

## 11.4: Solution Preparation

Preparing a solution of known concentration is perhaps the most common activity in any analytical lab. The method for measuring out the solute and the solvent depend on the desired concentration and how exact the solution's concentration needs to be known. Pipets and volumetric flasks are used when we need to know a solution's exact concentration; graduated cylinders, beakers, and/or reagent bottles suffice when a concentrations need only be approximate. Two methods for preparing solutions are described in this section.

### Preparing Stock Solutions

A **stock solution** is prepared by weighing out an appropriate portion of a pure solid or by measuring out an appropriate volume of a pure liquid, placing it in a suitable flask, and diluting to a known volume. Exactly how one measure's the reagent depends on the desired concentration unit. For example, to prepare a solution with a known molarity you weigh out an appropriate mass of the reagent, dissolve it in a portion of solvent, and bring it to the desired volume. To prepare a solution where the solute's concentration is a volume percent, you measure out an appropriate volume of solute and add sufficient solvent to obtain the desired total volume.

#### ✓ Example 11.4.1

Describe how to prepare the following three solutions: (a) 500 mL of approximately 0.20 M NaOH using solid NaOH; (b) 1 L of 150.0 ppm  $\text{Cu}^{2+}$  using Cu metal; and (c) 2 L of 4% v/v acetic acid using concentrated glacial acetic acid (99.8% w/w acetic acid).

*Solution*

(a) Because the desired concentration is known to two significant figures, we do not need to measure precisely the mass of NaOH or the volume of solution. The desired mass of NaOH is

$$\frac{0.20 \text{ mol NaOH}}{\text{L}} \times \frac{40.0 \text{ g NaOH}}{\text{mol NaOH}} \times 0.50 \text{ L} = 4.0 \text{ g NaOH}$$

To prepare the solution, place 4.0 grams of NaOH, weighed to the nearest tenth of a gram, in a bottle or beaker and add approximately 500 mL of water.

(b) Since the desired concentration of  $\text{Cu}^{2+}$  is given to four significant figures, we must measure precisely the mass of Cu metal and the final solution volume. The desired mass of Cu metal is

$$\frac{150.0 \text{ mg Cu}}{\text{L}} \times 1.000 \text{ M} \times \frac{1 \text{ g}}{1000 \text{ mg}} = 0.1500 \text{ g Cu}$$

To prepare the solution, measure out exactly 0.1500 g of Cu into a small beaker and dissolve it using a small portion of concentrated  $\text{HNO}_3$ . To ensure a complete transfer of  $\text{Cu}^{2+}$  from the beaker to the volumetric flask—what we call a **quantitative transfer**—rinse the beaker several times with small portions of water, adding each rinse to the volumetric flask. Finally, add additional water to the volumetric flask's calibration mark.

(c) The concentration of this solution is only approximate so it is not necessary to measure exactly the volumes, nor is it necessary to account for the fact that glacial acetic acid is slightly less than 100% w/w acetic acid (it is approximately 99.8% w/w). The necessary volume of glacial acetic acid is

$$\frac{4 \text{ mL CH}_3\text{COOH}}{100 \text{ mL}} \times 2000 \text{ mL} = 80 \text{ mL CH}_3\text{COOH}$$

To prepare the solution, use a graduated cylinder to transfer 80 mL of glacial acetic acid to a container that holds approximately 2 L and add sufficient water to bring the solution to the desired volume.

#### ? Exercise 11.4.1

Provide instructions for preparing 500 mL of 0.1250 M  $\text{KBrO}_3$ .

**Answer**

Preparing 500 mL of 0.1250 M  $\text{KBrO}_3$  requires

$$0.5000 \text{ L} \times \frac{0.1250 \text{ mol KBrO}_3}{\text{L}} \times \frac{167.00 \text{ g KBrO}_3}{\text{mol KBrO}_3} = 10.44 \text{ g KBrO}_3$$

Because the concentration has four significant figures, we must prepare the solution using volumetric glassware. Place a 10.44 g sample of KBrO<sub>3</sub> in a 500-mL volumetric flask and fill part way with water. Swirl to dissolve the KBrO<sub>3</sub> and then dilute with water to the flask's calibration mark.

## Preparing Solutions by Dilution

Solutions are often prepared by diluting a more concentrated stock solution. A known volume of the stock solution is transferred to a new container and brought to a new volume. Since the total amount of solute is the same before and after dilution, we know that

$$C_o \times V_o = C_d \times V_d \quad (11.4.1)$$

where  $C_o$  is the stock solution's concentration,  $V_o$  is the volume of stock solution being diluted,  $C_d$  is the dilute solution's concentration, and  $V_d$  is the volume of the dilute solution. Again, the type of glassware used to measure  $V_o$  and  $V_d$  depends on how precisely we need to know the solution's concentration.

