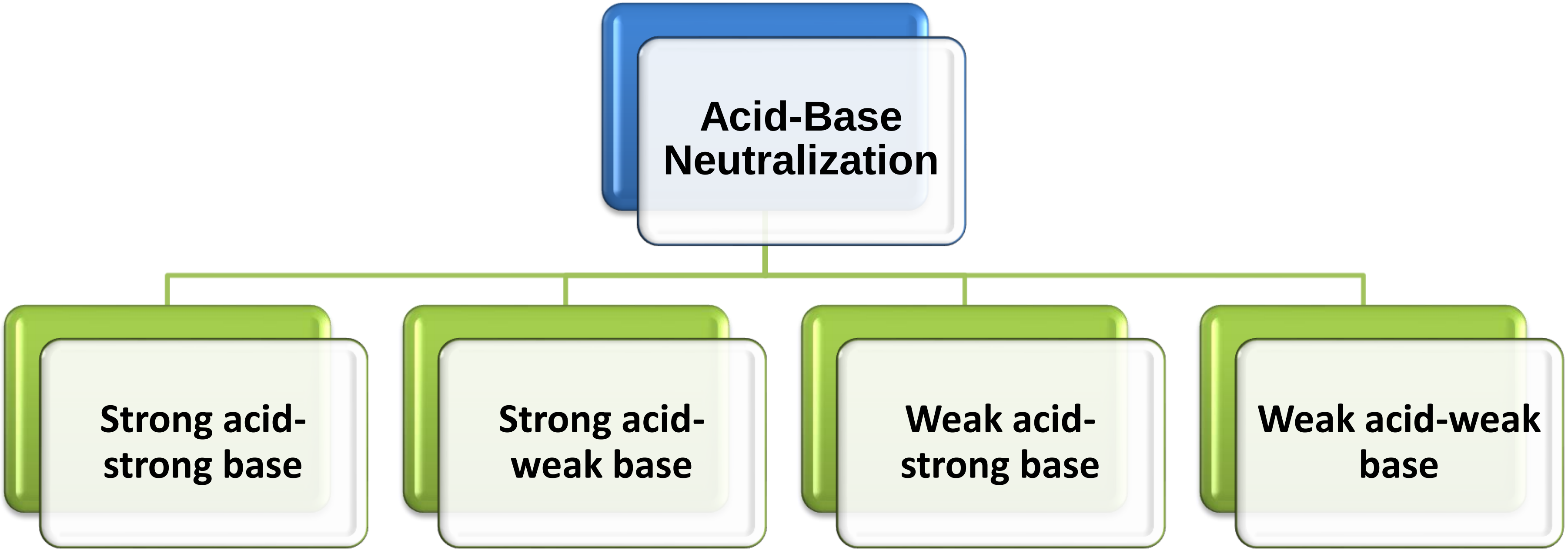
Fundamentals of Analytical Chemistry

م.د.مسار علي عواد

Titration and Acid-Base Neutralization



- Acid + Base → Water + Salt
- Ex: **$HCl + NaOH \rightarrow H_2O + NaCl$**

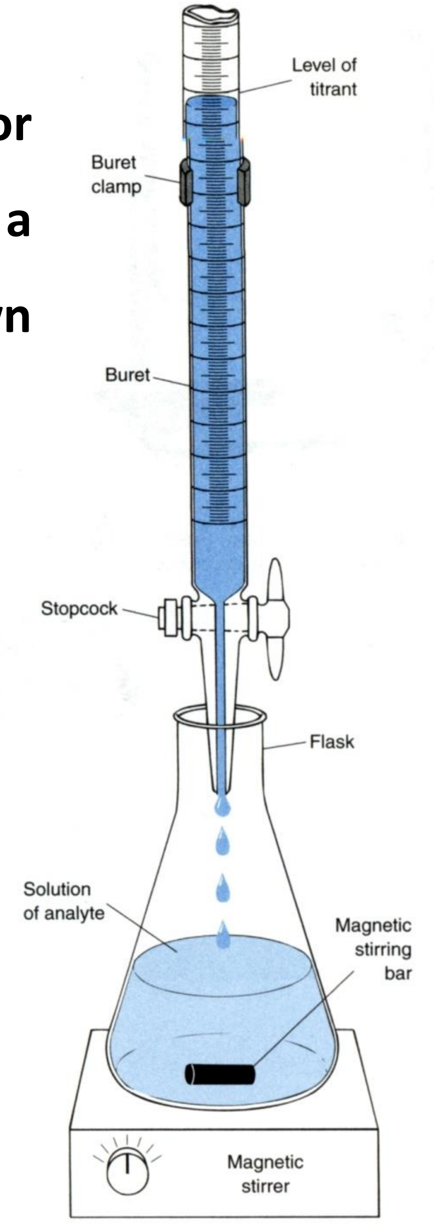
What is Acid-Base Titration?

