Preparing a solution of known concentration is perhaps the most common activity in any analytical lab. The method for measuring out the solute and solvent depend on the desired concentration unit and how exact the solution’s concentration needs to be known. Pipets and volumetric flasks are used when a solution’s concentration must be exact; graduated cylinders, beakers and reagent bottles suffice when 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 and diluting to a known volume. Exactly how this is done depends on the required concentration unit. For example, to prepare a solution with a desired molarity you weigh out an appropriate mass of the reagent, dissolve it in a portion of solvent, and bring 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 \(\PageIndex{1}\)

Describe how to prepare the following three solutions:

a. 500 mL of approximately 0.20 M \(\ce{NaOH}\) using solid \(\ce{NaOH}\)

b. 1 L of 150.0 ppm \(\ce{Cu^{2+}}\) using \(\ce{Cu}\) metal

c. 2 L of 4% v/v acetic acid using concentrated glacial acetic acid (99.8% w/w acetic acid)

**Solution**

a. Since the concentration is known to two significant figures the mass of \(\ce{NaOH}\) and the volume of solution do not need to be measured exactly. The desired mass of \(\ce{NaOH}\) is

\[
\text{mass of } \ce{NaOH} = \text{molarity} \times \text{volume} \times \text{molar mass of } \ce{NaOH}
\]

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

b. Since the concentration of \(\ce{Cu^{2+}}\) has four significant figures, the mass of \(\ce{Cu}\) metal and the final solution volume must be measured exactly. The desired mass of \(\ce{Cu}\) metal is

\[
\text{mass of } \ce{Cu} = \text{concentration} \times \text{volume} \times \text{molar mass of } \ce{Cu}
\]

To prepare the solution we measure out exactly 0.1500 g of \(\ce{Cu}\) into a small beaker and dissolve using small portion of concentrated \(\ce{HNO_3}\). The resulting solution is transferred into a 1-L volumetric flask. Rinse the beaker several times with small portions of water, adding each rinse to the volumetric flask. This process, which is called a quantitative transfer, ensures that the complete transfer of \(\ce{Cu^{2+}}\) to the volumetric flask. Finally, additional water is added to the volumetric flask’s calibration mark.

c. The concentration of this solution is only approximate so it is not necessary to measure the volumes exactly, 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 \(\PageIndex{1}\)

Provide instructions for preparing 500 mL of 0.1250 M \(\ce{KBrO_3}\).
Click here to review your answer to this exercise.

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

\[ C_\text{o} \times V_\text{o} = C_\text{d} \times V_\text{d} \]

where \(C_\text{o}\) is the stock solution’s concentration, \(V_\text{o}\) is the volume of stock solution being diluted, \(C_\text{d}\) is the dilute solution’s concentration, and \(V_\text{d}\) is the volume of the dilute solution. Again, the type of glassware used to measure \(V_\text{o}\) and \(V_\text{d}\) depends on how exact the solution’s concentration must be known.

Note

Equation \(\PageIndex{4}\) applies only when the concentration are written in terms of volume, as is the case with molarity. Using this equation with a mass-based concentration unit, such as % w/w, leads to an error. See Rodríguez-López, M.; Carrasquillo, A. J. Chem. Educ. 2005, 82, 1327-1328 for further discussion.

Exercise \(\PageIndex{2}\)

To prepare a standard solution of \(\ce{Zn^{2+}}\) you dissolve a 1.004 g sample of \(\ce{Zn}\) wire in a minimal amount of \(\ce{HCl}\) 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 \(\ce{Zn^{2+}}\), in μg/mL, in your standard solution?
Click here to review your answer to this exercise.

Example \(\PageIndex{2}\)

A laboratory procedure calls for 250 mL of an approximately 0.10 M solution of \(\ce{NH_3}\). Describe how you would prepare this solution using a stock solution of concentrated \(\ce{NH_3}\) (14.8 M).

\textbf{Solution}

Substituting known volumes in equation 2.2
and solving for $V_o$ gives $1.69 \times 10^{-3}$ liters, or 1.7 mL. Since we are making a solution that is approximately 0.10 M \(\ce{NH_3}\) we can use a graduated cylinder to measure the 1.7 mL of concentrated \(\ce{NH_3}\), transfer the \(\ce{NH_3}\) to a beaker, and add sufficient water to give a total volume of approximately 250 mL.

As shown in the following example, we can use Equation \(\PageIndex{4}\) to calculate a solution’s original concentration using its known concentration after dilution.

**Example \(\PageIndex{3}\)**

A sample of an ore was analyzed for \(\ce{Cu^{2+}}\) 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 gave the concentration of \(\ce{Cu^{2+}}\) as 4.62 μg/L. What is the weight percent of \(\ce{Cu}\) in the original ore?

**Solution**

Substituting known volumes (with significant figures appropriate for pipets and volumetric flasks) into Equation \(\PageIndex{4}\)

\[
( g/L \ce{Cu^{2+}})_o \times 20.00\ mL = 4.62\ g/L \ce{Cu^{2+}} \times 50.00\ mL
\]

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

\[
\dfrac{11.5\ \text{g Cu}^{2+}}{10^6\ \text{g}} \times 250.0\ mL = 2.88\ \text{g Cu}^{2+}
\]

The weight percent \(\ce{Cu}\) is

\[
\dfrac{2.88 \times 10^{-3}\ \text{g Cu}^{2+}}{1.25\ \text{g sample}} \times 100 = 0.231\% \text{ w/w Cu}^{2+}
\]

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