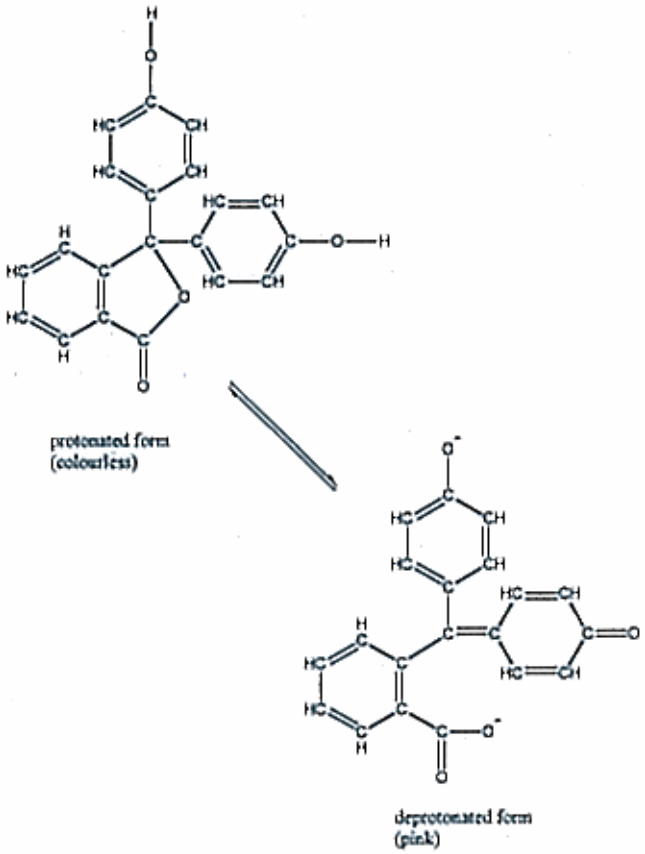
Chemical Indicators for Acid-Base Titrations

Phenolphthalein is an example of a substance whose colour depends on whether it is in its protonated form or its de-protonated form.



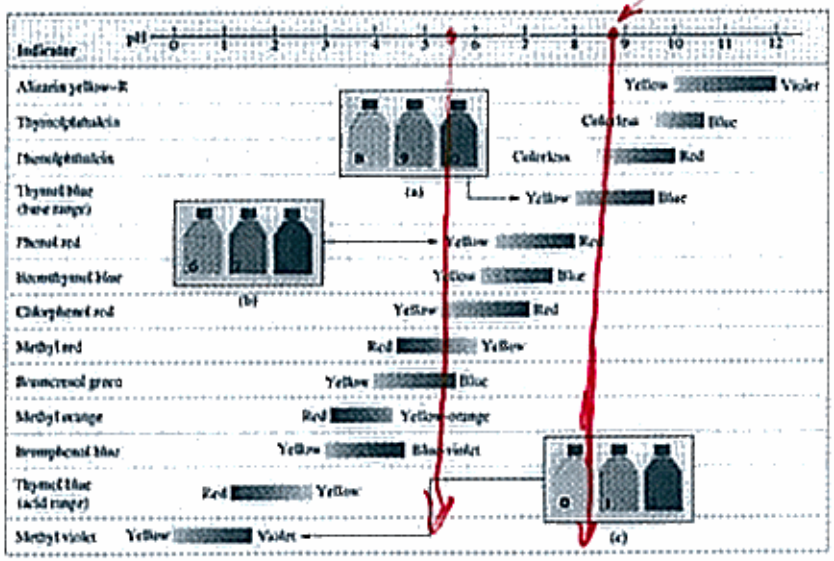
Consider the equilibrium involving the protanated and unprotonated forms of phenolphthalein in aqueous solution:

$$H_2In(aq) + 2\,H_2O(l) \rightleftharpoons In^{2-}(aq) + 2\,H_3O^+(aq)$$

In an acid-base titration, we add a small amount of phenolphthalein to the sample being titrated. Therefore, the indicator is a minor component of the solution (i.e. does not affect the pH) and the equilibrium above responds to the pH of the solution (as determined by the more abundant components of the solution).

Chemists have designed a number of different chemical indicators. Each indicator has its own transition interval. (See Figure 18-8 of the text.)

pH = 8.8



Want pH of solution at equivalence to lie within the transition interval.

As an example, consider phenolphthalein. It turns from colourless to pink in the pH range 8-10. Therefore, phenolphthalein is a suitable indicator for a titration if the pH at equivalence is between pH = 8.0 and pH = 10.0.

35

Example: Examine the titration curves on page 34. Select an appropriate indicator for each titration.

$CH_3COOH + NaOH \Rightarrow$ phenolphthalein or thymol blue

pH ≈ 8.8

at equivalence

$(CH_3)_3N + HCl \Rightarrow$ methyl red is best

pH ≈ 5.5

Concluding Remarks

For some reason, most students struggle with the concepts introduced in this module. If you are one of these students, then you may have focused too much on the details and not enough on the basic concepts!

The difference between the problems is what conc'ns go into the first row of the ICE table.

In order to help you master the basics, I've decided to include a couple of pedagogical examples and a fairly extensive list of review questions.

