FlexiPrep

Acid Base Titration, Objective, Theory, Key Terms, Choice of Indicators (For CBSE, ICSE, IAS, NET, NRA 2022)

Title: Acid Base Titration

What is Acid-Base Titration?

- An acid-base titration is an experimental technique used to acquire information about a solution containing an acid or base.
- Hundreds of compounds both organic and inorganic can be determined by a titration based on their acidic or basic properties. Acid is titrated with a base and base is titrated with an acid. The endpoint is usually detected by adding an indicator.
- An acid-base titration is an experimental procedure used to determine the unknown concentration of an acid or base by precisely neutralizing it with an acid or base of known concentration. It is filled with a solution of strong acid (or base) of known concentration.

Objective

To determine the concentration of an acid or base by measuring the volume of titrant (of known concentration) that reacts with it according to a stoichiometric proton-transfer reaction.

Theory

- An acid-base titration involves strong or weak acids or bases. Specifically, an acid-base titration can be used to figure out the following.
  - The concentration of an acid or base
  - Whether an unknown acid or base is strong or weak.
  - pK_a of an unknown acid or pK_b of the unknown base.
- Let us consider acid-base reaction which is proceeding with a proton acceptor. In water, the proton is usually solvated as H_3O^+ . H_2O is added to the base to lose (OH^-) or gain $\left(H_3O^+\right)$. Acid-base reactions are reversible.
- The reactions are shown below.

$$\text{HA} + H_2O \rightarrow H_3O^+ + A^- \text{ (base)}$$

$$\text{HA} + H_2O \rightarrow \text{BH}^+ + \text{OH}^- \text{ (acid)}$$

Here $[A^-]$ is the conjugate base, H^+B is conjugate acid. Thus, we say

$$\text{Acid} + \text{Base} \leftrightharpoons \text{Conjugate base} + \text{Conjugate acid}$$

Hence

$$K_A = \frac{[H_3O]^+[A]^-}{[\text{HA}][H_2O]}$$

$$K_B = \frac{[\text{HB}][\text{OH}]^-}{[B]^-}$$

$$K_w = \frac{[H]^+[\text{OH}]^-}{[H_2O]}$$

It is possible to give an expression for $\left[H^+\right]$ in terms of K_A, K_B and K_w for a combination of various types of strong and weak acids or bases.

Key Terms

- **Titration** – A process where a solution of known strength is added to a certain volume of a treated sample containing an indicator.
- **Titrant** – A solution of known strength of concentration used in the titration.
- **Titrand** – The titrand is any solution to which the titrant is added and which contains the ion or species being determined.
- **Titration curve** – A plot of pH Vs milliliters of titrant showing the manner in which pH changes Vs milliliters of titrant during an acid-base titration.
- **Equivalence point** – The point at which just adequate reagent is added to react completely with a substance.
- **Buffer solution** – A solution that resists changes in pH even when a strong acid or base is added or when it is diluted with water

