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Topic for SEMESTER-1(CEMA-CC-1-1-TH)

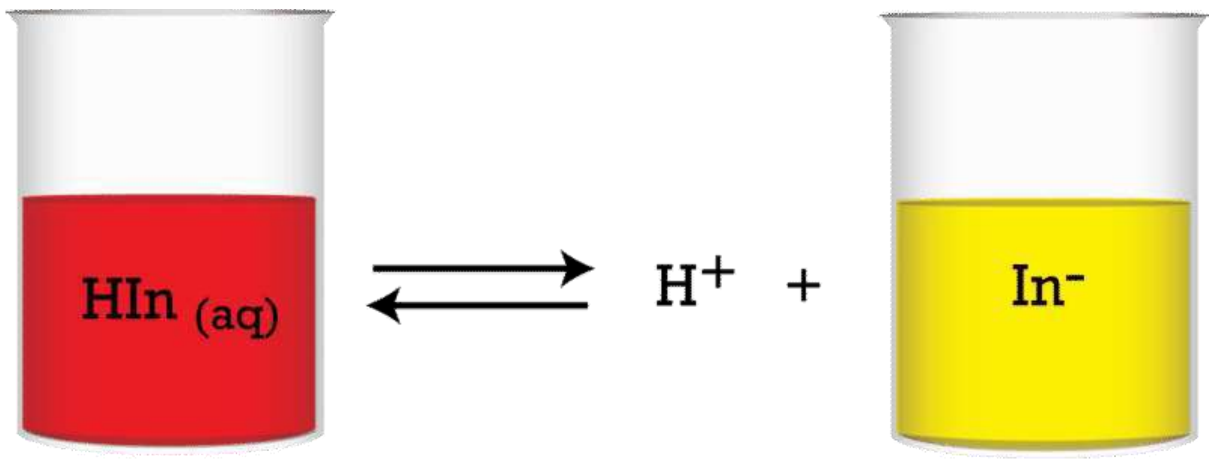
INORGANIC CHEMISTRY-1

ACID-BASE REACTION

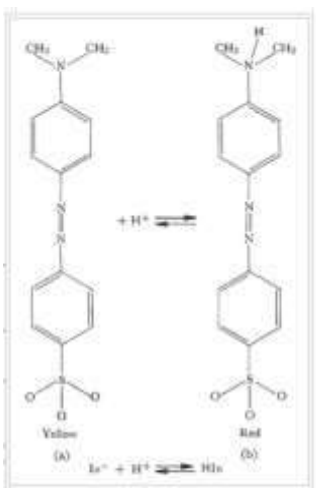
ACID-BASE INDICATORS:

Acid -base indicators are organic weak acids or bases. Indicators change their colour depending on hydrogen ion concentration in medium(whether alkaline or acidic).It has two forms:

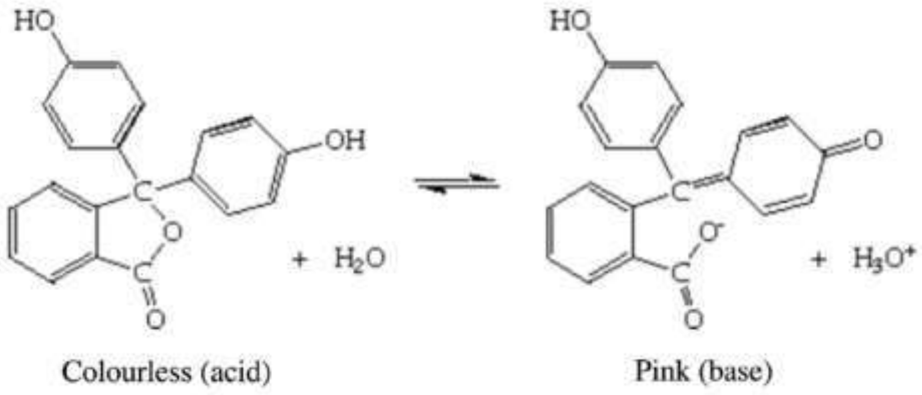
1) Ionized form (In^-)
2) Unionized form(HIn)



