Titration Curves (A2)

There are 4 types of characteristic pH curves:

I. Strong acid with strong base

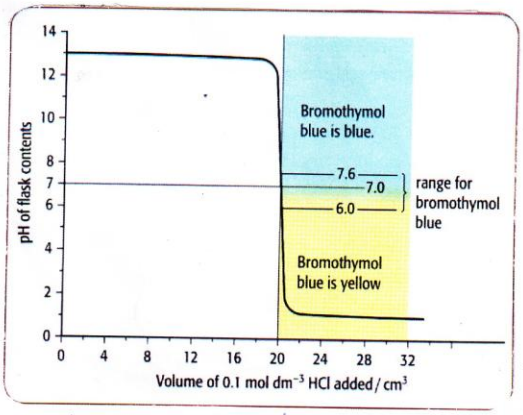
II. Strong acid with weak base

III. Weak acid with strong base

IV. Weak acid with weak base.

I. Strong acid with strong base

Titration curve shows the pH changes when 0.100 mol dm^{-3} sodium hydroxide is titrated with 0.100 mol dm^{-3} hydrochloric acid in the presence of bromothymol blue indicator:



A strong acid – strong base titration

The graph shows that:

- a sharp fall in the graph line between pH 10.5 and pH 3.5, in this region tiny additions of H^+ ions result in a rapid change in pH.
- a midpoint of the steep slope at pH 7.
- the midpoint of the sharp fall corresponds to the point at which the H^+ ions in the acid have exactly reacted with the OH^- ions in the alkali. This is the end-point of the titration.
- bromothymol blue indicator changed from blue to yellow over the range 7.6 to 6.0 when the slope is steepest.

Because there is a sharp change in pH over the region pH 3.5 to 10.5, other indicators which change colour within this region also suitable.

Suitable indicators – colour change range between pH 3.5 to 10.5.

Indicator	pH range	End-point
bromocresol green	3.8–5.4	4.7
methyl red	4.2–6.3	5.1
phenolphthalein	8.2–10.0	9.3

Non first choice indicators – although the midpoint of their colour range is just within the range of the steep slope, their full range is outside the lower limit of 3.5.

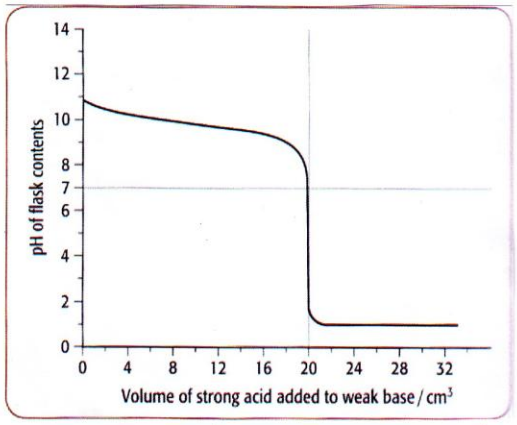
Indicator	pH range	End-point
methyl orange	3.2–4.4	3.7
bromophenol blue	2.8–4.6	4.0

Non suitable indicators – have midpoints in their colour ranges at pH values which do not correspond with the steepest point of the titration curve.

Indicator	pH range	End-point
methyl violet	0.0–1.6	0.8
methyl yellow	2.9–4.0	3.5
alizarin yellow	10.1–13.0	12.5.

II. Strong acid with weak base

Titration curve shows the pH changes when 0.100 $mol dm^{-3}$ aqueous ammonia is titrated with 0.100 $mol dm^{-3}$ nitric acid:



A typical strong acid – weak base titration

The graph shows that:

- a sharp fall in the graph line between pH 7.5 and pH 3.5.
- the midpoint of the steep slope is about pH 5.0

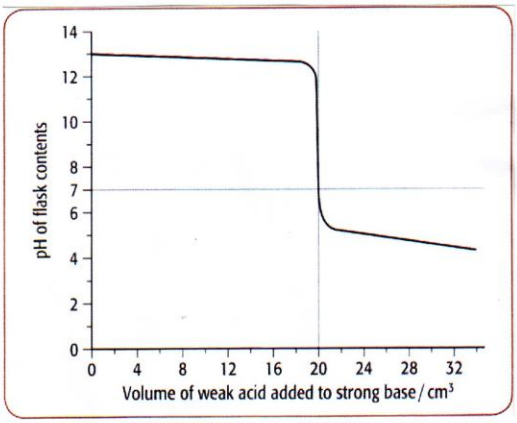
Methyl red is a suitable indicator for this titration because it changes colour between pH 4.2 and pH 6.3, values which correspond with the region of sharpest pH change.