Types of Acid-Base Titration

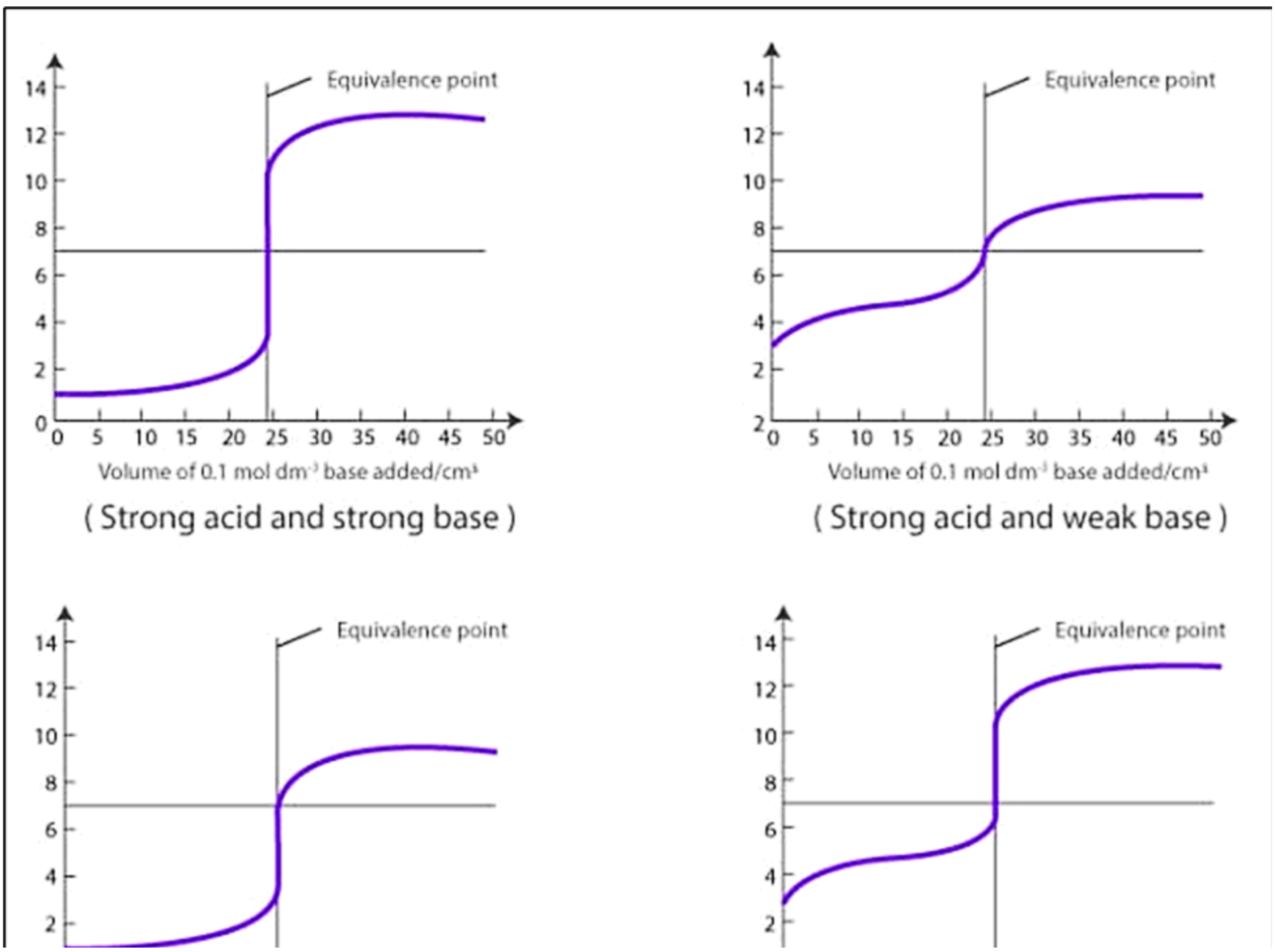
The types and examples of strong/weak acids and bases are tabulated below.

Sr. No	Types	Examples
1.	Strong acid – strong base	Hydrochloric acid and sodium hydroxide
2.	Weak acid – strong base	Ethanoic acid and sodium hydroxide
3.	Strong acid – weak base	Hydrochloric acid and ammonia
4.	Weak acid – weak base	Ethanoic and ammonia