Example: methyl orange indicator



Phenolphthalein indicator structure in acid and basic forms



Equilibrium between two forms of indicators :

i) $In_A + H_2O = In_B + H_3O^+$

or

$In_A = In_B + H^+$

Where In_A is the acidic form of the indicator(In) and In_B is the basic form of the indicator(In)

$K_{In} = [In_B][H_3O+]/ [In_A]$

or, $K_{In} [In_A]/ [In_B] = [H_3O+]$

or, $-\log K_{In} [In_A]/ [In_B] = -\log [H_3O+]$

or, $-\log K_{In} - \log [In_A]/ [In_B] = pH$

or, $pK_{In} + \log [In_B]/ [In_A] = pH$ ………..(i)

pK_{In} is indicator constant. $[In_B]/ [In_A]$ is pH dependent.

When the concentration of InA form is ten times than that of InB form i.e. $[In_A]/ [In_B] \sim 10$, we can see the colour of In_A form and it is the acidic colour. Similarly, when the concentration of In_B form is ten times than that of In_A form i.e. $[In_B]/ [In_A] \sim 10$, we can see the colour of In_B form and it is the basic colour.

The corresponding limit of pH is set as follows:

Acidic colour : $[In_A]/ [In_B] > 10$

From equation (i) we get,

$pH = pK_{In} + \log 1/ [10]$

or, $pH = pK_{In} - \log [10]$

or, pH= pK_{In} -1

Basic colour : $[In_B]/[In_A] > 10$

From equation (i) we get,
pH= pK_{In} +log [10]
or, pH= pK_{In} +log [10]
or, pH= pK_{In} +1
Therefore, the colour change interval is pH= $pK_{In} \pm 1$

For optimal accuracy, the color difference between the two colored species should be as clear as possible, and the narrower the pH range of the color change the better.

Indicators usually exhibit intermediate colours at pH values inside a specific transition range. For example, phenol red exhibits an orange colour between pH 6.8 and pH 8.4. The transition range may shift slightly depending on the concentration of the indicator in the solution and on the temperature at which it is used.

The following table shows the pH range of colour change of different indicators:

Indicator name	Acid colour(low pH colour)	Base colour(high pH colour)	pH range
Phenolpthalein	colourless	red	8.3-10.0
Methyl Orange	red	Orange	3.1-4.4
Bromo cresol	yellow	blue	3.8-5.4
Methyl red	red	yellow	4.4-6.2
Thymol blue(first transition)	red	yellow	1.2-2.8
Thymol blue(second transition)	yellow	blue	8.0-9.6

Bromothymol blue	yellow	6.0-7.6	blue
Congo red	Blue -violet	3.0-5.0	red
Phenol red	yellow	6.4-8.0	red
Alizarine Yellow R	yellow	10.2-12.0	red

In acid base titration the pH range at the equivalence point must be with the pH range of the indicator.

Choice of indiacator and neutralization curve in acid base titration:

The nature of variation of pH in any acid base titration is dependent on

i)The concentration of solution

ii)The nature of acid base taken

Neutralization curve or titration curve is obtained by plotting the pH values ar different stages of neutralization as ordinate against the volume of alkali added as abscissae.

