SHREE H. N. SHUKLACOLLEGE OF SCIENCE

(AFFILIATED TO SAURASHTRA UNIVERSITY)

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F.Y.B.SC.(SEM-1) (CBCS)

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BIOCHEMISTRY(101)

PHYSICAL AND CHEMICAL ASPECTS OF BIOCHEMISTRY

UNIT :5 SOLUTIONS

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" Sky is the Limit"

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• Solution

What is a Solution?

- A solution is a homogeneous mixture of two or more components in which the particle size is smaller than 1 nm.
- Common examples of solutions are sugar in water and salt in water solutions, soda water, etc. In a solution, all the components appear as a single phase. There is particle homogeneity i.e. particles are evenly distributed. This is why a whole bottle of soft drink has the same taste throughout.

Characteristics of Solution

Solutions have two components; one is solvent and the other is solute.

1. What is a Solvent?

The component that dissolves the other component is called the solvent.

2. What is Solute?

The component(s) that is/are dissolved in the solvent is/are called solute(s).

Generally solvent is present in major proportion compared to the solute. The amount of solute is lesser than the solvent. The solute and solvent can be in any state of matter i.e. solid, liquid or gas.

Solutions that are in the liquid state consist of a solid, liquid or gas dissolved in a liquid solvent. Alloys and air are examples of solid and gaseous solutions, respectively.

What Is Normality?

- **Normality** in Chemistry is one of the expressions used to measure the concentration of a solution.
- It is abbreviated as 'N' and is sometimes referred to as the equivalent concentration of a solution. It is mainly used as a measure of reactive species in a solution and during titration reactions or particularly in situations involving acid-base chemistry.

As per the standard definition, normality is described as the number of gram or mole equivalents of solute present in one litter of a solution.

Normality Formula

- Normality = Number of gram equivalents × [Volume of solution in litres]$^{-1}$
- Number of gram equivalents = Weight of solute × [Equivalent weight of solute]$^{-1}$
- N = Weight of Solute (gram) × [Equivalent weight × Volume (L)]
- N = Molarity × Molar mass × [Equivalent mass]$^{-1}$
- N = Molarity × Basicity = Molarity × Acidity

Uses of Normality

Normality is used mostly in three common situations.

- In determining the concentrations in acid-base chemistry. For instance, normality is used to indicate hydronium ions (H^3O^+) or hydroxide ions (OH^-) concentrations in a solution.
- Normality is used in precipitation reactions to measure the number of ions which are likely to precipitate in a specific reaction.
- It is used in redox reactions to determine the number of electrons that a reducing or an oxidising agent can donate or accept.

Limitations in Using Normality

Many chemists use normality in acid-base Chemistry to avoid the mole ratios in the calculations or simply to get more accurate results. While normality is commonly used in precipitation and redox reactions, there are some limitations to it. These limitations are as follows:

- It is not a proper unit of concentration in situations apart from the ones that are mentioned above. It is an ambiguous measure, and molarity or molality are better options for units.
- Normality requires a defined equivalence factor.
- It is not a specified value for a particular chemical solution. The value can significantly change depending on the chemical reaction. To elucidate further, one solution can actually contain different normalities for different reactions.

Normality Problems and Examples

Question 1. In the following reaction, calculate and find the normality when it is 1.0 M H_3PO_4

$H_3AsO_4 + 2NaOH \rightarrow Na_2HAsO_4 + 2H_2O$

Solution:

If we look at the given reaction, we can identify that only two of the H^+ ions of H_3AsO_4 react with NaOH to form the product. Therefore, the two ions are 2 equivalents. In order to find the normality, we will apply the given formula.

N = Molarity (M) × Number of equivalents

N = 1.0 × 2 (replacing the values)

Therefore, the normality of the solution = 2.0

Molar solution

- **Definition:** Molarity of a given solution is defined as the total number of moles of solute per litre of solution. The molality of a solution is dependent on the changes in physical properties of the system such as pressure and temperature as unlike mass, the volume of the system changes with the change in physical conditions of the system. Molarity is represented by M, which is termed as molar. One molar is the molarity of a solution where one gram of solute is dissolved in a litre of solution. As we know, in a solution, the solvent and solute blend to form a solution, hence, the total volume of the solution is taken.
- **Molarity Formula:**
- The equation for calculating molarity is the ratio of the moles of solute whose molarity is to be calculated and the volume of solvent used to dissolve the given solute.
- M=n/v
- Here,
- M is the molality of the solution that is to be calculated
- n is the number of moles of the solute
- V is the volume of solution given in terms of liters.
- **Example 1**
- A solution prepared using 15 g of sodium sulphate. The volume of the solution is 125 ml. Calculate the molarity of the given solution of sodium sulphate.
- **Solution:**
- The molecular formula for sodium sulphate is Na_2SO_4.
- The molecular formula for water is H_2O.
- The molecular mass of sodium sulphate is calculated as given below,
- M=23×2+32+16×4=142
- The number of moles of sodium sulphate in the given question is calculated as,

Mass in gram /molecure weight

=15/142

=0.106

The volume of the solution is 125 ml.