The Types and Examples of Strong/Weak Acids and Bases Are Tabulated Below

Titration Curve & Equivalence Point

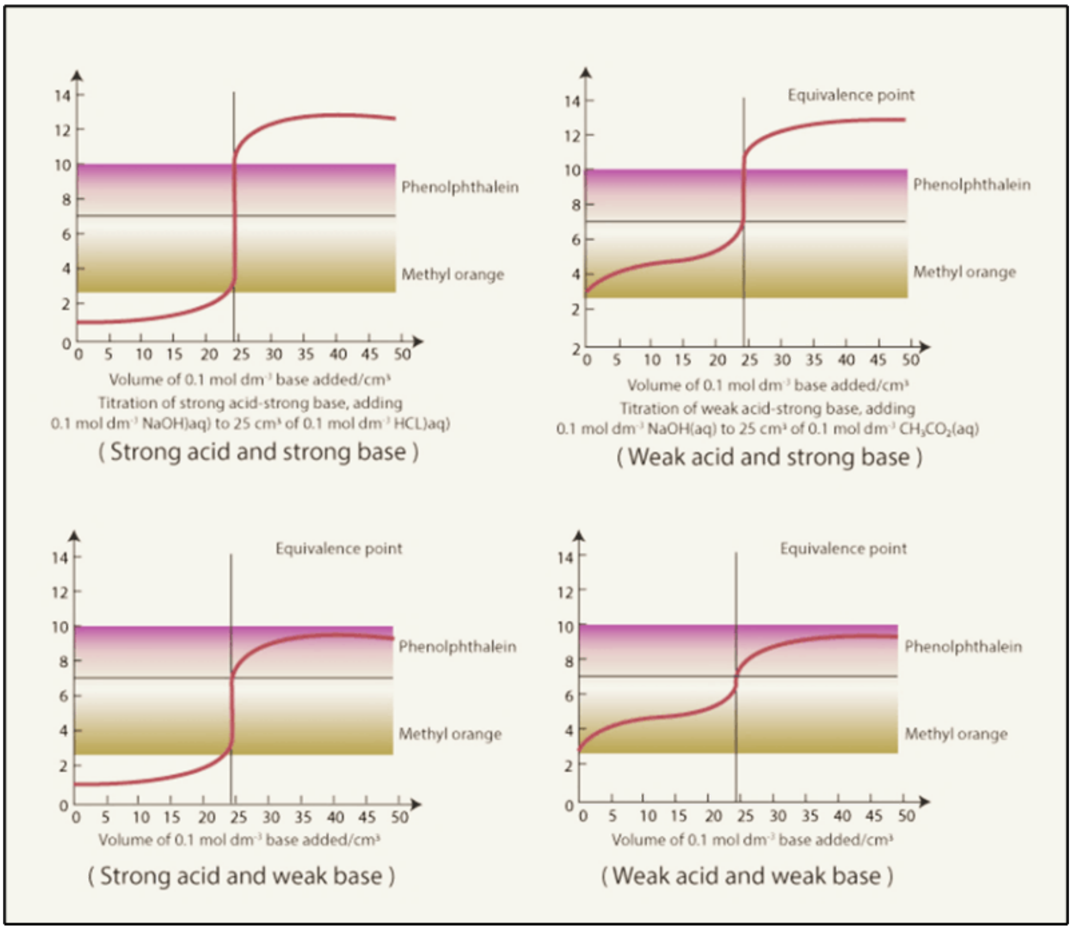
In a titration, the equivalence point is the point at which exactly the same number of moles of hydroxide ions have been added as there are moles of hydrogen ions. In a titration, if the base is added from the burette and the acid has been accurately measured into a flask. The shape of each titration curve is typical for the type of acid-base titration.


Equivalence point
14
12
10
8
6
4
2
0
0 5 10 15 20 25 30 35 40 45 50
Volume of 0.1 mol dm⁻³ base added/cm³
(Strong acid and strong base)
Equivalence point
Volume of 0.1 mol dm⁻³ base added/cm³
(Strong acid and weak base)
Equivalence point
Equivalence point

- The pH does not change in a regular manner as the acid is added. Each curve has horizontal sections where a lot of bases can be added without changing the pH much.
- There is also a very steep portion of each curve except for weak acid and the weak base where a single drop of base changes the pH by several units.
- There is a large change of pH at the equivalence point even though this is not centre on pH 7. This is relevant to the choice of indicators for each type of titration.

Choice of Indicators

- Acid-base indicators are substances which change colour or develop turbidity at a certain pH. They locate equivalence point and also measure pH. They are themselves acids or bases are soluble, stable and show strong colour changes. They are organic in nature.
- A resonance of electron isomerism is responsible for colour change. Various indicators have different ionization constants and therefore they show a change in colour at different pH intervals.
- Acid-base indicators can be broadly classified into three groups.
  - **The phthalein's and sulphophthaleins (eg; Phenolphthalein)**
  - **Azo indicators (eg; Methyl orange)**
  - **Triphenylmethane indicators (eg; Malachite green)**
- The two common indicators used in acid-base titration is Phenolphthalein and methyl orange. In the four types of acid-base titrations, the base is being added to the acid in each case. A graph is shown below where pH against the volume of base added is considered. The pH range over which the two indicators change colour. The indicator must change within the vertical portion of the pH curve.



The Choice of indicators based on the type of titration is tabulated below.

Types of titration	Indicators
Strong acid – Strong base	Phenolphthalein is usually preferred because of its more easily seen colour change.

