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 litre of a solution. When we say equivalent, it is the number of moles of reactive units in a compound.

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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

Normality is often denoted by the letter N. Some of the other units of normality are also expressed as eq L^{-1} or meq L^{-1}. The latter is often used in medical reporting.

How to Calculate Normality?

There are certain tips that students can follow to calculate normality.

1. The first tip that students can follow is to gather information about the equivalent weight of the reacting substance or the solute. Look up the textbook or reference books to learn about the molecular weight and the valence.
2. The second step involves calculating the no. of gram equivalent of solute.
3. Students should remember that the volume is to be calculated in litres.
4. Finally, normality is calculated using the formula and replacing the values.

Calculation of Normality in Titration

Titration is the process of gradual addition of a solution of a known concentration and volume with another solution of unknown concentration until the reaction approaches its neutralization. To find the normality of the acid and base titration:

$N_1 V_1 = N_2 V_2$

Where,

- N_1 = Normality of the Acidic solution
- V_1 = Volume of the Acidic solution
- N_2 = Normality of the basic solution
- V_3 = Volume of the basic solution

Normality Equations

The equation of normality that helps to estimate the volume of a solution required to prepare a solution of different normality is given by,

Initial Normality (N_1) × Initial Volume (V_1) = Normality of the Final Solution (N_2) × Final Volume (V_2)

Suppose four different solutions with the same solute of normality and volume are mixed; therefore, the resultant normality is given by;

$N_R = [N_aV_a + N_bV_b + N_cV_c + N_dV_d] \times [V_a+V_b+V_c+V_d]^{-1}$

If four solutions having different solute of molarity, volume and H^+ ions (n_a, n_b, n_c, n_d) are mixed then the resultant normality is given by;

$N_R = [n_aM_aV_a + n_bM_bV_b + n_cM_cV_c + n_dM_dV_d] \times [V_a+V_b+V_c+V_d]^{-1}$.

Relation Between Normality and Molarity

Normality and molarity are two important and commonly used expressions in chemistry. They are used to indicate the quantitative measurement of a substance. But what relation does molarity have with normality? We will understand the relationship between the two below.

Like normality, it is a unit of concentration in chemistry. Molarity is defined as the number of moles of solute per litre of solution. It is also known as molar concentration. Molarity is often used in the calculation of pH i.e. dissociation or equilibrium constants, etc.

The formula of molarity is given as:

⇒ Molarity (M) = No. of moles of solute × $[\text{volume of the solution in litres}]^{-1}$

Nonetheless, they are related as follows:

Now if we talk about the relation, normality contains molarity. While molarity is the first step in calculating the total volume or concentration of solutions, normality is used for more advanced calculations mainly in establishing a one-to-one relationship between acids and bases:

⇒ Normality = [Molarity × Molar mass] × $[\text{Equivalent mass}]^{-1}$

However, in this case, we have to find the basicity as well. Students can count the number of H^+ ions present in the acid molecule which it can donate. The following formula can be used to find the normality of bases:

⇒ Normality = Molarity × Basicity

Acidity can be determined by counting the number of OH^{-1} ions that a base molecule can donate. To calculate the normality for acids we can make use of the following formula:

⇒ Normality = Molarity × Acidity

We can also convert molarity to normality by applying the following equation.

⇒ N = M × number of equivalents

Differences Between Normality and Molarity

Here are some key differences between normality and molarity.

Normality	Molarity
Also known as equivalent concentration.	Known as molar concentration.
It is defined as the number of gram equivalent per litre of solution.	It is defined as the number of moles per litre of solution.
It is used in measuring the gram equivalent in relation to the total volume of the solution.	It is used in measuring the ratio between the number of moles in the total volume of the solution.
The units of normality are N or eq L^{-1}	The unit of molarity is M or Moles L^{-1}

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 oxidizing 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 used commonly 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, normality of the solution = 2.0.

Question 2. Calculate the normality of the solution obtained by dissolving 0.321 g of the salt sodium carbonate (Na_2CO_3) in 250 mL water. (Assuming the salt solution is being used in a complete neutralization by a strong acid.)

Solution:
Given: 0.321 g Na_2CO_3 (molar mass =106 g/mol) in 250 mL or 0.25 L solution.
Now, Na_2CO_3 forms a basic salt solution and can participate is neutralization reaction as follows:
$Na_2CO_3 + 2H^+$(from acid) $\rightarrow H_2CO_3 + 2Na^+$
Now, normality is defined as the number of equivalents per litre of solution. OR. normality= no. of equivalents/Volume(in Litre)
We know that number of equivalents is, Number of moles x n-factor.
Also, the n-factor for bases is defined as the number of OH- released per molecule (for Arrhenius type bases) OR it is the number of H+ accepted per molecule (for Lowry Bronsted type bases). Here, Na_2CO_3 is a Lowry Bronsted base with n-factor 2. (refer to the first reaction)
Now,
Number of moles, n = Mass/molar mass = 0.321/ (106) = 0.003
Number of equivalents = n x n-factor = 0.003 x 2 = 0.006
Hence, normality = No. of equivalents/ V (in litre) = 0.006/0.25 = 0.024 N
Question 3. What is the normality of the following?

- **0.1381 M NaOH**
- **0.0521 M H_3PO_4**

Solution:

a. N = 0.1381 mol/L × (1 eq/1mol) = 0.1381 eq/L = 0.1381 N

b. N = 0.0521 mol/L × (3 eq/1mol) = 0.156 eq/L = 0.156 N

Question 4. What will the concentration of citric acid be if 25.00 ml of the citric acid solution is titrated with 28.12 mL of 0.1718 N KOH?

Solution:

$N_a \times V_a = N_b \times V_b$

Na × (25.00 mL) = (0.1718N) (28.12 mL)

Therefore, the concentration of citric acid = 0.1932 N.

Question 5. Find the normality of the base if 31.87 mL of the base is used in the standardization of 0.4258 g of KHP (eq. wt = 204.23)?

Solution:

0.4258 g KHP × (1 eq/204.23g) × (1 eq base/1eq acid):

= 2.085×10^{-3} eq base/0.03187 L = 0.6542 N

Normality of the base is = 0.6542 N.

Question 6. Calculate the normality of acid if 21.18 mL is used to titrate 0.1369 g Na2CO3?

Solution:

0.1369 g Na_2CO_3 × (1 mol/105.99 g) × (2 eq/1 mol) × (1 eq acid/1 eq base):

= 2.583×10^{-3} eq acid/0.02118 L = 0.1212 N

Normality of the acid = 0.1212 N.