Acid-Base Indicators

An acid-base indicator is a chemical species (usually a weak acid) that changes colour over a specified range of pH (this is the operational definition of an indicator)

Its weak acid form has a different colour than its conjugate base form. The observed colour depends on the dominant species present, - acid or base.

The general equilibrium for acid-base indicators is as follows:

(* 'In' is the generic symbol for indicator)

$$HIn\ (aq) + H_2O \leftrightarrow H_3O^+\ (aq) + In^-\ (aq)$$
Colour A Colour B

In an acid, there would be lots of H_3O^+, so it would shift left - colour A

In a base, there would be lots of OH^-, so it would shift right - colour B (OH^- will react with the hydronium ions, decreasing them and causing it to shift right)

To determine an appropriate acid-base indicator for an acid-base titration, you must **know the equivalence point and use the indicator table**.

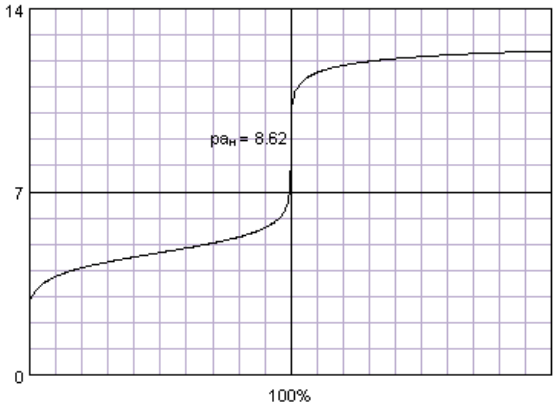
Simply choose the indicator whose pH range would include the pH of the equivalence point .

Example: A titration is known to have a pH of 6.7 at the equivalence point, which indicator(s) could you use?

Answer: check your table, you could use:

Bromothymol blue (HBb)
Chlorophenol red (HCh)
Litmus (HLt)
Phenol red (HPr)

You should also be able to pick an indicator according to a titration curve.
Example: which indicator could be used with this titration?



Simply find the equivalence point and match it with the table - equivalence point pH about 8.6
Therefore you could use:

Thymol blue (Htb)
Phenolphthalein (HPh)

You should also be able to identify the pH of a solution given the colour of the solution or the colour of the solution given the pH.

Example: A solution of unknown pH turns yellow when orange (IV) is placed in it. When methyl orange is added to it, it turns red. What is the pH?

Look at your table

orange (IV) red(1.4)-yellow(2.8)
Yellow is at upper end, so pH >2.8

methyl orange red(3.2)-yellow(4.4)
Red at lower end, pH < 3.2

Therefore pH lies between 2.9 and 3.1

You should also be able to answer questions dealing with the indicators and Le Châtelier's Principle

Example : Phenol red indicator (HPr) had a yellow colour below pH 6.6 and a red colour above 8.0

Write a net ionic equation for the reaction between phenol red and water

Answer: $HPr\ (aq) + H_2O\ (l) \leftrightarrow H_3O^+\ (aq) + Pr^-\ (aq)$

Predict the position of the indicator equilibrium when a drop of indicator is added to a flask containing 50.0 mL of 0.100 nitric acid

Answer: The high concentration of H_3O^+ will react with the Pr^- to form HPr (aq), shifting equilibrium to the left - this will turn the colour yellow

How would you get an opposite shift?
Answer: add a base, this will react with the hydronium ions, decreasing them and causing it to shift right, [HPr] will decrease, and [Pr^-] will increase. The solution will turn red.

Reaction Mechanisms for Multi-proton Transfer

Remember doing a reaction mechanism ? It shows the steps in a reaction. We add the steps together and cancel out what appears as both a reactant and a product. We can see how things progress in the reaction mechanisms for situations when we have an acid or base that is 'poly'

Here's what you do:

1. Drop spectator ions
2. The number of steps should equal the number of protons donated or accepted.
3. The products in the first and second steps are the reactants in the second or third steps.
4. Remember the steps are sequential - one after the other

$Na_3BO_3\ (aq) + HCl\ (aq) \rightarrow H_3BO_3\ (aq) + NaCl\ (aq)$

First of all, drop the spectator ions (Na^+, Cl^-) so BO_3^{3-} is the base and remember strong acids are written as H_3O^+

$BO_3^{3-}\ (aq) + H_3O^+\ (aq) \rightarrow HBO_3^{2-}\ (aq) + H_2O\ (l)$
$HBO_3^{2-}\ (aq) + H_3O^+\ (aq) \rightarrow H_2BO_3^-\ (aq) + H_2O\ (l)$
$H_2BO_3^-\ (aq) + H_3O^+\ (aq) \rightarrow H_3BO_3\ (aq) + H_2O\ (l)$

$BO_3^{3-}\ (aq) + 3\ H_3O^+\ (aq) \rightarrow H_3BO_3\ (aq) + 3H_2O\ (l)$

three steps = three proton transfers

Example:
The concentration of a solution of arsenic acid, $H_3AsO_4\ (aq)$ is determined by titrating it with sodium hydroxide, NaOH (aq)

(i) Write the equation for the step(s) and the overall reaction

(ii) Draw and label a titration curve