Expressing the above values in terms of litres,

Volume =125/1000
=0.125

Now, using the formula given above, we calculate the molarity of the given solution.

Molarity=number of moles of solute /volume of solution

=0.106/0.125

=0.85M

The molarity of the given solution is 0.85M.

Molal solution

Molality is one of the important properties of solutions. It is used to express the concentration of a solute in a solution and mostly depends on the mass of the solvent. Molality is also referred to as molal concentration. It is usually denoted by the letter "m".

The concept of molality was basically framed as a relation to molarity which is described as the molar concentration of a solution.

Molality Definition and Formula

Molality (m) is defined as the number of moles of solute per kilogram of solvent. The formula for molality is given as,

Molality (m) = moles of solute/kilograms of solvent

SI Unit of Molality

The SI unit of molality is moles per kilogram (mol/kg). For example, a solution whose molality is given as 6 mol/kg is stated as 6 molal or 6 m.

Advantages and Disadvantages of Using Molality

The advantage of using molality as a measure of concentration is that molality, as mentioned above, is solely dependent on the mass of the solute and the solvent. It means that these factors are not affected by changes in temperature or even pressure, as in the case of solutions prepared volumetrically. Secondly, it is quite useful because, in a solution, the molality of one solute is independent of the existence of other solutes.

Molality Examples

Question: Calculate the molality of a solution where 0.5 grams of toluene (C_7H_8) is dissolved in 225 grams of Benzene (C_6H_6).

Solution:

Calculate the moles of the given solute.

Toluene – Molecular weight

C_7H_8=7.12.+1.8 =92

Using the formula:

Moles of toluene=mass in grams /molecular weight

=0.054 m

So, the mole of toluene is 0.054 mole.

Now, calculate the kilogram of solvent.

225 grams of benzene /1000

=0.225 kg

As the final step, calculate the molality using the formula.

Molality (m) =moles of toluene/mass of benzene in gram

=0.054 /0.225 =0.24 m

Percentage

In mathematics, a **percentage** is a number or ratio that can be expressed as a fraction of 100. If we have to calculate percent of a number, divide the number by the whole and multiply by 100.

Hence, the **percentage means,** a part per hundred. The word per cent means **per 100**. It is represented by the symbol **"%"**.

Percentage Formula

To determine the percentage, we have to divide the value by the total value and then multiply the resultant by 100.

Percentage formula = (Value/Total value) × 100

Example: 2/5 × 100 = 0.4 × 100 = 40 per cent

How to calculate the percentage of a number?

To calculate the percentage of a number, we need to use a different formula such as:

P% of Number = X

where X is the required percentage.

If we remove the % sign, then we need to express the above formulas as;

P/100 * Number = X

Example: Calculate 10% of 80.

Let 10% of 80 = X

10/100 * 80 = X

X = 8

Stock solution and working solution

What is stock solution?

Stock solutions can best be described as concentrated solutions of known, accurate concentrations that will be diluted for future laboratory use.

While you may choose not to prepare stock solutions, doing so can help streamline your operation and save you a lot of time and resources in the process.

- How do you find stock solutions?
- **Stock Solution Dilutions**

1. $C_1 \times V_1 = C_2 \times V_2$
2. C_1 = stock concentration (beginning concentration)
3. V_1 = volume of stock required to prepare new solution.
4. C_2= concentration of new or working solution (desired concentration)
5. V_2= volume of new solution desired.

Solved Examples

Example 1

A chemist needs 1.5M hydrochloric acid for a reaction. The solution available is 6M of HCl. What is the volume of 6M HCl to be diluted to obtain 5L of 1.5M HCl?

Solution

Initial concentration of HCl is 6M

Final concentration of HCl is 1.5M

Final volume of solution is 5L

The initial volume needs to be found.