Phenolphthalein would not be a suitable indicator to use because it only changes colour in alkaline region (pH 8.2 to 10.0) which do not correspond to the sharp pH change.

The phenolphthalein would change colour only gradually as more and more acid is added, instead of changing suddenly on the addition of a single drop at the end-point.

III. Weak acid with strong base

Titration curve shows the pH changes when 0.100 mol dm^{-3} aqueous sodium hydroxide is titrated with 0.100 mol dm^{-3} benzoic acid:



A typical weak acid - strong base titration

The graph shows that:

- a sharp fall in the graph line between pH 11 and pH 7.5.
- the midpoint of the steep slope is at about pH 9

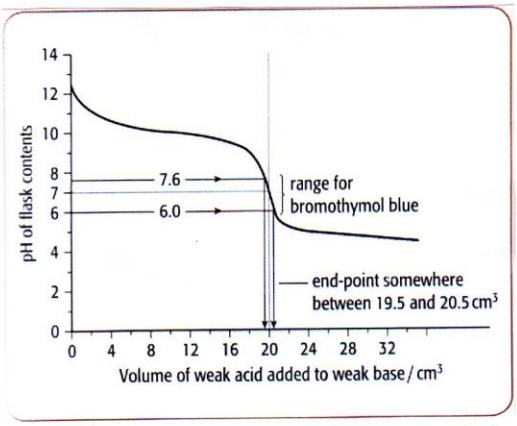
There is a sharp change in pH over the region pH 7.5 to 11.0, phenolphthalein is a suitable indicator to use in this titration.

Phenolphthalein changes colour between pH 8.2 and pH 10.0, values which correspond with the region of sharpest pH change.

Methyl orange would not be a suitable indicator to use because it only changes colour in acidic regions which do not correspond to the sharp pH change.

Weak acid with weak base

Titration curve shows the pH changes when 0·100 mol dm^{-3} aqueous ammonia is titrated with 0·100 mol dm^{-3} aqueous benzoic acid:



A typical weak acid – weak base titration

The graph shows that there is no sharp fall in pH values as titration was carried out.

No acid-base indicator is suitable to determine the end-point of this reaction.

In the example shown, indicator bromothymol blue:

- starts changing colour when 19.50 cm^3 of acid have been added.
- finishes changing colour when 20.50 cm^3 of acid have been added.

Such a gradual colour change on addition of acid is not acceptable when accuracy of reading the end-point to the nearest 0.05 cm^3 is required.

Exercise 1

Suggest a suitable indicator to find the end-points of the reactions between:

i) 0.0500 mol dm^{-3} nitric acid and 0.0500 mol dm^{-3} aqueous ammonia

ii) 2.00 mol dm^{-3} aqueous sodium hydroxide and 1.00 mol dm^{-3} sulfuric acid

iii) 0.00500 mol dm^{-3} aqueous potassium hydroxide and 0.00500 mol dm^{-3} butanoic acid.

Workings

i) strong acid – weak base titration

steepest part of the pH curve – 7.5 to 3.5.

indicators with suitable colour change range: bromocresol green (3.8–5.4), methyl red (4.2–6.3) and bromothymol blue (6.0–7.6)

ii) strong acid – strong base titration

steepest part of the pH curve – 10.5 to 3.5.

suitable indicators: methyl orange (3.2–4.4), bromophenol blue (2.8–4.6), bromocresol green (3.8–5.4), methyl red (4.2–6.3), bromothymol blue (6.0–7.6) and phenolphthalein (8.2–10.0)

iii) weak acid – strong base titration

steepest part of the pH curve – 11.0 to 7.5.

suitable indicators — phenolphthalein

Exercise 2

Suggest why phenolpthalein would not be a suitable indicator to use to find the end-point when 0.0100 moldm^{-3} hydrochloric acid is titrated against 0.0100 moldm^{-3} urea, a weak base.

Workings

strong acid – weak base titration.

steepest part of the pH curve – 3.0 to 9.0.
(in acidic regions)

phenolphthalein has colour change range (pH 8.0 – 10.0) and midpoint above pH 9 (End-point 9.3)

This is a pH value which does not correspond with the steepest point of the pH curve.