Molarity and Normality

It is often helpful to know how many moles of solute are present in one liter of solution, especially when these solutions are involved in chemical reactions. Molarity and normality describe the numbers (moles) of reactants or products dissolved in one liter of solution.

Molarity: M = moles of solute contained in one liter of solution.

The molecular weight of glucose sugar is 180 g/mole. If 360 g of glucose is dissolved in enough water to make one liter of solution, the concentration of glucose is 2.00M:

$$\frac{360\text{g}}{1\text{ L}} \times \frac{1\text{ mole}}{180\text{g}} = \frac{2.00\text{ mole}}{\text{L}} = 2.00\text{ M}$$

Normality: N = moles of reactive units per liter (equivalents per liter)

Where molarity describes the moles of a complete substance per liter of solution, normality describes only the moles of reactive species per liter of solution. Normality is always a multiple of molarity. It describes the "equivalent" moles of reactants involved in chemical reactions.

An "equivalent" is an older chemical term, used before chemists knew the exact relationship between atomic weights and atomic structure. Before chemists could count the number of atoms in a given mass of a substance, they utilized mass ratios to calculate how much of one element would react with another. They learned from experiments how much of one element was required to react with a standard amount of another one, or its "equivalent weight." Dalton's atomic theory and Avagadro's number revolutionized stoichiometry. Chemists could now count the exact number of atoms by weighing them, giving rise to the "mole."

Today, equivalents are used to describe how many reactive moles of reactive species are involved in a reaction. They are also used to describe concentrations of selected portions of chemical compounds. The "equivalent weight" of a chemical element is the gram atomic weight divided by its valence. The equivalent can also be formally defined through the amount of substance which will either:

1. react with or supply one mole of hydrogen ions (H^+) in an acid–base reaction; or
2. react with or supply one mole of electrons in a redox reaction.

Normality in Acid-Base Reactions: In an acid-base reaction, normality is a measure of the protons (H^+) or hydroxides (OH^-) that react with one another. Consider a 1 M solution of sulfuric acid, H_2SO_4. Normality is a measure of the moles of protons in the solution. Since 2 protons are available to react on each molecule of H_2SO_4, the normality is 2 N. The same is true for bases containing more than one hydroxide ion. An 0.2 M solution of $Ca(OH)_2$ is actually 0.4 N with respect to OH^- ions. The beauty of normality is that identical volumes of any acid solution will exactly neutralize the same volume of any base solution, regardless of the acids or bases involved if their normalities are equivalent. This simplifies acid-base titration calculations, where the equation $C_aV_a = C_bV_b$ can be used to determine the normality of the titrated species.

Normality of Redox Reagents: In reduction-oxidation reactions, electrons move from oxidized atoms to reduced atoms. To calculate the normality of a redox reactant, the number of electrons donated or accepted per mole of the reactant. The mass of a reactant that donates or accepts one mole of electrons during the reaction is the "equivalent weight" of this reactant. Dividing the total grams of a reactant by the equivalent weight yields the “equivalents” of this reactant. Consider the following redox reaction:

$$Zn + 2Cu^{2+} \rightarrow Zn^{2+} + 2\,Cu^{+}$$

Each zinc atom donates two electrons during the reaction, while each atom of copper accepts only one electron. One-half mole of Zn donates one mole of electrons, so the equivalent weight of zinc is onehalf of the atomic weight: 65.4 / 2 = 32.6 g/equivalent. However, since one mole of copper atoms accepts only one mole of electrons, the equivalent weight of copper in this reaction equals its atomic weight: 63.5 / 1 = 63.5 g/equivalent. In other reactions, copper may accept 2 moles of electrons per mole of atoms. In such a case, the equivalent weight of copper would be one-half its atomic weight. Thus, we see that equivalent weight and normality depend on the reaction. Only by knowing the numbers of electrons donated or accepted during this reaction can the equivalent weight be calculated… and it is specific to only this reaction.