- It is a quantitative analysis method to determine an acid's or bases' concentration by precisely neutralizing them with a standard solution of either acid or base of known concentration.
- Both titrations involve in the neutralization reaction.

$$HCl + KOH \longrightarrow H2O + KCl$$

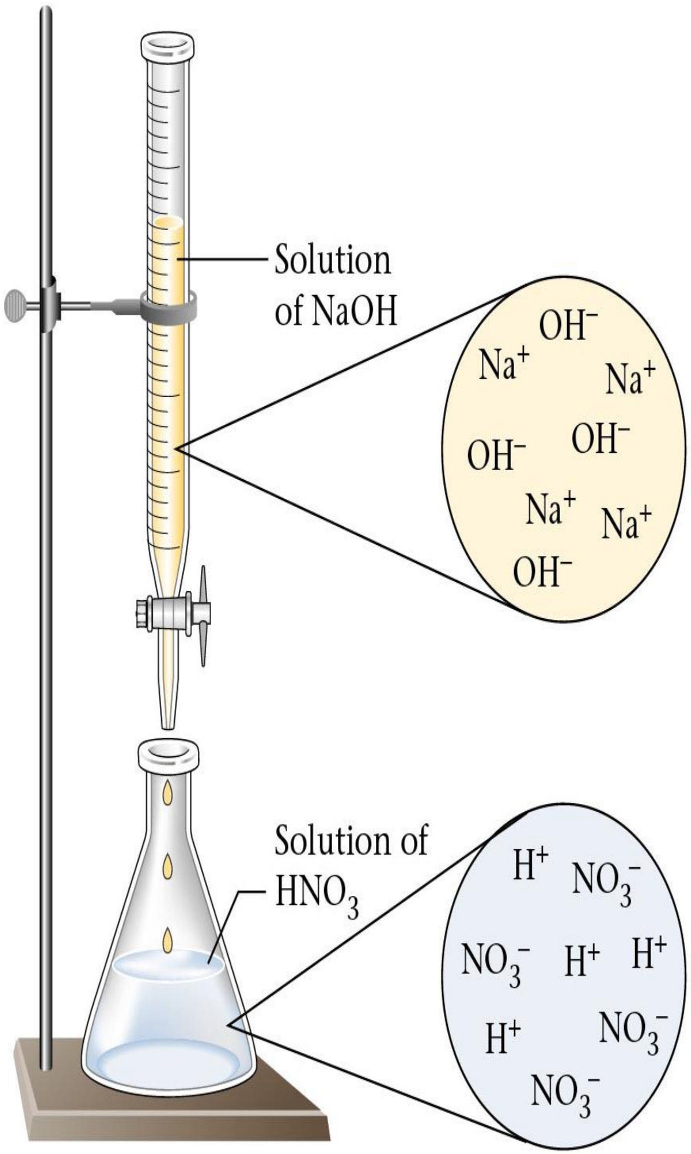
Acid + Alkali ⟶ Salt + Water

Or $H^+ + OH^- \longrightarrow H_2O$



What is Acid-Base Titration?

❖ The strength of an acid can be determined using a standard solution of a base. This process is called **acidimetry**.