Neutralization Curve of strong acid vs strong base(e,g NaOH vs HCl)

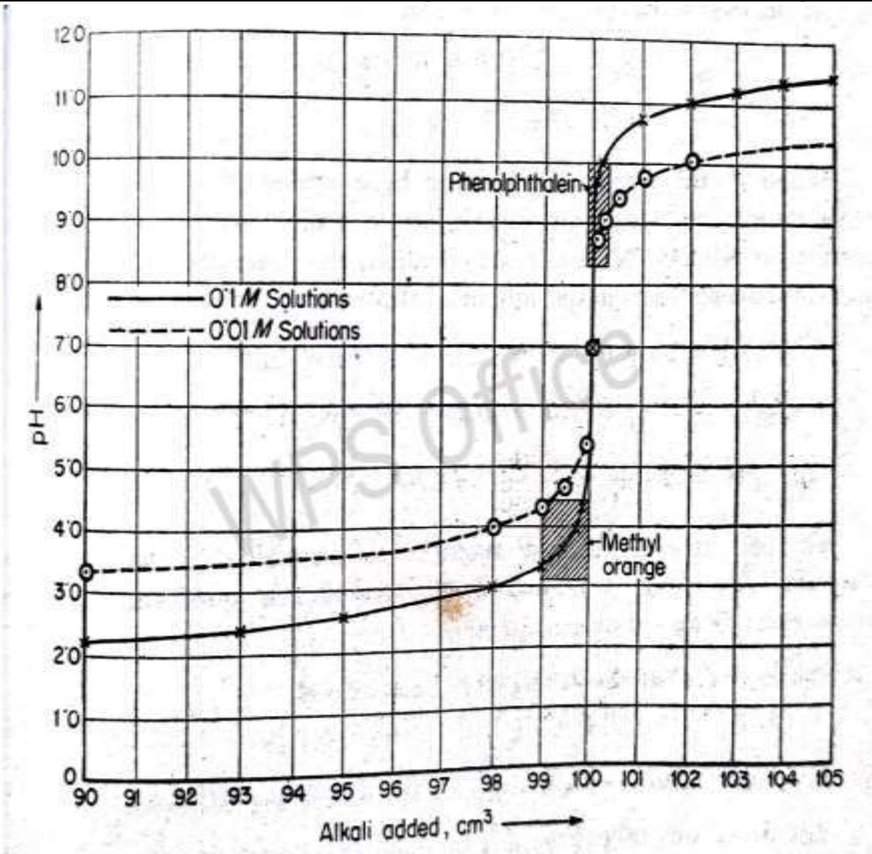


Fig. 1 Titration of 100cm^3 of HCl by NaOH

A strong acid- strong base titration is performed using a phenolphthalein indicator. Phenolphtalein is chosen because it changes color in a pH range between 8.3 – 10. It will appear pink in basic solutions and clear in acidic solutions. In the case of a strong acid-strong base titration, this pH transition would take place within a fraction of a drop of actual neutralization, since the strength of the base is high.

On the other hand, using methyl orange, you would titrate until there is the very first trace of orange in the solution. If the solution becomes red, you are getting further the equivalence point. In the methyl orange case, half-way stage where the mixture of red and yellow produces an orange colour happens at pH 3.7-nowhere near neutral.

Neutralization Curve of weak acid vs strong base(e.gCH_3COOH vs NaOH)

