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- Analytical Chemistry/elective
- Fourth stage

Introduction to volumetric analysis calculations

- Volumetric analysis is a chemical analytical procedure based on the measurement of volumes of reacting solutions. It uses titration to determine the concentration of a solution by carefully measuring the volume of one solution needed to react with another. In this process, a measured volume of a standard solution, the titrant, is added from a burette to the solution of unknown concentration .

- When the two substances are present in an exact stoichiometric ratio, the reaction is said to have reached the equivalence or stoichiometric point.

- To determine when this occurs, another substance, the indicator, is also added to the reaction mixture. This is an organic dye, which changes color when the reaction is complete. This color change is known as the endpoint; ideally, it will coincide with the equivalence point. For various reasons, there is usually some difference between the two, though if the indicator is carefully chosen, the difference will be negligible. Some indicators include Litmus and methyl.

- Orange, Methyl Red, Phenolphthalein, and Thymol Blue. A typical titration is based on a reaction of the general type:
- $aA + bB \rightarrow products$
- where A is the titrant, B is the substance titrated, and a:b is the stoichiometric ratio between the two.

Applications of Titration

- Titration can be applied to any of the following chemical reactions:

1. Acid-base
2. Complexation
3. Oxidation-reduction
4. Precipitation

Only acid-base titration will be treated here, though the basic principles are the same in all cases.

Acid-Base Titrations

Acid-base titration involves measuring the volume of a solution of the acid (or base) required to completely react with a known volume of a base (or acid) solution. The relative amounts of acid and base needed to reach the equivalence point depend on their stoichiometric coefficients. It is therefore critical to have a balanced equation before attempting calculations based on acid-base reactions. Below we define some of the common terms associated with acid-base reactions.

A molar solution

A molar solution contains one mole of the substance per liter of solution. For example, a molar solution of sodium hydroxide contains 40 g ($NaOH$ = 40 g/mol) of the solute per liter of solution. The concentration of a solution expressed in moles per liter of solution is known as the molarity of the solution.

Standard solution

A standard solution is one of known concentration. For example, titration of an unknown acid might use a carefully prepared 0.1250 M solution of sodium carbonate.

Standardization

Standardization involves determining the concentration of a solution by accurately measuring the volume of that solution required to react with an exactly known amount of a primary standard. The solution thus standardized is called a secondary standard and is used to analyze unknown samples. An example of a primary standard is sodium carbonate solution. It can readily be prepared by dissolving pure anhydrous sodium carbonate in water. A standardized base can be used to determine the concentration of an unknown acid solution, and vice-versa.

Calculations Involving Acid–Base Titration

Generally, calculations concerning acid-base reactions involve the concepts of reaction stoichiometry, number of moles, mole ratio, and molarity. The key requirements here are: the volume and concentration (molarity or normality) of the titrant; a balanced chemical equation between the reacting substances; and the mole ratio of the titrant to the substance being titrated.

A calculation involving mass and percentage of substance titrated

Consider the reaction between titrant A and titrated substance B. The balanced equation is

$aA + bB \rightarrow cC + dD$

The mole ratio of B to A is given by

$R = \frac{b}{a}$

Note: R as used here is just a symbol, and not the gas constant. Any other letter such as K, U, or B could have been used

Calculations

To calculate the mass and percentage of substance titrated, follow these steps:

1. Write a balanced equation for the reaction between A and B.

2. Calculate the moles of titrant A.

moles of *A* $= \frac{mLAMA}{1000mL/L}$

Calculate the moles of titrated substance B:

moles of *B* = moles of *A*×*R* = $\frac{mLAMA}{1000mL/L}$ × R

Calculate the mass of substance (*B*) titrated:

Mass of *B* in grams = moles of *B* × MW of *B* = $\frac{mLAMA}{1000mL/L}$ × R × MW*B*

Calculate the percentage of substance *B* in the sample:

- $\%B = \frac{Mass\ of\ B\ in\ grams}{Mass\ of\ sample\ in\ grams} \times 100 = \left(\frac{gB}{g\ sample}\right) \times 100$

Example

A chemistry student was given a mini-project to analyse ethanoic acid in a 100-g sample of a marine plant extract. The student conducted a titration and found that it took 20 mL of 0.625 M NaOH to neutralize 25 mL of a solution of the marine plant extract. Calculate:

(a)The mass of ethanoic acid in the sample (b) The percentage of ethanoic acid in the sample.

NaOH+CH3COOH -⟶ CH3COONa+H2O