Solution Concentrations

A chemical reaction depends on the amounts of reactant(s) present in a solution. Therefore, it becomes necessary to know how much the reactant is present. This amount is measured in terms of solution concentration.

The ***solution concentration*** *is the amount of solute present in a fixed amount of solution or solvent.* The concentration of a solution can be expressed in various ways, but we consider here the most common method (unit) of expressing it. This is known as a ***molar concentration or simply known as molarity (M)****, which is defined as the number of moles of solute present in 1 liter (L) of solution,* the equation for which is,

$$\text{Molarity(M)} = \frac{\text{moles of solute(mol)}}{\text{volume of solution in liters(L)}}$$

Note that the unit of molarity is mol/L. This unit is also indicated by M (capital). Thus,

$$\text{M} \equiv \text{mol/L}$$

For example, a 2.5 molar sodium chloride (NaCl) solution is written as 2.5M NaCl, which means that 2.5 moles of solute (NaCl) are present in one liter (1 L) of solution.

To calculate the molarity, you need the moles of solute in the numerator and the volume of solution expressed in liters in the denominator. The ratio of these quantities yields the molarity of the solution. Note that the above equation contains three parameters, knowing any two the third one can be calculated.

Example

If 4.5 g of NaOH are dissolved in 250 ml solution, what is the molarity of the solution?

Answer

In order to calculate the molarity, you need moles of NaOH and the volume in liters. To calculate the moles, you need the molar mass of NaOH, which is 40 g/mol. The mol of NaOH is calculated as

$$\text{moles of NaOH} = 4.5\ \text{g} / 40\ (\text{g/mol}) = 0.112\ \text{mol NaOH}$$

The volume 250 ml is equal to 0 .250 L. Now substituting these values in the above equation yields the molarity of the solution.

$$\text{molarity(M)} = \frac{\text{moles of solute(mol)}}{\text{volume of solution in liters(L)}} = \frac{0.112\,\text{mol}}{0.250\,\text{L}} = 0.448\,\frac{\text{mol}}{\text{L}} = 0.448\,\text{M}$$

Therefore, the answer is 0.448 M.

Example

How many grams of potassium nitrate (KNO_3) are required to prepare a 50 ml solution whose concentration is 3.75 M?

Answer

First you calculate the moles of KNO_3 and then convert it to grams using the molar mass. To solve for moles of KNO_3, you need to convert the volume into liters (50 ml = 0.050 L), and substitute in the molarity equation.

$$\text{molarity}\,KNO_3 = \frac{\text{moles of}\,KNO_3}{\text{volume solution in liters}}$$

moles of KNO_3 = molarity of KNO_3 x volume of solution in liters
= 3.75 (mol/L) x 0.05 L = 0.187 mol

grams of KNO_3 = 0.187 mol x 101.110 g/mol = 18.906 g KNO_3

Example

How many mL of a 0.245 M KCl solution contains 6.25 g KCl?

Answer

First you need to get the moles of KCl from 6.25 g.

$$\text{mol}\,KCl = \frac{6.25\text{g}}{74.55(\text{g}/\text{mol})} = 0.0838\,\text{mol}\,KCl$$

Then the volume is calculated first in L and then converted into mL using the conversion, 1 L = 1000mL.

$$\text{volume(L)} = \frac{0.0838\,\text{mol}}{0.245(\text{mol}/\text{L})} = 0.342\,\text{L} = 342.19\,\text{mL}$$

Click on

Hands on Practice to Calculate Molarity

Dilution of Solutions

Most of the time, the concentrated solutions, especially acids and bases, are purchased and stored in the laboratory. As needed, these "stock" solutions are diluted to desired concentrations. Here, the technique of "dilution" is used. ***Dilution*** *is the procedure for preparing the less concentrated solution from a more concentrated solution using the water as a diluting agent.*

Suppose you brought an orange juice which is labeled as 10% juice. If your system cannot take this concentration, you usually dilute it with water. In fact, you are using the dilution technique. Let say for an argument that you are interested in diluting 10% juice to 5% juice. Now the question is how much water you need to add? In order to make 5% juice from 10% juice, you need to add equal amount of water. For example, if you have a glass (500 ml) of 10% juice, you add equal amount of water (500 ml) to make it 5% juice. When you added the water, the total volume will be two glasses (1000 mL). This can be put into a more general form as,

$$(\text{concentration} \times \text{volume})_{\text{initial}} = (\text{concentration} \times \text{volume})_{\text{final}}$$

$$10\% \times 500\ \text{ml} = 5\ \% \times \text{volume}_{\text{final}}$$

Therefore,

$$\text{volume}_{\text{final}} = 10\% \times 500\ \text{ml} / 5\% = 1000\ \text{mL}$$

1000 mL is not the amount of water added; rather it is the final volume of the diluted juice. To get the amount of water added, subtract the initial volume of the juice from the final volume of the juice.

$$\text{volume of water} = \text{volume}_{\text{final}} - \text{volume}_{\text{initial}}$$

$$\text{volume of water added} = 1000\ \text{mL} - 500\ \text{mL} = 500\ \text{mL}$$

In chemistry, the concentration is expressed in molarity not in %. Hence, the equation that applicable using the molarity is,

$$M_i \times V_i = M_f \times V_f$$

Where M_i is the initial molar concentration, V_i is the initial volume (in mL or L., it does not make any difference), M_f is the final molarity, and V_f is the final volume of the solution.

Example

A student wishes to make 750 mL of 2.5M HNO3 solution from 6M stock solution. How would she do it?

Answer

First, she needs to calculate the amount of 6M solution required.

$M_i = 6$ M $\qquad M_f = 2.5$ M

$V_i = ?$ $\qquad V_f = 750$ mL

Now, substituting the above values into $M_i \times V_i = M_f \times V_f$ yields,

$$6 \text{ M} \times V_i = 2.5 \text{ M} \times 750 \text{ mL}$$

Therefore,

$$V_i = (2.5 \text{ M} \times 750 \text{ mL}) / 6 \text{ M} = 312.5 \text{ mL}$$

$$\text{Amount of water} = V_f - V_i = 750 \text{ mL} - 312.5 \text{ mL} = 437.5 \text{ mL}$$

Therefore, she take 312.5 mL of 6 M HNO_3 solution and adds 437.5 mL of water to that to make 750 mL of 2.5 M HNO_3 solution.