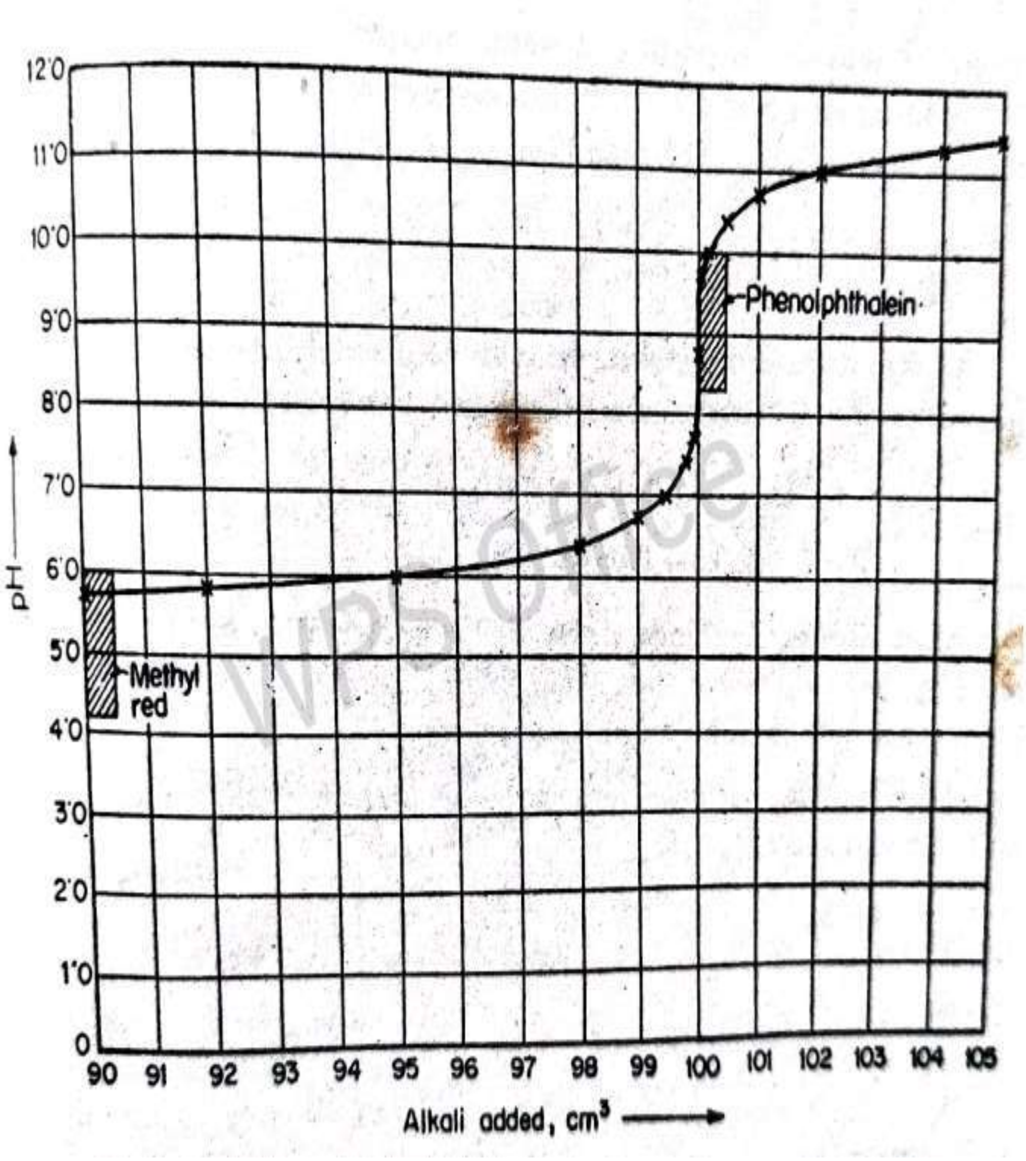


Fig.2 Titration of acetic acid with NaOH(both 0.1 M)

An aqueous solution of acetic acid (ethanoic acid), $CH_3COOH(aq)$, is a weak acid.
An aqueous solution of sodium hydroxide, NaOH(aq), is a strong base. Below is the balanced chemical reaction for the reaction between $CH_3COOH(aq)$ and NaOH(aq):

$CH_3COOH_{(aq)} + NaOH_{(aq)} \rightarrow CH_3COONa_{(aq)} + H_2O_{(l)}$

At the equivalence point $CH_3COONa(aq)$, the salt of a weak acid and a strong base, is present so a solution of CH_3COONa will have a pH > 7 (CH_3COO^- is a weak base)
Consider thymol blue (pH range 8.0 - 9.6) or phenolphthalein (8.3 - 10.0) as suitable indicators.

