

54: CHANGING THE CONCENTRATION OF A SOLUTION

Often, it will be necessary to change a solution of one concentration to a different concentration by either diluting or concentrating it. It is important for the scientist to come to a good understanding of dilution and concentration processes. It is also important to understand how to calculate the concentration after such a change is made.

Dilution

There are endless examples of real-life situations where the ability to calculate the effect of dilution on a solution's concentration is important. Laboratories are unique in that dilution calculations are not just part of life, they are a way of life. Figures 1 and 2 illustrate some of the best-known and most heavily used tools in the laboratory. These are tools used to carry out precise and accurate dilutions.

Not only are glassware tools needed to carry out a dilution properly, you need the appropriate mathematical tools as well. A useful equation for calculating the change of concentrations due to dilution is:

$$V_1 C_1 = V_2 C_2$$

That is, for a single solution that is diluted by adding additional solvent, the original volume (V_1) times the original concentration (C_1) is equal to the final volume (V_2) times the final concentration (C_2). For example, if 2 mL of a solution containing 250 mg/L of manganese sulfate

were diluted to 1 L, what would be the concentration of the dilute solution?

$$\begin{aligned} V_1 &= 2 \text{ mL} = 0.002 \text{ L} \\ C_1 &= 250 \text{ mg/L} \\ V_2 &= 1 \text{ L} \\ C_2 &= \text{unknown} \end{aligned}$$

Note that the units of volume and concentration must be the same on both sides of the equation to form an equality. If you are given V_1 in mL, be sure V_2 isn't in L, or your dilution will be off by a factor of 1,000! We calculate:

$$(0.002 \text{ L}) \left(\frac{250 \text{ mg}}{\text{L}} \right) = (1 \text{ L}) \left(\frac{C_2 \text{ mg}}{\text{L}} \right)$$

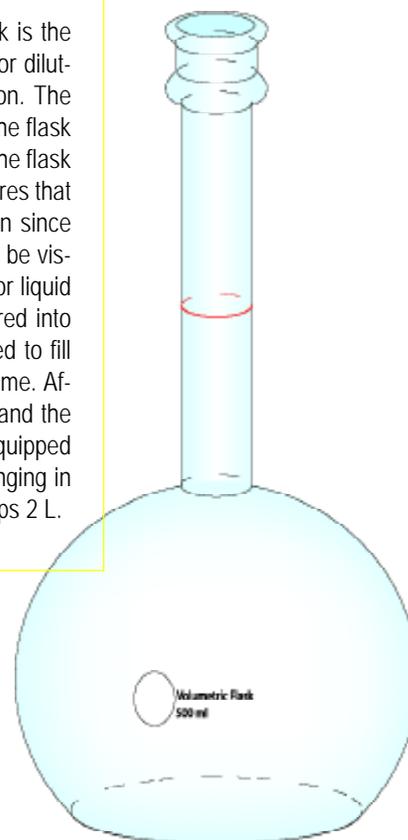
Now, since we assured ourselves that all of the units matched before we started, we can drop them out to make it simple to do the calculation:

$$\frac{0.002 \cdot 250}{1} = C_2$$

or:

$$C_2 \frac{\text{mg}}{\text{L}} = 0.5 \frac{\text{mg}}{\text{L}}$$

Figure 1. The volumetric flask is the main tool used in laboratories for diluting solutions with great precision. The red line etched on the neck of the flask marks the precise volume that the flask contains. The narrow neck assures that there is little error in the dilution since even small errors in volume will be visible. A precise amount of solid or liquid containing the solute is measured into the flask and the solvent is used to fill the flask to the appropriate volume. Afterward, the flask is stoppered and the solution is mixed well. A well-equipped laboratory will contain flasks ranging in volume from 10 mL up to perhaps 2 L.



More information on the subject of dilution is included in the Appendix, Method 4. There instruction is given on how to carry out and calculate serial 2-fold and 10-fold dilutions. Serial dilutions will not be covered in the next quiz. Your laboratory activities should give you plenty of experience.

Concentration

The formula above for calculating the concentration of a solution after diluting by adding more solvent also works for determining the new concentration after removing solvent by evaporation or distillation. In both cases the amount of solute stays the same while the amount of solvent changes. You might be asked to calculate the concentration of a solution after concentrating it from V_1 to V_2 , where V_2 is a smaller volume than V_1 . Use the same equation you just used. It doesn't matter that the volume is going down instead of up; the relationship between volume and concentration still holds.

Finally, you might need to know the amount of solute present in a solution of a given volume and concentration. The amount of solute present in any solution can be calculated at any point in time as follows:

$$S \text{ (mg)} = C \text{ (mg/L)} V \text{ (L)}$$

If you know the volume and the concentration, the amount of solute can be easily calculated, regardless of what you have done to it beforehand. For example, let's say we have a solution of 6.00 M sodium hydroxide and we want to know what weight of sodium hydroxide is present in 10.0 mL of this solution. We just do the math:

$$? \text{ mg NaOH} = \frac{6 \text{ mol}}{\text{L}} \left| \frac{10.0 \text{ mL}}{1,000 \text{ mL}} \right| \left| \frac{1 \text{ L}}{1,000 \text{ mL}} \right| \left| \frac{50.0 \text{ g}}{1 \text{ mol}} \right| \left| \frac{1000 \text{ mg}}{1 \text{ g}} \right| = 3.00 \times 10^3 \text{ mg NaOH}$$

Now let's prove ourselves by solving some problems.



Figure 2. If 1.00 mL of solution that is 2.50 M in methyl red is placed in the 500 mL volumetric flask and diluted to the mark, what is the resulting concentration of methyl red? In a real lab we might do this kind of calculation several times a day.

Exercises

- 1) Calculate the molarity of a solution prepared by diluting 100 mL of 12.0 M HCl with 350 mL of water. **Caution:** I said we *diluted it with* 350 mL of water. The final volume (V_2) is not 350 mL.
- 2) Calculate the molarity of a solution prepared by diluting 630 mL of 0.525 M $K_2Cr_2O_7$ with 1,000 mL of water.
- 3) What volume of 16.0 M H_2SO_4 should be used to prepare 500 mL of 0.50 M H_2SO_4 solution?
- 4) What is the concentration (mg/L) of 250. mL of a 525 mg/L solution of KCl that has evaporated to a volume of 150 mL?
- 5) What is the concentration of a solution that was 1.2 g/L in $Cu(NO_3)_2$ if it is diluted to a total volume of 1.00 L?
- 6) What is the mass of aluminum in 17.5 mL of a 30.0 M solution of aluminum hydroxide?