Indicators in chemistry

According to Ostwald Theory of acid-base indicator, an acid-base indicator is a weak organic acid or weak organic base which remains partially dissociated/protonated in aqueous solution and of which, ionised and unionised forms possess different colour. If HI_n be an indicator (a weak acid) then its dissociation may be represented as:

$$\underset{\substack{\text{Acid}\\\text{Colour A}}}{HI_n} \qquad \underset{\substack{\text{Base}\\\text{Colour B}}}{H^+ + I_n^-}$$

The dissociation constant of an acid indicator is called indicator constant and is denoted by the symbol K_{in},

$$[H^+] = K_{HIn} \times \frac{[HIn]}{[In^-]} \qquad -\log[H^+] = -\log K_{HIn} - \log\frac{[HIn]}{[In^-]}$$

$$\therefore \quad \mathbf{pH = pK_{HIn} + \log\frac{[In^-]}{[HIn]}},$$

$$\mathbf{pH = pK_{HIn} + \log\frac{[Ionised\ form]}{[Unionised\ form]}}$$

Upon decreasing the pH of solution containing the indicator, the dissociation equilibrium shifts towards left and the ratio $[I_n^-]/[HI_n]$ decreases and at certain ratio, the colour A(colour of the acidic form of the indicator dominates over the colour B (colour of the basic form of the indicator). Contrary to this at certain high pH the ratio $[I_n^-]/[HI_n]$ becomes high enough to push colour B to dominate over colour A. In between the two extreme ratios the indicator displays intermediate colour. If the minimum pH = x at which colour A predominates over colour B and the maximum

pH = y at which colour B predominates over colour A, then x – y is known as pH range of the indicator.

Types of indicators:

1) **Acid base indicators:** Used in neutralization reactions

   Change their colour depending on pH of solution. e.g. Phenolphthalein, Methyl red, litmus etc.

2) **Redox indicators:** Used in oxidation – reduction reactions.

   Colour changes with the change of emf e.g., $KMnO_4$, N-phenyl anthranilic acid.

3) **Adsorption indicators:** Change of colour due adsorption of a substance on its surface.

4) **Radioactive indicators:** Used in the study of variety of reactions as tracer.

   Their presence is detected by suitable devices. e.g., D^2, O^8, I^{127}etc.

1 g equivalent acid neutralizes 1g equivalent base completely. But in practice, there is no any visible indication that the reaction is complete. Indicators do the job pretty well. They show a variation in their colour between certain pH limits, called indicator range or pH range.

Features of a Good Indicator:

- It should change the colour at a pH which falls in proximity to the end point for a given reaction.
- Colour change should be very sharp.
- Colour should be stable and brilliant.
- The two colours of an indicator should be contrasting so that they can easily be distinguished.

Indicators	pH range	Colour in	
		Acidic	Basic
Methyl orange	3.1 – 4.5	Pink	Yellow
Methyl red	4.2 – 6.3	Red	Yellow
Litmus	5.4 – 7.5	Red	Blue
Phenolphthalein	8.0 – 9.8	Colourless	Colourless
Thymolphthalein	9.3 – 10.5	Colourless	Blue

Internal indicator: Added into the titration mixture before titration. e.g., Phenolphthalein, N–Phenyl anthranilic acid, Starch + KI etc.

External indicator: Only a small fraction of the reaction mixture is taken out and checked for end point by adding the indicator e.g., $K_3[Fe(CN)_6]$.

Self indicator : When any of the titrant itself changes colour during a titration, there is no need to use other external substances. e.g., $KMnO_4$ in redox reactions decolourises at end point.

Titration	Indicator used
Strong acid Vs strong base	Phenolphthalein, methyl red Methyl orange, methyl red
Strong acid Vs weak base	Phenolphthalein, thymolphthalein
Weak acid Vs strong base	No suitable indicator (carried out using conductivity methods)
Weak acid Vs weak base	

Universal Indicator (Multiple Range Indicator)

It is a mixture of certain indicators in a definite proportion, which shows different colour changes over a wide range of pH.

Common universal indicator is prepared by dissolving

1 g phenolphthalein
2 g Methyl orange
3 g Methyl yellow
4 g Bromothymol blue
5 g Thymol blue

} In 500 mL absolute ethanol and then adding NaOH solution till it turns yellow.

It's colour change ranges are:

pH	2	4	6	8	10
Colour	Red	Orange	Yellow	Green	Blue