Neutralization Curve of weak base vs strong acid (e.g NH_4OH vs HCl)

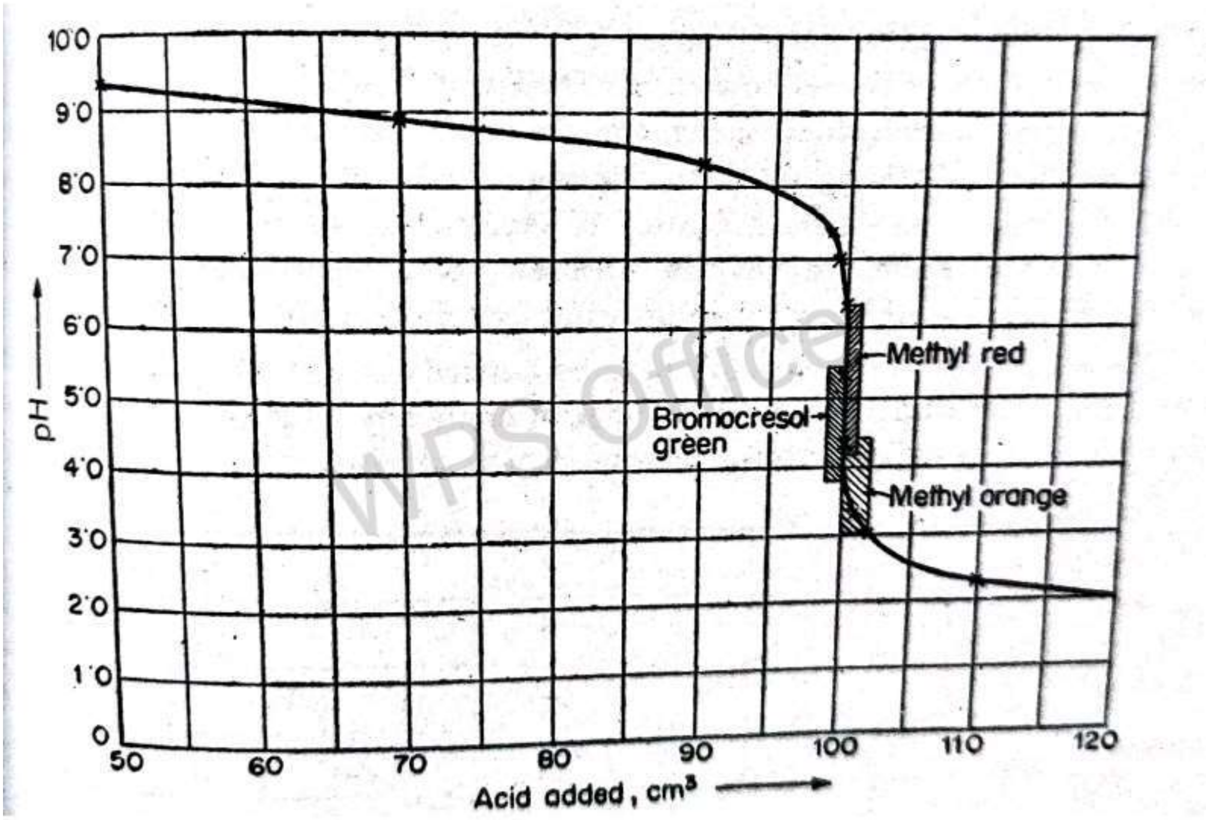


Fig.3 Titration of aqueous ammonia vs HCl (both 0.1M)

An aqueous solution of hydrochloric acid, HCl(aq), is a strong acid.
An aqueous solution of ammonia, NH_3(aq), is a weak base.
The balanced chemical reaction below represents the reaction between HCl(aq) and NH_3(aq):

$$HCl_{(aq)} + NH_{3(aq)} \rightarrow NH_4Cl_{(aq)}$$

NH_4Cl is the salt of a strong acid and a weak base, so a solution of NH_4Cl will have a pH < 7 (NH_4^+ is a weak acid)
A suitable indicator would be methyl red (pH range 4.4 - 6.0)

Neutralization Curve of weak acid vs weak base(e.gCH_3COOH vsNH_4OH)

