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Thermodynamic and solution Chemistry Support

CHAPTER I :Concentration

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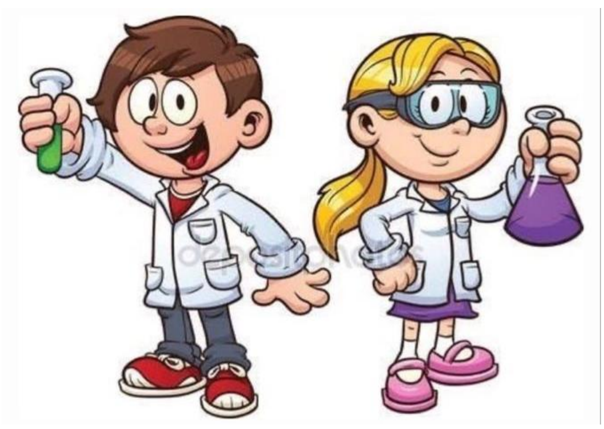

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I. Introduction:

To describe the concentrations of solutions quantitatively

Many people have a qualitative idea of what is meant by concentration. Anyone who has made instant coffee or lemonade knows that too much powder gives a strongly flavored, highly concentrated drink, whereas too little results in a dilute solution that may be hard to distinguish from water. In chemistry, the concentration of a solution is the quantity of **a solute** that is contained in a particular quantity of **solvent** or solution. Knowing the concentration of solutes is important in controlling the stoichiometry of reactants for solution reactions. Chemists use many different methods to define concentrations, some of which are described in this section.

In chemistry, the word "concentration" relates to the components of a mixture or solution. Here is the definition of concentration and a look at different methods used to calculate it.

II. Concentration Definition

In chemistry, **concentration** refers to the amount of a substance in a defined space. Another definition is that concentration is the ratio of solute in a solution to either solvent or total solution. Concentration is usually expressed in terms of mass per unit volume. However, the solute concentration may also be expressed in moles or units of volume. Instead of volume, concentration may be per unit mass. While usually applied to chemical solutions, concentration may be calculated for any mixture.

Unit Examples of Concentration: g/cm^3, kg/l, M, m, N, kg/L

I.1 How to Calculate Concentration

Concentration is determined mathematically by taking the mass, moles, or volume of solute and dividing it by the mass, moles, or volume of solution (or, less commonly, the solvent). Some examples of concentration units and formulas include:

I.2 Molarity

The most common unit of concentration is molarity, which is also the most useful for calculations involving the stoichiometry of reactions in solution. The molarity (M) is defined as the number of moles of solute present in exactly 1 L of solution. It is, equivalently, the number of millimoles of solute present in exactly 1 mL of solution:

Molarity =moles of solute liters of solution =mmoles of solute milliliters of solution

The units of molarity are therefore moles per liter of solution (mol/L), abbreviated as M. An aqueous solution that contains 1 mol (342 g) of sucrose in enough water to give a final volume of 1.00 L has a sucrose concentration of 1.00 mol/L or 1.00 M. In chemical notation, square brackets around the name or formula of the solute represent the molar concentration of a solute. Therefore, [sucrose]=1.00M is read as “the concentration of sucrose is 1.00 molar.”

Molarity (M) - moles of solute/liters of solution (not solvent!)

- **Mass Concentration (kg/m^3 or g/L)** - mass of solute/volume of solution
- **Normality (N)** - grams active solute/liters of solution
- **Molality (m)** - moles of solute/mass of solvent (not mass of solution!)
- **Mass Percent (%)** - mass solute/mass solution x 100% (mass units are the same unit for both solute and solution)
- **Volume Concentration (no unit)** - volume of solute/volume of mixture (same units of volume for each)
- **Number Concentration (1/m^3)** - number of entities (atoms, molecules, etc.) of a component divided by the total volume of the mixture
- **Volume Percent (v/v%)** - volume solute/volume solution x 100% (solute and solution volumes are in the same units)
- **Mole Fraction (mol/mol)** - moles of solute/total moles of species in the mixture
- **Mole Ratio (mol/mol)** - moles of solute/total moles of all *other* species in the mixture
- **Mass Fraction (kg/kg or parts per)** - mass of one fraction (could be multiple solutes)/total mass of the mixture
- **Mass Ratio (kg/kg or parts per)** - mass of solute/mass of all *other* constituents in the mixture
- **PPM (parts per million)** - a 100 ppm solution is 0.01%. The "parts per" notation, while still in use, has largely been replaced by mole fraction
- **PPB (parts per billion)** - typically used to express contamination of dilute solutions

Some units may be converted from one to another. However, it's not always a good idea to convert between units based on the volume of solution to those based on mass of solution (or vice versa) because volume is affected by temperature.

