Titration

Titration is a technique used to measure the amount or concentration of a substance (analyte) using a reaction with a second substance of known concentration (titrant). The titrant is measured using a burette or similar measuring device. The titration is based on stoichiometric principles and is used to find an equivalence point such that both analyte and titrant are limiting reagents. A small (trace) amount of an indicator substance is frequently used to find the end-point of a titration. The indicator changes form due to changes in chemical environment that occur at or near the equivalence point.

- equivalence point = stoichiometric point (balance between analyte and titrant)

- end point = change in indicator – usually a change in colour (a well chosen indicator will change colour very close to the equivalence point)

Types of titrations depend on the type of chemistry involved between the analyte and the titrant:

- acid/base titration (acid base neutralization)
- redox titration (oxidation reduction)
- complexometric titration (ligand like attraction)
- zetapotential titration (electrochemical potential)

In addition titrations can be performed using a back titration method or may be multiple component titrations.

Acid Base – Titration Calculations

All titration calculations are done using non-equilibrium techniques. Even when a weak acid or base is involved, the degree to which equilibrium calculations would effect the final outcome is insignificant. This is good news, because it makes the mathematics much simpler. When in doubt, remember that titration calculations are something that you would have had the ability to do at the end of the grade eleven chemistry course – stoichiometry!! By the way, **H^{1+} ions** are referred to as **protons** (i.e. a hydrogen atom nucleus!)

Part I: Determine the protism of the acid or base

Protism is equal to the number of protons that an acid would loose when completely neutralized and/or the number of protons that a base would gain when completely neutralized (proton = H^{1+}).

e.g.	HCl	monoprotic	can donate one proton
	H_2SO_4	diprotic	can donate two protons
	H_3PO_4	triprotic	can donate three protons
	CH_3COOH	monoprotic	can donate one protons

In the last example, the three hydrogens attached to the carbon are as always strongly covalently bonded and are called **non-acidic protons**, the hydrogen bonded to the oxygen is a polarized covalent bond with ionic character and is therefore an **acidic proton.** Only acidic protons can react in an acid base titration. This same principle applies to other organic compounds.

e.g.	NaOH	monoprotic	OH^{1-} can accept one proton
	Na_2CO_3	diprotic	CO_3^{2-} can accept two protons
	K_3PO_4	triprotic	PO_4^{3-} can accept three protons
	$Ba(OH)_2$	diprotic	each of OH^{1-} can accept a proton

In the case bases, the protism will always be equal to the **total negative charge** in the formula

Part II: Write the correct form of the titration equation for the neutralization reaction

When presented with an acid base titration, write the chemical equation for the reaction if you can (one acid with one base) followed by the correct form of the **titration equation**. The titration equation relates the moles of acid (n_A) and the moles of base (n_B) taking into account the protism of the particular acids and bases involved.

e.g. HCl is neutralized with NaOH (both monoprotic)

$HCl + NaOH \rightarrow NaCl + H_2O$

$n_A = n_B$ is the correct form of the titration equation

e.g. H_2SO_4 is neutralized with Na_3PO_4 (diprotic and triprotic)

$3H_2SO_4 + 2Na_3PO_4 \rightarrow 3Na_2SO_4 + 2H_3PO_4$

$2n_A = 3n_B$

Here the coefficients in front of n_A and n_B reflect the protism of the acid and the base. One way to think of this is "the acid produced two moles of protons per mole of acid, therefore the moles of acid must be multiplied by two, the base accepts three moles of protons per mole of base, therefore the moles of base must be multiplied by three". The protism numbers compensate for the fact that more that one proton is involved on these acids and bases.

Part III: Solve the problem as asked.

The problem itself will specify if the acid or base comes in solution or solid form. (Yes that's correct, a solid can be an acid or a base for the purposes of titration.) If the acid/base is in solution form the relation **n=CV** must be used. If the acid/base is in solid form, frequently a mass conversion is needed somewhere in the problem.

Multiple Acid/Base Problems.

Some titration questions involve more than one acid or base. All previous rules apply and simple addition is used to add multiple acids or base components together.

e.g. H_3PO_4 is to be neutralized by a combination of sodium hydroxide (NaOH) and barium hydroxide ($Ba(OH)_2$).

optional: $H_3PO_4 + 3NaOH \rightarrow Na_3PO_4 + 3H_2O$

optional: $2H_3PO_4 + 3Ba(OH)_2 \rightarrow Ba_3(PO_4)_2 + 6H_2O$

Please note that a single neutralization reaction cannot be written successfully for this situation. The titration equation will be:

$$3n_A^{H_3PO_4} = n_B^{NaOH} + 2n_B^{Ba(OH)_2}$$

Please note the use of superscripts to differential the acid and base components.