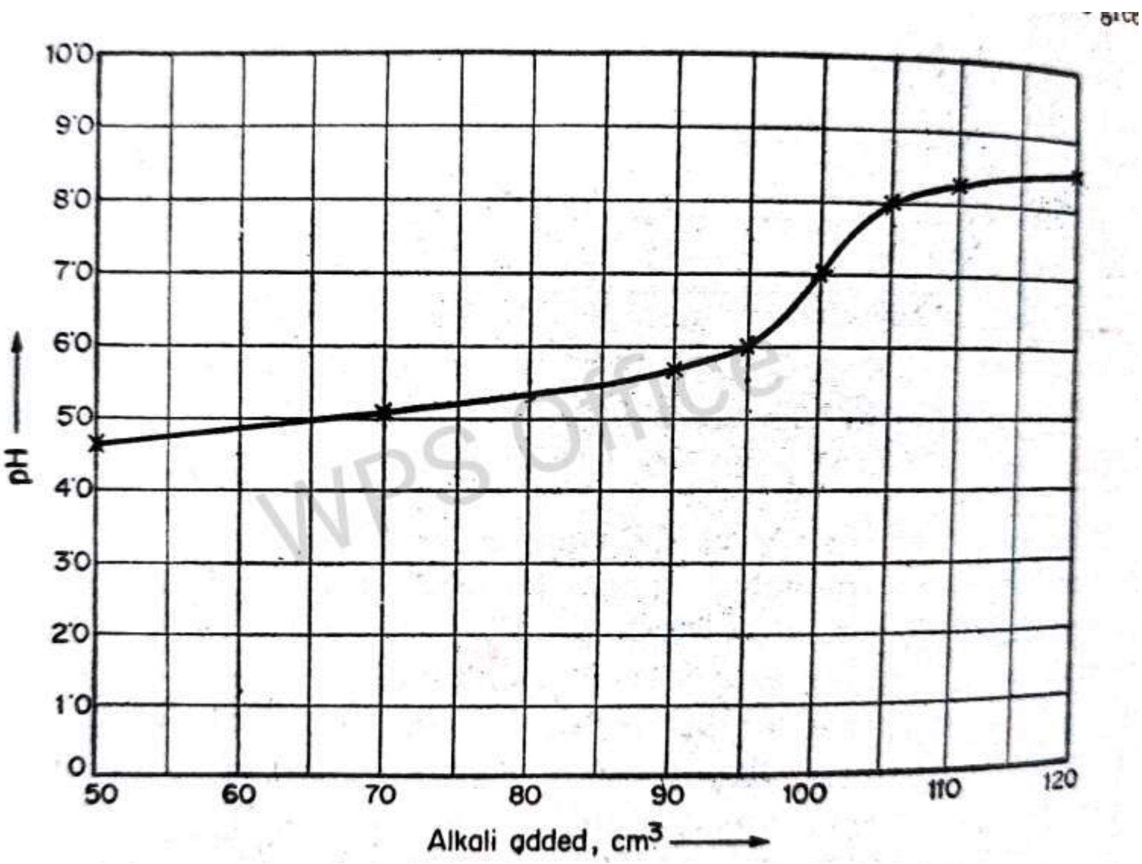


Fig.4 Titration of 100cm ^{3} of 0.1 M acetic acid by 100cm ^{3} 0.1 M ammonium hydroxide .

Mixed indicator is used. Change of pH is very gradual.Indicator used here is mixtutre of methyl red and methylene blue which shows sharp colour change at Ph=7 from violet blue to green.

Example:

In the titration of a weak acid with a strong base, which indicator would be the best choice?

A. Methyl Orange

B. Bromocresol Green

C. Phenolphtalein

The correct answer is C. In the titration of a weak acid with a strong base, the conjugate base of the weak acid will make the pH at the equivalence point greater than 7. Therefore, you would want an indicator to change in that pH range. Both methyl orange and bromocresol green change color in an acidic pH range, while phenolphtalein changes in a basic pH.