I.3 Strict Definition of Concentration

In the strictest sense, not all means of expressing the composition of a solution or mixture fall under the simple term "concentration". Some sources *only* consider mass concentration, molar concentration, number concentration, and volume concentration to be true units of concentration.

I.4 Concentration Versus Dilution

Two related terms are *concentrated* and *dilute*. Concentrated refers to chemical solutions that have high concentrations of a large amount of solute in the solution. If a solution is concentrated to the point where no more solute will dissolve in the solvent, it is said to be *saturated*. Dilute solutions contain a small amount of solute compared with the amount of solvent.

In order to concentrate a solution, either more solute particles must be added or some solvent must be removed. If the solvent is nonvolatile, a solution may be concentrated by evaporating or boiling off solvent.

Dilutions are made by adding solvent to a more concentrated solution. It's common practice to prepare a relatively concentrated solution, called a stock solution, and use it to prepare more dilute solutions. This practice results in better precision than simply mixing up a dilute solution because it can be difficult to obtain an accurate measurement of a tiny amount of solute. Serial dilutions are used to prepare extremely dilute solutions. To prepare a dilution, stock solution is added to a volumetric flask and then diluted with solvent to the mark.

I.5 1. Concentration in Parts Per Million (ppm)

The parts of a component per million parts (10^6) of the solution.

$$ppm(A)=Mass\ of\ ATotal\ mass\ of\ the\ solution\times106$$

I.6 2. Mass Percentage (w/w):

When the concentration is expressed as the percent of one component in the solution by mass it is called mass percentage (w/w). Suppose we have a solution containing component A as the solute and B as the solvent, then its mass percentage is expressed as:

Mass % of A =

$$\frac{Mass\ of\ component\ A\ in\ the\ solution}{Total\ mass\ of\ the\ solution} \times 100$$

I.7 3. Volume Percentage (V/V):

Sometimes we express the concentration as a percent of one component in the solution by volume, it is then called as volume percentage and is given as:

volume % of A =

$$\frac{Volume\ of\ component\ A\ in\ the\ solution}{Total\ volume\ of\ the\ solution} \times 100$$

For example, if a solution of NaCl in water is said to be 10 % by volume that means a 100 ml solution will contain 10 ml NaCl.

I.8 4. Mass by Volume Percentage (w/V):

This unit is majorly used in the pharmaceutical industry. It is defined as the mass of a solute dissolved per 100mL of the solution.

% w/V = (Mass of component A in the solution/ Total Volume of the Solution)x 100

I.9 5. Molarity (M):

One of the most commonly used methods for expressing the concentrations is molarity. It is the number of moles of solute dissolved in one litre of a solution. Suppose a solution of ethanol is marked 0.25 M, this means that in one litre of the given solution 0.25 moles of ethanol is dissolved.

Molarity (M) = Moles of Solute/Volume of Solution in litres

I.106. Molality (m):

Molality represents the concentration regarding moles of solute and the mass of solvent. It is given by moles of solute dissolved per kg of the solvent. The molality formula is as given-

$$Molality(m)=Moles\ of\ soluteMass\ of\ solvent\ in\ kg$$

I.117. Normality

It is the number of gram equivalents of solute present in one litre of the solution and it is denoted by N.

$$N=Weight\ of\ solute\ in\ gramsEquivalent\ mass\times Volume\ in\ liter$$

The relation between normality and molarity.

- N x Eq.Wt = Molarity x Molar mass
- N = Molarity x Valency
- N = Molarity x Number of H^+ or OH^- ion.

I.128. Formality

It is the number of gram formula units present in one litre of solution. It is denoted by F.

$$F=Weight\ of\ solute\ in\ gramFormula\ wt\times Volume\ in\ liter$$

It is applicable in the case of ionic solids like NaCl.

I.139. Mole Fraction:

If the solution has a solvent and the solute, a mole fraction gives a concentration as the ratio of moles of one component to the total moles present in the solution. It is denoted by x.

Suppose we have a solution containing A as a solute and B as the solvent. Let n_A and n_B be the number of moles of A and B present in the solution respectively. So, mole fractions of A and B are given as:

$$xA=nAnA+nB$$

$$xB=nBnA+nB$$

The above-mentioned methods are commonly used ways of expressing the concentration of solutions. All the methods describe the same thing that is, the concentration of a solution, each of them has its own advantages and disadvantages. Molarity depends on temperature while mole fraction and molality are independent of temperature. All these methods are used on the basis of the requirement of expressing the concentrations.