give solution **C**. Additional distilled water is then added to **C** to give a final volume of 1.0000 L. What is the final concentration of sulfuric acid in solution **C**?
2. A solution was prepared by mixing 250 mL of 0.547 M NaOH with 50.0 mL of 1.62 M NaOH and then diluting to a final volume of 1.50 L. What is the molarity of Na^+ in this solution? To what final volume should 75.00 mL of 0.889 M HCl(aq) be diluted to prepare 0.800 M HCl(aq)?