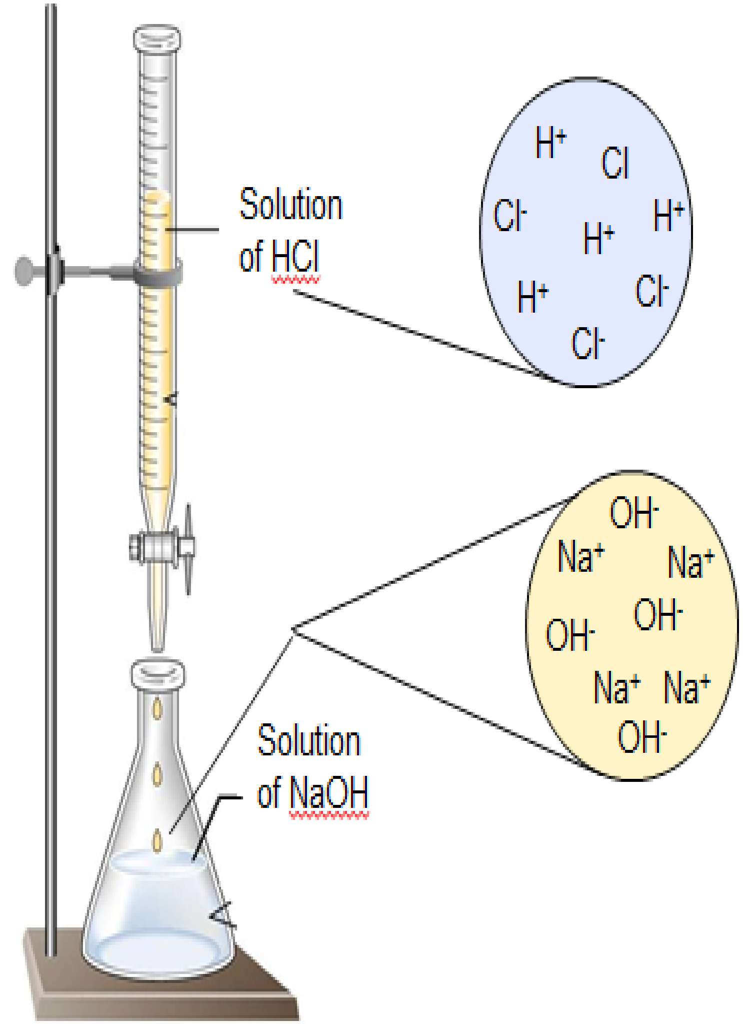


HNO3 + NaOH → H2O + NaNO3

$$\text{moles } H_3O^+ = \text{moles } OH^-$$
$$M \cdot V \cdot n = M \cdot V \cdot n$$

What is Acid-Base Titration?

the strength of a base can be found with the help of a standard solution of an acid, which is known as alkalimetry.



$$HCl + NaOH \longrightarrow H_2O + NaCl$$

$$\text{moles } H_3O^+ = \text{moles } OH^-$$
$$M{\cdot}V{\cdot}n = M{\cdot}V{\cdot}n$$

What is Acid-Base Titration?

In general, the reaction of an acid with a base produces water and one of a class of compounds called salts.

$$\underset{2\text{ mol}}{2HCl(aq)} + \underset{1\text{ mol}}{Ca(OH)_2(aq)} \longrightarrow \underset{1\text{ mol}}{CaCl_2(aq)} + \underset{2\text{ mol}}{2H_2O(l)}$$

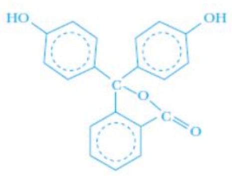
moles H_3O^+ = moles OH^-
$M \cdot V \cdot 2 = M \cdot V \cdot 1$

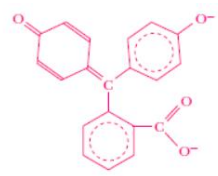
$$\underset{1\text{ mol}}{H_2SO_4(aq)} + \underset{2\text{ mol}}{2NaOH(aq)} \longrightarrow \underset{1\text{ mol}}{Na_2SO_4(aq)} + \underset{2\text{ mol}}{2H_2O(l)}$$

