Methods of Expressing analytical concentrations:

- **Normality,**
- **Formality.**

Formality: is a substance's total concentration in solution without regard to its specific chemical form. There is no difference between a substance's molarity and formality if it dissolves without dissociating into ions. The molar concentration of a solution of glucose, for example, is the same as its formality.

Molarity: The number of moles of solute per liter of solution (M).

Formality: The number of moles of solute, regardless of chemical form, per liter of solution (F).

So is formality the same as molarity? *Sometimes yes*.

Formality does not take into account **what happens to a chemical compound once it's dissolved**. That is, it won't matter if the compound is an electrolyte or a non-electrolyte.
If you dissolve sodium chloride, NaCl, in water, you know that it dissociates completely and exists as ions in solution

$$NaCl_{(aq)} \rightarrow Na^+_{(aq)} + Cl^-_{(aq)}$$

So if you dissolve **one mole** of NaCl in **one liter** of water, you will have

$$F = \frac{\text{moles of solute}}{\text{liters of solution}}$$

$$F = \frac{\text{1 mole NaCl}}{\text{1 L}} = \text{1 formal}$$

The molarity of this solution, on the other hand, is said to be 1 molar in sodium cations and 1 molar in chloride anions, **not** 1 molar in sodium chloride.
And here's the difference between formality and molarity.
Molarity actually takes into account what happens to the solute once it's dissolved. Formality does not.

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Name	Units	Symbol
molarity	$\frac{\text{moles solute}}{\text{liters solution}}$	M
formality	$\frac{\text{moles solute}}{\text{liters solution}}$	F
normality	$\frac{\text{equivalents solute}}{\text{liters solution}}$	N
molality	$\frac{\text{moles solute}}{\text{kilograms solvent}}$	m
weight percent	$\frac{\text{grams solute}}{\text{100 grams solution}}$	% w/w
volume percent	$\frac{\text{mL solute}}{\text{100 mL solution}}$	% v/v

Normality

The normality 'N' of a solution is, given by the number of equivalents of solute per liter of solution:

$$N = \frac{Gram\ eq.of\ Solute}{Volume\ of\ sol.in\ litre} = \frac{Weight}{Equivalent\ weight} \times \frac{1000}{V\ ml}$$

$$\text{Equivalent Weight} = \frac{Molar\ Mass}{n}$$

The number of **equivalents,** *n*, is based on a reaction unit, which is that part of a chemical species involved in a reaction (Is the amount of a substance that reacts with (or is equivalent to) an arbitrary amount of another substance in a given chemical reaction.)

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- By this definition, an equivalent is the number of moles of an ion in a solution, multiplied by the valence of that ion. If 1 mol of NaCl and 1 mol of CaCl2 dissolve in a solution, there is 1 equiv Na, 2 equiv Ca, and 3 equiv Cl in that solution. (The valency of calcium is 2, so for that ion 1 mole is 2 equivalents.)
- Valency is defined as the combining capacity of atoms or molecules. It is obtained from the number of electrons present in the outermost shell of an atom.

In a precipitation reaction, for example, the reaction unit is the charge of the cation or anion involved in the reaction; thus for the reaction

$$Pb^{2+}(aq) + 2I^{-}(aq) \rightleftharpoons PbI_2(s)$$

$n = 2$ for Pb^{2+} and $n = 1$ for I^-.

In an acid–base reaction, the reaction unit is the number of H^+ ions donated by an acid or accepted by a base. For the reaction between sulfuric acid and ammonia

$$H_2SO_4(aq) + 2NH_3(aq) \rightleftharpoons 2NH_4^{+}(aq) + SO_4^{2-}(aq)$$

It was found that $n = 2$ for H_2SO_4 and $n = 1$ for NH_3. For a complexation reaction, the reaction unit is the number of electron pairs that can be accepted by the metal or donated by the ligand.

In the reaction between Ag^+ and NH_3 ,

$$Ag^{+}(aq) + 2NH_3(aq) \rightleftharpoons Ag(NH_3)_2^{+}(aq)$$

The value of n for Ag^+ is 2 and that for NH_3 is 1. Finally, in an oxidation–reduction reaction the reaction unit is the number of electrons released by the reducing agent or accepted by the oxidizing agent; thus, for the reaction

$$2Fe^{3+}(aq) + Sn^{2+}(aq) \rightleftharpoons Sn^{4+}(aq) + 2Fe^{2+}(aq)$$

$n = 1$ for Fe3+ and $n = 2$ for Sn2+. Clearly, determining the number of equivalents for a chemical species requires an understanding of how it reacts.