Substituting the values, we get

Vi = 1.5 x 5.0 / 6

= 1.3 L

Working solution

- Working Solution is a name given to a chemical solution made for actual use in the lab, usually made from diluting or combining stock or standard solutions.
- What is the difference between stock and working solution?
  We define a stock solution as a concentrate, that is, a solution to be diluted to some lower concentration for actual use. We may use just the stock solution or use it as a component in a more complex solution. We refer to the solution that we end up using as a working solution.20-May-2005

Preparation of w/v solution(weight per volume (W/V)

<u>% w/v solution</u>

Percent of weight of solution in the total volume of solution. Percent here is the number of grams of solute in 100 mL of solution.

Example: A 4% (W/V) NaCl solution is 4 g of NaCl in 100 mL of solution.

weight per volume: used where a solid chemical is dissolved in a liquid (e.g. if I dissolve 10 g of table salt, sodium chloride, to make up a total volume of 100 mL of a solution then I have made a 10% w/v solution of sodium chloride)

%v/v solution

If the percent concentration of a material in solution is expressed as 'v/v', this is known as the volume concentration of the solute in solution. This expression is commonly used when the solute is measured by volume before being added to the solution.

volume per volume: used where both chemicals are liquids (e.g. if I dilute 50 mL of acetic acid by adding it to 50 mL of water there is now 50 mL of acetic acid in a total volume of 100 mL, hence the acetic acid concentration is now 50% v/v

Dilution solution

Definition of Dilution. **Dilution** is the process of reducing the concentration of a solute in **solution**, usually simply by mixing with more solvent.

Example 1: You can add water to concentrated orange juice to **dilute** it until it reaches a concentration that is pleasant to drink.

Tap water is an **example** of a **dilute solution**; it contains very small quantities of dissolved minerals. A concentrated **solution** contains a relatively large amount of the solute in the same volume of solvent. ... For **example**, commercial hydrochloric acid (HCl) and sulfuric acid (H_2SO_4) are concentrated **solutions**

Concept of density and specific gravity

Density

What Is Density?

The density of material shows the denseness of that material in a specific given area. A material's density is defined as its mass per unit volume. Density is essentially a measurement of how tightly matter is packed together. It is a unique physical property of a particular object

The principle of density was discovered by the Greek scientist Archimedes. It is easy to calculate density if you know the formula and understand the related units The symbol ρ represents density or it can also be represented by the D.

$$Density=mass/volume$$

Unit of Density

- Though the SI unit of density is kg/m^3, for convenience we use g/cm^3 for solids, g/ml for liquids, and g/L for gases.
- Density can be explained as the relationship between the mass of the substance and the volume it takes up.
- In a qualitative term, it shows how much heavy an object is at constant volume.
- Different substances have different densities, which means for the same volume of different substances weigh differently.

Applications of Density

- The knowledge of the densities of two substances helps you in separation techniques. For example, the separation of oil from water. If there is a leakage of an oil tank in the ocean then oil drops start to float on the water due to less density than the water.
- Another well-known application of density is determining whether an object will float on water or not. The floating of ships and diving of submarines are due to their density difference.

Solved Examples

Question 1:

Take two boxes that have the same volume. Fill the first box with x balls and the second box with 6x balls. If the mass of each ball is the same, which box would weigh more?

Solution:

The box that has more balls has more mass per unit of volume.

Here the first box contains x number of balls and the second box contains a 6x number of balls. Since the number of balls in the second box is 6 times the first box, the second box would weigh more. This property of matter is called density.

Question 2:

Calculate the density of water if it has a mass of 1160 Kg and a volume of 1 m^3?

Solution:

Given,

Mass = 1160 Kg

Volume = 1 m^3

Density is given by the formula:

Density = Mass/Volume

$\rho = 1160/1 = 1160\ kg/m^3$

Specific gravity

What is the principle of specific gravity?

Specific gravity (also known as "relative density") is the ratio between the weight of a stone in the air and the weight of an equal volume in water.

By convention, the temperature of the water is 4° C and at standard atmosphere because the density of water is greatest under these conditions.

The relative density of a solid or liquid, usually when measured at a temperature of 20°C, compared with the maximum density of water (at 4°C).

For example, the specific gravity of carbon steel is 7.8, that of lead is 11.34, and that of pure gold is 19.32.

2 Types of Specific Gravity of Aggregate (Bulk Specific Gravity & Absolute Specific Gravity) Specific gravity of aggregate is much more important for concrete mix design, though it gives an idea of the quality of aggregates.

In general, specific gravity is the mass of material by the mass of an equal volume of water.