Weak acid-strong base	Phenolphthalein is used and change sharply at the equivalence point and would be a good choice.
Strong acid-weak base	Methyl orange will change sharply at the equivalence point.
Weak acid-weak base	Neither phenolphthalein, not methyl orange is suitable. No indicator is suitable because it requires a vertical portion of the curve over two pH units.

The Choice of Indicators Based on the Type of Titration is Tabulated Below

Materials for a Titration Procedure

- Burette
- White tile (used to see a color change in the solution)
- Pipette
- pH indicator (the type depends on the reactants)
- Erlenmeyer or conical flask
- Titrant (a standard solution of known concentration; a common example is aqueous sodium carbonate)
- Analyte, or titrand (the solution of unknown concentration)

Equivalence Point Indicators

- Before you begin the titration, you must choose a suitable pH indicator, preferably one that will experience a color change (known as the "end point") close to the reaction's equivalence point; this is the point at which equivalent amounts of the reactants and products have reacted. Below are some common equivalence point indicators:
  - strong acid-strong base titration: phenolphthalein indicator
  - weak acid-weak base titration: bromothymol blue indicator
  - strong acid-weak base titration: methyl orange indicator the base is off the scale (e. g. , $pH > 13.5$) and the acid has $pH > 5.5$: alizarine yellow indicator
  - the base is off the scale (e. g. , $pH > 13.5$) and the acid has $pH > 5.5$: alizarine yellow indicator
  - the base is off the scale (e. g. , $pH > 13.5$) and the acid has $pH > 5.5$: alizarine yellow indicator
  - the acid is off the scale (e. g. , $pH < 0.5$) and the base has $pH < 8.5$: thymol blue indicator

Questions

What Are the Types of Acid Base Titration?

Answer:

Types of acid – base Titration

Sr. No	**Types**	**Examples**
1.	Strong acid – strong base	Hydrochloric acid and sodium hydroxide
2.	Weak acid – strong base	Ethanoic acid and sodium hydroxide
3.	Strong acid – weak base	Hydrochloric acid and ammonia
4.	Weak acid – weak base	Ethanoic and ammonia

Types of Acid – Base Titration

What is a Titrant in an Acid Base Titration?

Answer:

Acid-Base titrations are usually used to find the amount of a known acidic or basic substance through acid base reactions. The reagent (titrant) is the solution with a known molarity that will react with the analyte.

Which Indicator is Used in Acid Base Titration?

Answer:

Phenolphthalein

Phenolphthalein is another commonly used indicator for titrations, and is another weak acid. In this case, the weak acid is colorless and its ion is bright pink. Adding extra hydrogen ions shifts the position of equilibrium to the left, and turns the indicator colorless.

Indicator	pK_{ind}
Phenolphthalein	9.3

Phenolphthalein

Why Phenolphthalein is Colorless in Acid?

Answer:

In nature, phenolphthalein is lowly acidic. And it dissociates itself into and ions in aqueous solution. The solution's pink colour is due to the concentration of ions within the solution. The concentration of in the solution is very low under acidic conditions and the concentration of is high, therefore it is colorless.

Why is Acid Base Titration Important?

Answer:

The purpose of a strong acid-strong base titration is to determine the acid solution concentration by titrating it with a basic solution of known concentration, or vice versa until there is neutralization. The reaction between a strong acid-base and a strong base will, therefore, result in water and salt.

Example

Problem

A 1.2 gm sample of a mixture of $(Na_2\ CO_3 + NaHCO_3)$ is dissolved and titrated with $0.5N\ \ HCl$. With phenolphthalein, the endpoint is at 15 ml while after further addition of methyl orange a second endpoint is at $22\ \ ml$. Calculate the percentage composition of the mixture.

Solution

$15 + 15 = 30$ ml acid is necessary to neutralize $Na_2\ CO_3$ completely.

Total volume needed $= 15 + 22 = 37$ ml

$(37 - 30) = 7$ ml acid is needed for neutralizing $NaHCO_3$

Therefore, $Na_2\ CO_3$ composition (%) is

$$= \left[\frac{30 \times 0.5 \times 0.053}{1.2}\right] \times 100 = 66.25\%$$

$$= \frac{7 \times 0.5 \times 0.042 \times 100}{1.2} = 24.50\%\ NaHCO_3$$