Solutions are homogeneous mixtures of solute and solvent. This definition says nothing about the physical state of a solution. While we commonly think of liquid solutions, solutions can just as easily be gases or solids.

- **Solvent** - the most abundant substance in a solution. In a liquid solution, the solvent does the dissolving.
- **Solute** - all other substances in a solution. In a liquid solution, the solute is dissolved.

It is possible for a solution to have more than one solute, air and sea water are two examples, but a solution can have only one solvent.

- **Solubility** - The amount of solute that can be dissolved in a given amount of solvent at a given temperature. Different substances have different solubilities. There are even Rules for determining the solubility of salts – which we will see later.

A solution whose solvent is water is an aqueous solution.

A solution whose solvent is alcohol is a tincture.

Metallic solutions are alloys.

Factors Affecting Solubility

"Like dissolves like":

- Polar substances dissolve in polar solvents
- Nonpolar substances dissolve in nonpolar solvents

Dissolving Ionic Compounds in Aqueous Solutions

- Electropositive hydrogen of the water molecule is attracted to negatively charged ions
- Electronegative oxygen of the water molecule is attracted to positively charged ions
- Hydration - The solution process with water as the solvent

Nonpolar Solvents

- Polar and ionic compounds are not soluble in nonpolar solvents
- Fats, oils and many petroleum products are soluble in nonpolar solvents
- Nonpolar solvents include CCl₄ and toluene (methyl benzene), C₆H₅CH₃

Liquid Solutes and Solvents

- Immiscible - Liquid solutes and solvents that are not soluble in each other
  - Oil and water
• Miscible - Liquids that dissolve freely in one another in any proportion
  o Benzene and carbon tetrachloride (both nonpolar)
  o Water and ethanol (both polar)

**Solute s: Electrolytes vs. Nonelectrolytes**

• **Electrolyte**
  o A substance that dissolves in water to give a solution that conducts electric current
  o Solutions of acids, bases and salts are electrolytes

• **Nonelectrolyte**
  o A substance that dissolves in water to give a solution that does not conduct an electric current

• **Measuring Conductivity – Types of solutions:**

  ![Electrolytes:](image)

  - **strong electrolytes**
    - completely dissociate into ions
    - solutions strongly conduct electricity
  - **weak electrolytes**
    - incompletely dissociate into ions
    - solutions weakly conduct electricity
  - **nonelectrolytes**
    - no dissociation
    - solutions don’t conduct electricity

**Effects of Pressure on Solubility**

• Pressure has no real effect on the solubilities of liquids and solids in liquid solvents
• Increasing pressure increases the solubility of gases in liquids
Effects of Temperature on Solubility

- Solubility of solids (generally) increases with temperature
- Solubility of gases decreases with temperature

Solubility Rules

1. All common compounds of Group I and ammonium ions are soluble.
2. All nitrates, acetates, and chlorates are soluble.
3. All binary compounds of the halogens (other than F) with metals are soluble, except those of Ag, Hg(I), and Pb. Note that Pb halides are soluble in hot water.
4. All sulfates are soluble, except those of barium, strontium, calcium, lead, silver, and mercury (I). The latter three are slightly soluble.
5. Except for rule 1, carbonates, hydroxides, oxides, silicates, and phosphates are insoluble.
6. Sulfides are insoluble except for calcium, barium, strontium, magnesium, sodium, potassium, and ammonium.

A saturated solution contains the maximum amount of solute that can be dissolved in a given amount of solvent at a given temperature.

Preparing a saturated salt solution:

Sodium chloride has a solubility of 35.7 grams in 100 cm³ of COLD water. That would be 357 grams of NaCl in one liter of H₂O.

- Weigh out 357 grams of NaCl.
- Add the salt to a 1 liter volumetric flask.
- Add H₂O at room temperature to the graduation line and stir until dissolved.
- You now have "saturated" salt water.
  - What is the volume of the solution?
How many moles of NaCl are in the sample?
How many particles of sodium chloride are in this sample?
How many sodium ions, \( \text{Na}^+ \), are in this sample?

**Concentration** is a comparison of the amounts of solute and solvent.

Describing a solution as "strong" or "weak" gives some comparison of the amounts of solute and solvent, but it is only a general idea. Even the terms "dilute" and "concentrated" do not give enough information to make quantitative calculations. To be able to compare solutions quantitatively, "how much" solute and solvent must be known.

The most common units of solution concentration involves **moles**.

**Molarity (M)** = moles of solute per cubic decimeter (dm\(^3\)) of solution.

Remember the following:

- Volume refers to the volume of the total solution, not just the volume of the solvent.
- One cubic decimeter (dm\(^3\)) = 1000 cm\(^3\) = 1 liter = 1000 ml

**Molarity Calculation Examples:**

The dimensional analysis solution is shown for three sample problems.

Study how each problem is solved, understanding each step in the conversion process. When you understand the solution process, use your calculator to find the answer with the proper number of significant digits.

**Note:** In the first two examples, the problem gives a mass of solute in a volume of solution. This may be written as "mass over volume", the form needed for molarity.

Two fractions are needed: one to convert mass to moles and one to convert volume units to dm\(^3\).

1. What is the molarity of a liter of solution containing 100 g of copper (II) chloride?

   \[
   \begin{array}{ccc}
   100 \text{ g CuCl}_2 & 1 \text{ mole CuCl}_2 & 1 \text{ liter} \\
   1 \text{ liter} & 134.5 \text{ g CuCl}_2 & 1 \text{ dm}^3 \\
   \end{array}
   \]

2. Calculate the molarity of a solution containing 25 g AgNO\(_3\) in 100 ml of solution.

   \[
   \begin{array}{ccc}
   25 \text{ g AgNO}_3 & 1 \text{ mole AgNO}_3 & 1000 \text{ ml} \\
   100 \text{ ml} & 170 \text{ g AgNO}_3 & 1 \text{ dm}^3 \\
   \end{array}
   \]

**Note:** Problem #3 is different.

It asks "how do you prepare?" a certain volume of solution with a certain molar concentration. Even though it asks a different question, it is still a problem that converts units, therefore it is worked with dimensional analysis.