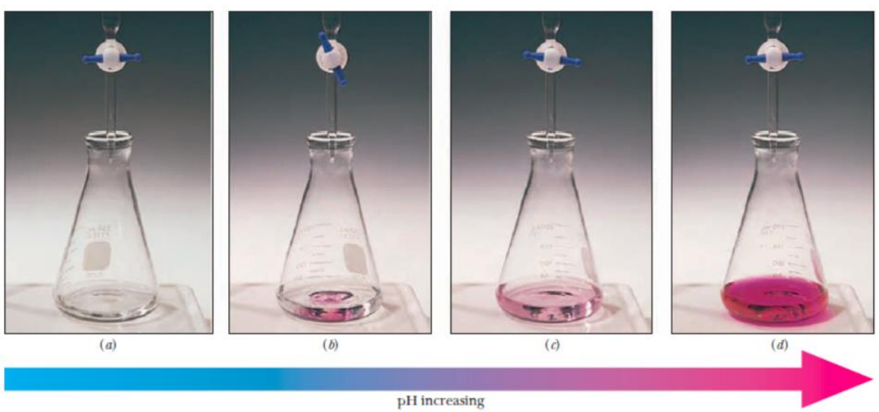
moles H_3O^+ = moles OH^-
$M \cdot V \cdot 1 = M \cdot V \cdot 2$

Indicators

- **Indicators** are often added to the analyte solution to produce an observable physical change (signaling the end point) at or near the equivalence point.
- Large changes in the relative concentration of analyte or titrant occur in the equivalence-point region. These concentration changes cause the indicator to change in appearance.


Acid form, colorless

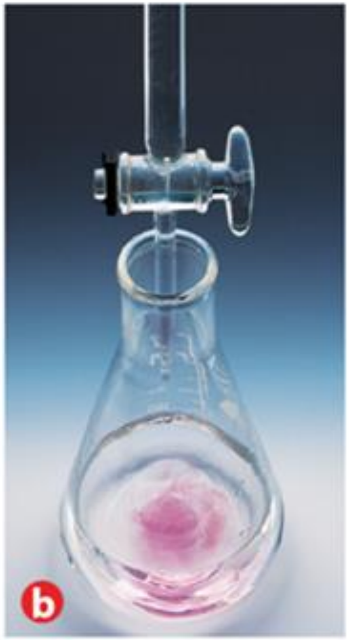

Basic form, pink



Indicators	Acid Colour	Range	Base Colour
Methyl Violet	yellow	0.0 – 1.6	blue
Malachite green	yellow	0.2 – 1.8	blue-green
Cresol red	red	1.0 – 2.0	yellow
Thymol blue	red	1.2 – 2.8	yellow
Benzopurpurin 4B	violet	1.2 – 3.8	red
Orange IV	red	1.4 – 2.6	yellow
Phloxine B	colourless	2.1 – 4.1	pink
2,4-Dinitrophenol	colourless	2.8 – 4.0	yellow
Methyl yellow (in ethanol)	red	2.9 – 4.0	yellow
Bromophenol blue	yellow	3.0 – 4.6	blue-violet
Congo red	blue	3.1 – 4.9	red
Methyl orange	red	3.2 – 4.4	yellow
Bromocresol green	yellow	4.0 – 5.6	blue
alpha-Naphthyl red	red	4.0 – 5.7	yellow
Methyl red	red	4.8 - 6.0	yellow
Litmus (azolitmin)	red	5.0 - 7.0	blue
Bromocresol purple	yellow	5.2 - 6.8	violet
4-Nitrophenol	colourless	5.4 - 6.6	yellow
Bromothymol blue	yellow	6.0 - 7.6	blue
Phenol red	yellow	6.4 - 8.0	red

The titration of an acid with a base

Acid solution with indicator



Added base is measured with a buret.

Color change shows neutralization.