Note that Equation 11.4.1 applies only to those concentration units that are expressed in terms of the solution's volume, including molarity, formality, normality, volume percent, and weight-to-volume percent. It also applies to weight percent, parts per million, and parts per billion if the solution's density is 1.00 g/mL. We cannot use Equation 11.4.1 if we express concentration in terms of molality as this is based on the mass of solvent, not the volume of solution. See Rodríguez-López, M.; Carrasquillo, A. *J. Chem. Educ.* **2005**, 82, 1327-1328 for further discussion.

### ✓ Example 11.4.2

A laboratory procedure calls for 250 mL of an approximately 0.10 M solution of NH<sub>3</sub>. Describe how you would prepare this solution using a stock solution of concentrated NH<sub>3</sub> (14.8 M).

*Solution*

Substituting known volumes into Equation 11.4.1

$$14.8 \text{ M} \times V_o = 0.10 \text{ M} \times 250 \text{ mL}$$

and solving for  $V_o$  gives 1.7 mL. Since we are making a solution that is approximately 0.10 M NH<sub>3</sub>, we can use a graduated cylinder to measure the 1.7 mL of concentrated NH<sub>3</sub>, transfer the NH<sub>3</sub> to a beaker, and add sufficient water to give a total volume of approximately 250 mL.

Although usually we express molarity as mol/L, we can express the volumes in mL if we do so both for both  $V_o$  and  $V_d$ .

### ? Exercise 11.4.2

To prepare a standard solution of Zn<sup>2+</sup> you dissolve a 1.004 g sample of Zn wire in a minimal amount of HCl and dilute to volume in a 500-mL volumetric flask. If you dilute 2.000 mL of this stock solution to 250.0 mL, what is the concentration of Zn<sup>2+</sup>, in µg/mL, in your standard solution?

**Answer**

The first solution is a stock solution, which we then dilute to prepare the standard solution. The concentration of Zn<sup>2+</sup> in the stock solution is

$$\frac{1.004 \text{ g Zn}^{2+}}{500.0 \text{ mL}} \times \frac{10^6 \mu\text{g}}{\text{g}} = 2008 \mu\text{g Zn}^{2+}/\text{mL}$$

To find the concentration of the standard solution we use Equation 11.4.1

$$\frac{2008 \mu\text{g Zn}^{2+}}{\text{mL}} \times 2.000 \text{ mL} = C_d \times 250.0 \text{ mL}$$

where  $C_d$  is the standard solution's concentration. Solving gives a concentration of  $16.06 \mu\text{g Zn}^{2+}/\text{mL}$ .

As shown in the following example, we can use Equation 11.4.1 to calculate a solution's original concentration using its known concentration after dilution.

#### ✓ Example 11.4.3

A sample of an ore was analyzed for  $\text{Cu}^{2+}$  as follows. A 1.25 gram sample of the ore was dissolved in acid and diluted to volume in a 250-mL volumetric flask. A 20 mL portion of the resulting solution was transferred by pipet to a 50-mL volumetric flask and diluted to volume. An analysis of this solution gives the concentration of  $\text{Cu}^{2+}$  as  $4.62 \mu\text{g/mL}$ . What is the weight percent of Cu in the original ore?

*Solution*

Substituting known volumes (with significant figures appropriate for pipets and volumetric flasks) into Equation 11.4.1

$$(C_{\text{Cu}})_o \times 20.00 \text{ mL} = 4.62 \mu\text{g/mL Cu}^{2+} \times 50.00 \text{ mL}$$

and solving for  $(C_{\text{Cu}})_o$  gives the original concentration as  $11.55 \mu\text{g/mL Cu}^{2+}$ . To calculate the grams of  $\text{Cu}^{2+}$  we multiply this concentration by the total volume

$$\frac{11.55 \mu\text{g Cu}^{2+}}{\text{mL}} \times 250.0 \text{ mL} \times \frac{1 \text{ g}}{10^6 \mu\text{g}} = 2.888 \times 10^{-3} \text{ g Cu}^{2+}$$

The weight percent Cu is

$$\frac{2.888 \times 10^{-3} \text{ g Cu}^{2+}}{1.25 \text{ g sample}} \times 100 = 0.231\% \text{ w/w Cu}^{2+}$$

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