Introduction

A practical way to get soluble compounds to react is to put them in aqueous solution and mix the solutions. According to Arrhenius's ionic theory of solutions, soluble ionic compounds break into free-floating ions when dissolved in water. These free ions can react chemically to form precipitates and other new compounds. To know how much of an aqueous solution to use for one of these reactions, you need a good way to describe how much of the ionic compound is in the solution. In other words, you need a simple-to-use unit for **concentration**.

Molarity

Molarity, abbreviated M or M**,** is defined as the **number of moles solute** (the dissolved substance) per **liter of solution**. In other words, each liter of 1.0 M sodium chloride solution contains 1.0 moles of sodium chloride. In equation form,

$$\text{Molarity}\,(\underline{\text{M}}) = \frac{\text{moles solute}}{\text{liters solution}}$$

This unit makes it very easy to determine the moles of reagent in a particular volume of solution. You **don't even need to know the formula weight** of the reagent if the molarity is known.

Applications of molarity

This note pack provides examples of several common calculations involving molarity.

1. Calculating the moles of a reagent in a given volume of solution.
2. Calculating the volume of solution containing a given number of moles.
3. Preparation of a solution by dissolving a solid in a liquid.
4. Dilution of a solution where the amount of water to add is specified.
5. Preparation of a solution by diluting a more concentrated solution.

Calculating the moles of a reagent in a given volume of solution

In volumetric analysis (also called titration), you start with a solution of **known** concentration and react it with a solution of **unknown** concentration. You can then determine the concentration of the unknown solution by finding out how many moles of reagent was in the known solution.

You dispense 17.24 mL of 0.778 M NaOH. How many moles of NaOH were in the solution?

Since the molarity of a solution is the number of moles of the dissolved substance present in one liter of solution, **use molarity as a conversion factor** to convert from liters to moles.

0.778 mol NaOM = L

$$17.24\,\text{mL} \times \frac{10^{-3}\,\text{L}}{\text{mL}} \times \frac{0.778\,\text{mol NaOH}}{\text{L}} = \mathbf{0.0134\,mol\,NaOH}$$

17.24 mL of the solution contained **0.0134 moles of NaOH**. Since molarity is moles per **liter**, you had to convert the volume to liters (mL = 10^{-3} L) before using molarity.

Calculating the volume of solution containing a given number of moles.

Say you need to dispense **0.236 moles** of HCl to do an acid-base reaction. Pure HCl is a gas, and you normally find HCl in the laboratory dissolved in water. You want to know how much of this HCl solution to pour out to get 0.236 moles. Let's say we have a bottle of 4.00 M HCl.

So, *How many mL of 4.00 M HCl would you need to dispense to get 0.236 moles HCl?*

Use molarity as a conversion factor to convert moles HCl to volume of solution.

4.00 mol HCl = L

$$1.236\,\text{mol HCl} \times \frac{\text{L HCl solution}}{4.00\,\text{mol HCl}} = \mathbf{0.0590\,L\,HCl\,solution}$$

You need 0.0590 L or **59.0 mL of the 4.00 M HCl solution** to get 0.236 moles.

Preparation of a solution by dissolving a solid in a liquid

You may have to prepare solutions with certain concentrations for your reactions. If you need to prepare a given amount of solution by dissolving a solid in water, you must first calculate how much solid you need.

You need to *make 155 mL of a 2.00 M solution of the salt sodium chloride (NaCl, FW = 58.44 g/mol). How much sodium chloride do you need to weigh out?*

To do this, figure out **how many moles of NaCl are in 155 mL of 2.00 M solution**. This is a calculation to find out how many moles of NaCl are in a given amount of solution.

$$155\,\text{mL solution} \times \frac{10^{-3}\,\text{L}}{\text{mL}} \times \frac{2.00\,\text{mol NaCl}}{\text{L solution}} = 0.310\,\text{mol NaCl}$$

You need 0.310 moles NaCl. Convert this to grams to find out how much NaCl you need to weigh on a balance.. Use the formula weight of NaCl as a conversion factor.

$$0.310\ \text{mol NaCl} \times \frac{58.44\ \text{g NaCl}}{\text{mol NaCl}} = \mathbf{18.1\ g\ NaCl}$$

To make this solution, dissolve **18.1 g NaCl** in enough water to make 155 mL of solution.

<u>Dilution of a solution where the amount of water to add is specified</u>

Standard analysis procedures often involve preparing a solution by diluting with water. In these procedures, you are told how much water to add to a given amount of solution and you need to determine the concentration of the new solution. To determine the concentration of the new solution, you need to remember an important fact. **The number of moles of solute does not change when you dilute a solution**.

Put mathematically,

$$M \times V = \text{constant}$$

If M is the concentration (in molarity, moles per liter) and V is the volume of the solution in liters, then M times V equals the number of moles of solute in the solution. When you add water, the total amount of solute will not change. Only the **concentration** will decrease.

The **dilution equation** is based on this relationship.

$$M_1 \times V_1 = M_2 \times V_2$$

... where M_1 and V_1 are the molarity and volume of the undiluted solution, and M_2 and V_2 are the molarity and total volume of the diluted solution. The volume units cancel out, so you can use any volume units you choose - as long as you **use the same volume units for both V_1 and V_2**.. (In other words, you can use mL instead of L)

For example, *you are instructed to add 50.0 mL of water to 25.0 mL of 3.00 M KOH solution. What is the concentration of the new solution?*

Use the dilution equation. Remember that V_2 is the **total volume** of diluted solution , **not the amount of water added**.

Total volume: 50.0 mL + 25.0 mL = 75.0 mL

$$(3.00\,\underline{M}) \times (25.0\ \text{mL}) = M_2 \times (75.0\ \text{mL})$$

M_2 = **1.00 <u>M</u> KOH**

The concentration of the dilute solution is 1.00 M.

Preparation of a solution by diluting a more concentrated solution

Chemicals are often purchased as concentrated solutions because a small volume of solution is easy to transport than a large volume. In the lab, you dilute these solutions down to the concentration you want by adding water.

How do you prepare 155 mL of 2.00 M NaCl solution using 10.00 M NaCl solution and water?

You need to calculate the volume of 10.00 M NaCl needed. Since this is a dilution problem, use the dilution equation.

$$M_1 \times V_1 = M_2 \times V_2$$

Solve for V_1, the volume of undiluted solution.

$$(10.00\,\underline{\text{M}}\ \text{NaCl}) \times V_1 = (2.00\,\underline{\text{M}}\ \text{NaCl}) \times (155\,\text{mL})$$

V_1 = **31.0 mL of 10.00 M solution required**.

To make 155 mL of the 2.00 M solution from 10.00 M NaCl solution, take 31.0 mL of the 10.00 M solution and dilute it with water to 155 mL. This means you'll need to add about 124 mL of water.

Summary

After reading through this note pack, you should be familiar with the definition of **molarity** and basic calculations involving this unit. Molarity is a handy way to describe the concentration of liquid solutions. In your labs you will almost always see solution concentration expressed in this unit.