Acid-Base Indicators

A. Finding the equivalence point of a titration

1) **Use a pH meter**

a) **Plot pH versus titrant volume**

b) Center vertical region = equivalence point

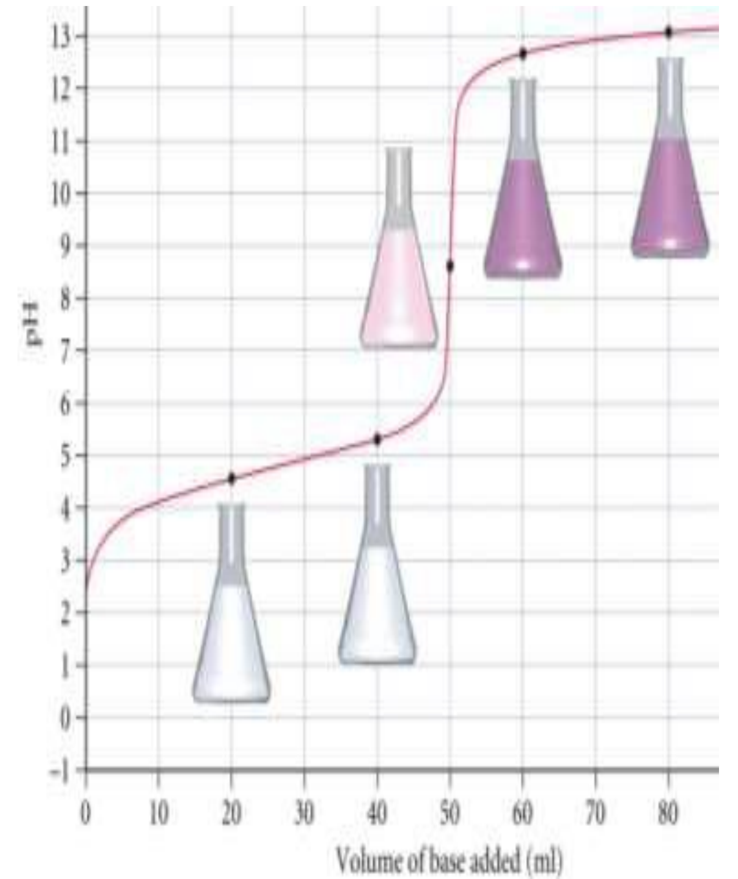
2) **Use an Acid-Base Indicator**

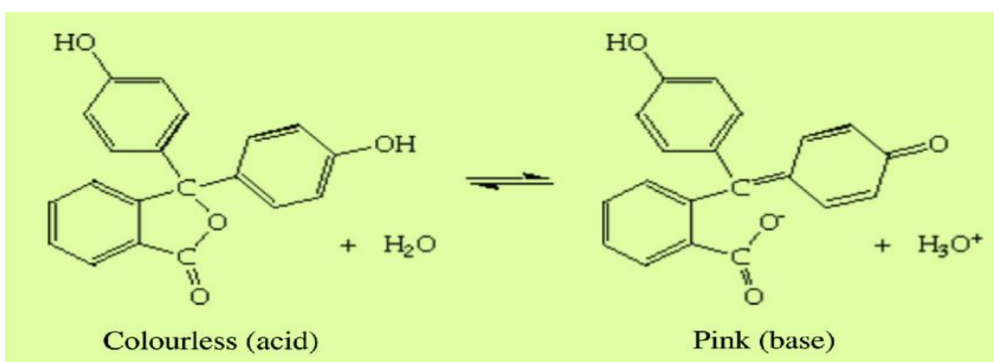
a) **Acid-Base Indicator = molecule that changes color based on pH**

b) Choose an indicator that changes color at the equivalence point

c) End Point = when the indicator changes color. If you have chosen the wrong indicator, the end point will be different than the eq. pt.

d) Indicators are often Weak Acids that lose a proton (causing the color change) when [OH-] reaches a certain concentration



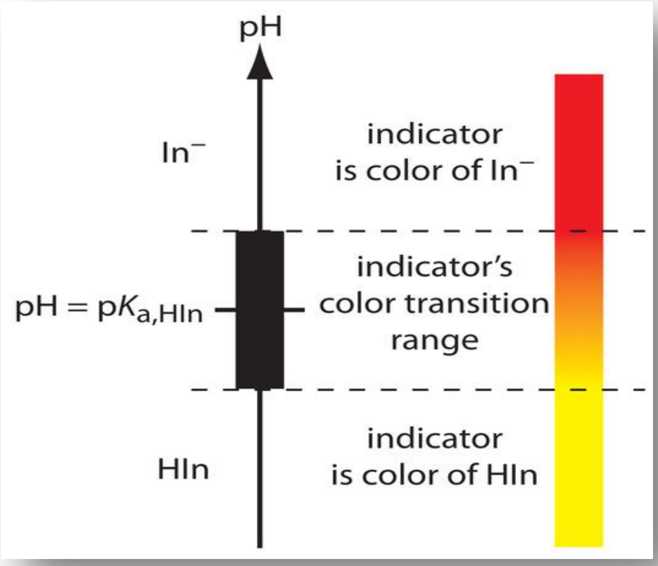


Acid-base indicators

General Many indicators are weak acids and partially dissociate in aqueous solution

$$HIn_{(aq)} \rightleftharpoons H^{+}_{(aq)} + In^{-}_{(aq)}$$

The un-ionised form (HIn) is a different colour to the anionic form (In^{-}).