Normality is the number of **equivalent weights** (EW) per unit volume and, like formality, is independent of speciation. An equivalent weight is defined as the ratio of a chemical species' **formula weight** (FW) to the number of its equivalents

$$EW = \frac{FW}{n}$$

Consequently, the following simple relationship exists between normality and molarity.

$$N = n \times M$$

Example 2.1 illustrates the relationship among chemical reactivity, equivalent weight, and normality. .FW for H_3PO_4 [H=1*3, P=30.97, O=15.99*4] = 97.9

EXAMPLE 2.1

Calculate the equivalent weight and normality for a solution of 6.0 M H_3PO_4 given the following reactions:

(a) $H_3PO_4(aq) + 3OH^-(aq) \rightleftharpoons PO_4^{3-}(aq) + 3H_2O(\ell)$

(b) $H_3PO_4(aq) + 2NH_3(aq) \rightleftharpoons HPO_4^{2-}(aq) + 2NH_4^+(aq)$

(c) $H_3PO_4(aq) + F^-(aq) \rightleftharpoons H_2PO_4^-(aq) + HF(aq)$

SOLUTION

For phosphoric acid, the number of equivalents is the number of H^+ ions donated to the base. For the reactions in (a), (b), and (c) the number of equivalents are 3, 2, and 1, respectively. Thus, the calculated equivalent weights and normalities are

(a) $EW = \frac{FW}{n} = \frac{97.994}{3} = 32.665 \qquad N = n \times M = 3 \times 6.0 = 18\ N$

(b) $EW = \frac{FW}{n} = \frac{97.994}{2} = 48.997 \qquad N = n \times M = 2 \times 6.0 = 12\ N$

(c) $EW = \frac{FW}{n} = \frac{97.994}{1} = 97.994 \qquad N = n \times M = 1 \times 6.0 = 6.0\ N$

Differences between Normality and Molarity

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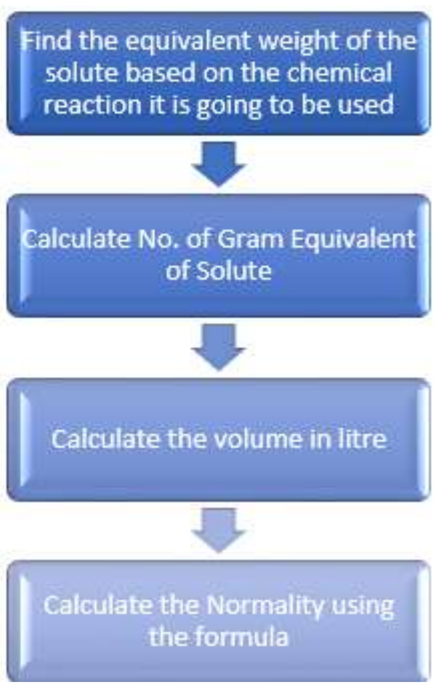
Normality	Molarity
Also known as equivalent concentration.	Known as molar concentration.
It is defined as the number of gram equivalent per litre of solution.	It is defined as the number of moles per litre of solution.
It is used in measuring the gram equivalent in relation to the total volume of the 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}

How to calculate Normality of the Solution



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 is 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.

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Home work

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

$$H_3{}^{+}PO_4{}^{-} + 2Na^{+}OH^{-} \rightarrow Na_2HPO_4 + 2H_2O$$

2. Calculate the normality of 0.321 g sodium carbonate when it is mixed in a 250 mL solution.

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الوزن الذري والتكافؤ لـ ٣٠ عنصر من عناصر الجدول الدوري

العنصر	العدد الذري	الوزن الذري	التكافؤ
Hydrogen	1	1.0079	(-1), +1
Helium	2	4.0026	0
Lithium	3	6.941	+1
Beryllium	4	9.0122	+2
Boron	5	10.811	-3, +3
Carbon	6	12.0107	(+2), +4
Nitrogen	7	14.0067	-3, -2, -1, (+1), +2, +3, +4, +5
Oxygen	8	15.9994	-2
Fluorine	9	18.9984	-1, (+1)
Neon	10	20.1797	0
Sodium	11	22.9897	+1
Magnesium	12	24.305	+2
Aluminum	13	26.9815	+3
Silicon	14	28.0855	-4, (+2), +4
Phosphorus	15	30.9738	-3, +1, +3, +5
Sulfur	16	32.065	-2, +2, +4, +6
Chlorine	17	35.453	-1, +1, (+2), +3, (+4), +5, +7
Argon	18	39.948	0
Potassium	19	39.0983	+1
Calcium	20	40.078	+2
Scandium	21	44.9559	+3
Titanium	22	47.867	+2, +3, +4
Vanadium	23	50.9415	+2, +3, +4, +5
Chromium	24	51.9961	+2, +3, +6
Manganese	25	54.938	+2, (+3), +4, (+6), +7
Iron	26	55.845	+2, +3, (+4), (+6)
Nickel	27	58.6934	+2, +3, (+4)
Cobalt	28	58.9332	(+1), +2, (+3), (+4)
Copper	29	63.546	+1, +2, (+3)
Zinc	30	65.39	+2

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