Example: When ~~it is~~ is it appropriate to set up and use the following equilibrium to calculate the pH of the solution?

$$CH_3COOH(aq) + H_2O(l) \rightleftharpoons CH_3COO^-(aq) + H_3O^+(aq)$$

- dissolving CH_3COOH in water
- dissolving CH_3COOH & CH_3COONa in water
- dissolving CH_3COOH & HCl (strong acid) in water
- "partial neutralization" of CH_3COOH with NaOH (i.e. before the equivalence pt. in titration of CH_3COOH with NaOH)

Example: ~~When it is~~ is it appropriate to set up and use the following equilibrium to calculate the pH of the solution?

$$CH_3COO^-(aq) + H_2O(l) \rightleftharpoons CH_3COOH(aq) + OH^-(aq)$$

- dissolve CH_3COONa in water
- dissolve CH_3COOH and CH_3COONa in water
- complete neutralization of CH_3COOH by NaOH (i.e. at equiv. pt. of titration of CH_3COOH by NaOH)
- dissolve CH_3COOH and "excess" NaOH in water (past equivalence point)

Make sure you can answer the questions on the following pages. Answer the questions in your own words! Add your own questions to the list.

CB's study questions for Module 4:

What is an acid? a base?

What is the difference between a strong acid and a weak acid?

What are the common strong acids? What are the common strong bases?

What is meaning or significance of K_a? What is meaning or significance of K_b?

How is the % ionization of a weak acid related to the initial concentration of the weak acid?

What factors should be considered to decide whether a salt is acidic, basic or neutral?

Why can some metal ions make a solution acidic?

What is a conjugate acid-base pair? How is the acid strength of HA related to the base strength of A^-?

Why don't ions such as Cl^-, Br^-, I^-, NO_3^- and ClO_4^- have any affect on pH of an aqueous solution?

How does the addition of NaA affect the % ionization of HA, a weak acid, in water?

How does the addition of strong acid (e.g. HCl) affect the % ionization of HA, a weak acid, in water?

How does the addition of a strong base (e.g. NaOH) affect the % ionization of B, a weak base, in water?

What is a buffer solution?

Why is a buffer able to resist changes in pH even when strong acid is added?

How do I select the components for preparing a buffer of a desired pH?

After having selected an acid-base pair for preparing a buffer, what are two different approaches for obtaining the desired buffer ratio?

What chemical reaction occurs when I mix weak acid and strong base? What equilibrium should I set up to calculate the final pH if I mix a large amount of weak acid and a smaller amount of strong base together in the same solution?

What equilibrium should I set up for calculating pH if

(a) I dissolve a salt, NaA, in water (when I know that HA is a weak acid)

A list of study questions forces you to:

- be a critical and active reader when reviewing your lecture notes and examples from class
- think in your own words
- focus on concepts (i.e. on chemistry) rather than on calculations

You can se this approach for studying in all of your courses!!

(b) *I mix a large amount (e.g. 0.5 mol) of a weak acid HA and a smaller amount of strong base (e.g. 0.1 mol NaOH) together in solution?*

(c) *I mix a small amount (e.g. 0.1 mol) of a weak acid and a larger amount of strong base (e.g. 0.5 mol NaOH)*

(d) *I mix equal amounts of HA and NaOH together in solution*

(e) *I have not yet reached the equivalence point in a titration of HA, a weak acid, with NaOH*

(f) *I have reached the equivalence point in a titration of HA, a weak acid, with NaOH*

(g) *I am past the equivalence point in a titration of HA, a weak acid, with NaOH*

(h) *I add a small amount of strong base (e.g. 0.05 mol NaOH) to a solution containing 0.100 mol HA and 0.150 mol NaA?*

(i) *I add a small amount of strong acid (e.g. 0.005 mol HCl) to a solution containing 0.100 mol HA and 0.150 mol NaA*

What does the titration curve look like when a weak acid (HA) is titrated with strong base (e.g. NaOH)?

How does the composition of the solution change when a weak acid (HA) is titrated with strong base (e.g. NaOH)?

What does the titration curve look like when a weak base (B) is titrated with strong acid (e.g. HCl)?

How does the composition of the solution change when a weak base (B) is titrated with strong acid (e.g. HCl)?

What are the primary components in the solution at the equivalence point in the titration of a weak acid (HA) with strong base (e.g. NaOH)? Is the solution acidic, basic or neutral at the equivalence point? Why?

What are the primary components in the solution at the equivalence point in the titration of a weak base (B) with strong acid (e.g. HCl)? Is the solution acidic, basic or neutral at the equivalence point? Why?

How do I select an appropriate indicator for an acid-base titration?

How do I calculate the pH of an aqueous solution of a weak polyprotic acid, H_2A ?

What are the mass and charge balance equations for 0.10 mol L^{-1} H_2A, given that H_2A is a weak acid? What about 0.10 mol L^{-1} NaHA?

How do I decide, without any pH calculations, whether a 0.10 mol L^{-1} NaHA(aq) is acidic, basic or neutral, given that H_2A is a weak polyprotic acid?

What structural factors affect the strength of a binary acid?

What structural factors affect the strength of an oxo-acid?