Apply Le Chatelier's Principle to predict any colour change

In acid

- increase of [H+]
- equilibrium moves to the left to give red undissociated form

In basic

increase of [OH^{-}]
- OH^{-} ions remove H+ ions to form water;
- $H^{+}(aq) + OH^{-}(aq) = H_2O(l)$
- equilibrium will move to the right to produce a blue colour

Summary

In acidic solution (←)

$pH = pK_{in} \pm 1$

$$HIn_{(aq)} \rightleftharpoons H^{+}_{(aq)} + In^{-}_{(aq)}$$

In alkaline solution (→)

the behavior of an acid-type indicator

$$HIn + H_2O \rightleftharpoons In^- + H_3O^+$$

The equilibrium-constant expression for the dissociation of an acid-type indicator takes the form

$$K_a = \frac{[H_3O^+][In^-]}{[HIn]}$$

Rearranging leads to

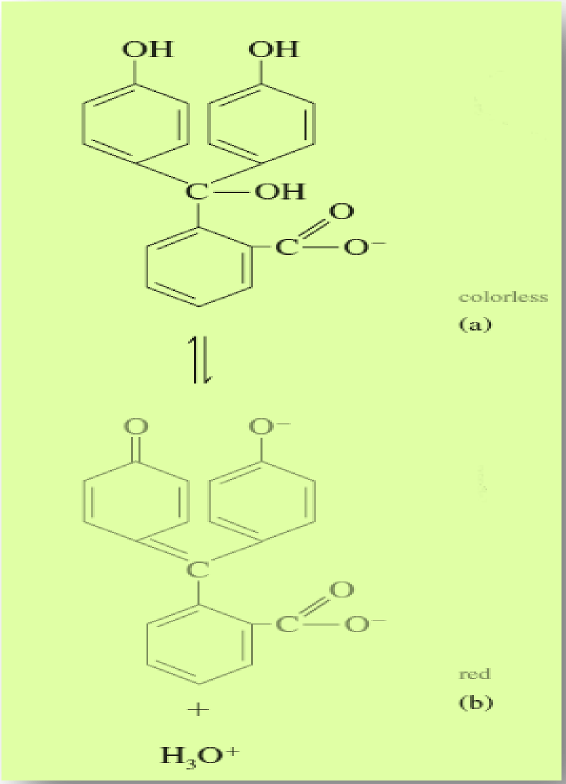
$$[H_3O^+] = K_a \frac{[HIn]}{[In^-]}$$

$$pH = pK_a + \log [In^-]/[HIn]$$

We see then that the **hydronium ion** is proportional to the **ratio** of the **concentrationof the acid** form to the **concentration of the base form** of the indicator

The equilibrium for a base-type indicator

$$In + H_2O \rightleftharpoons InH^+ + OH^-$$



Color change and molecular modes for phenolphthalein.
(a) Acidic form after hydrolysis of the lactone form.
(b) Basic form.

the behavior of an acid-type indicator

- we can write that the average indicator, HIn, exhibits its pure acid color when $\frac{[HIn]}{[In^-]} \geq \frac{10}{1}$
- and its base color when $\frac{[HIn]}{[In^-]} \leq \frac{1}{10}$

$$pH = pK_a \pm 1$$

$$pH = pK_a + \log(1/10) = \mathbf{pK_a - 1}$$
$$pH = pK_a + \log(10/1) = \mathbf{pK_a + 1}$$

$$[H_3O^+] = K_a \frac{[HIn]}{[In^-]} \longrightarrow [H_3O^+] = 10K_a \quad \textbf{or} \quad [H_3O^+] = 0.1\,K_a$$

- Most indicators require a transition range of about 02 pH units.
- The p*Ka* of the indicator should be close to the pH of the equivalence point.
- The human eye is not very sensitive to color differences in a solution containing a mixture of HIn and In. particularly when the ratio **[HIn]/[In2]** is greater than about **10** or smaller than about **0.1**. **Because of this restriction**.