As in any dimensional analysis problem, the first step is to write down what is given in the problem. Look closely at how the given information is written to begin dimensional analysis.
3. How much NaCl is needed to prepare 250 ml of 0.5 M salt water?

The key difference in the two types of molarity problems is that one asks for a concentration and the other provides a concentration.

You must decide which type of problem you have so you can set it up correctly!

Many chemicals are stored as “stock solutions”. A stock solution is one whose concentration is known exactly. Notice the information on the label in the drawing.

Making Dilutions:

Stock solutions can be made less concentrated by dilution with solvent.

The number of moles of solute does not change when more solvent is added to the solution.

If a solution is diluted from volume 1 \((V_1)\) to volume 2 \((V_2)\), the molarity \((M)\) of that solution changes according to the equation:

\[
M_1 V_1 = M_2 V_2
\]

Moles in original solution 1 = moles in diluted solution 2

The volume units must be the same for both volumes in this equation.

Dilution calculation example: How do you prepare 100 ml of 0.40 M MgSO\(_4\) from a stock solution of 2.0 M MgSO\(_4\)?

There are two solutions involved in this problem. Notice that you are given two concentrations, but only one volume.

- Solution #1 is the one for which you have only concentration - the solution that is already sitting on the shelf.
- Solution #2 is the one for which you have both concentration and volume - the solution that you are going to prepare.

At least until you are comfortable with this type of problem, it may be helpful to write out what numbers go with what letters in the equation before beginning.

\[
M_1 = 2.0 \text{ M MgSO}_4 \quad V_1 = \text{unknown}
\]

\[
M_2 = 0.40 \text{ M MgSO}_4 \quad V_2 = 100 \text{ ml}
\]

To solve the problem, do the following:
Write the equation: \( M_1 V_1 = M_2 V_2 \)

Manipulate the equation: \( V_1 = \frac{M_2 V_2}{M_1} \)

Put numbers into the equation: \( V_1 = \frac{(0.40 \text{M})(100 \text{ ml})}{2.0 \text{ M}} \)

Do the calculation: \( V_1 = 20 \text{ ml} \)

Describe preparing the solution as follows: Add 80 ml of distilled water to 20 ml of the 0.40 M MgSO\(_4\) solution.

**mass percent** = the percent of a solution's total mass that is solute.

Many commercial solutions are labeled with mass percent. This solution concentration compares the mass of the solute to the total mass of the solution.

Example:

A bottle of bleach contains 25 grams of sodium hypochlorite (bleach) in 100 grams of water. What is the mass percent of bleach in the solution?

\[
\frac{25 \text{ g bleach}}{125 \text{ g total mass}} = \frac{20}{100} = 20\% \text{ bleach}
\]

**volume percent** = the percent of a solution's total volume that is solute.

Many commercial solutions are also labeled with volume percent. This solution concentration compares the volume of the solute to the total volume of the solution.

Example:

A bottle of rubbing alcohol contains 150 mL of isopropyl alcohol (rubbing alcohol) in 200 mL of solution. What is the volume percent of isopropyl alcohol in the solution?

\[
\frac{150 \text{ mL isopropyl alcohol}}{200 \text{ mL solution}} \times 100\% = 75\% \text{ isopropyl alcohol}
\]

**Sorta Solutions**

**Suspensions** - A mixture from which particles settle out upon standing

- Colloids
  - Colloidal Dispersions (Colloids)
    1. Tiny particles suspended in some medium
  - Tyndall Effect
    1. Scattering of light by particles
      a. Light passes through a solution
      b. Light is scattered in a colloid
Volatility

- Nonvolatile substances
  - Substances that have little or no tendency to become a gas under existing conditions

- Volatile substances
  - Substances with a definite tendency to become gases under existing conditions

Effect of Solutes on Vapor-Pressure

- Any nonvolatile solute will lower the vapor pressure of a solution, having two noticeable effects
  - Raising the boiling point of the solution
  - Lowering the freezing point of the solution

Osmosis

Osmosis is the process where solvent molecules move through a semipermeable membrane from a dilute solution into a more concentrated solution (which becomes more dilute).

Osmotic pressure is the pressure applied to the solution that stops the process of osmosis. Osmotic pressure is a colligative property of a substance since it depends on the concentration of the solute and not its chemical nature.

Osmosis - Blood Cells

The Effect of Osmotic Pressure on Red Blood Cells

The effect of osmotic pressure on red blood cells is shown. From left to right, the effect is depicted of a hypertonic, isotonic and hypotonic solution on red blood cells.
**Hypertonic Solution or Hypertonicity**

When the osmotic pressure of the solution outside the blood cells is higher than the osmotic pressure inside the red blood cells, the solution is hypertonic. The water inside the blood cells exits the cells in an attempt to equalize the osmotic pressure, causing the cells to shrink.

**Isotonic Solution or Isotonicity**

When the osmotic pressure outside the red blood cells is the same as the pressure inside the cells, the solution is isotonic with respect to the cytoplasm. This is the usual condition of red blood cells in plasma. The cells are normal.

**Hypotonic Solution or Hypotonicity**

When the solution outside of the red blood cells has a lower osmotic pressure than the cytoplasm of the red blood cells, the solution is hypotonic with respect to the cells. The cells take in water in an attempt to equalize the osmotic pressure, causing them to swell and potentially burst.