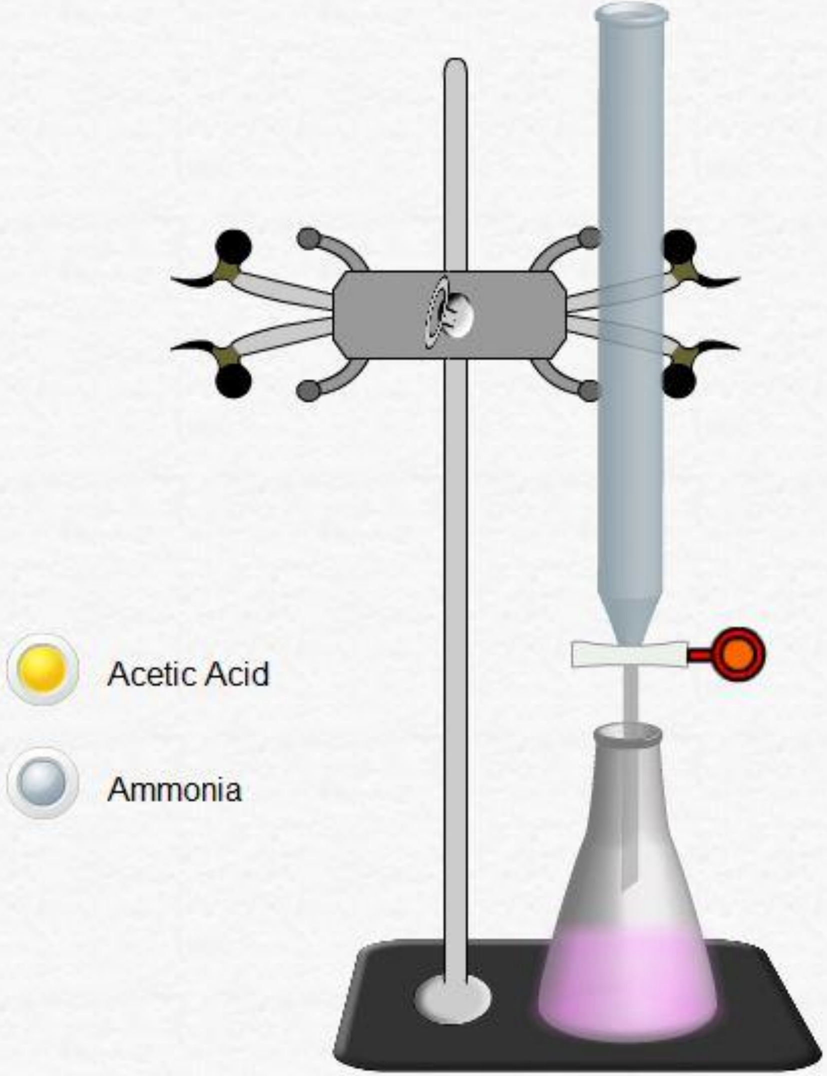
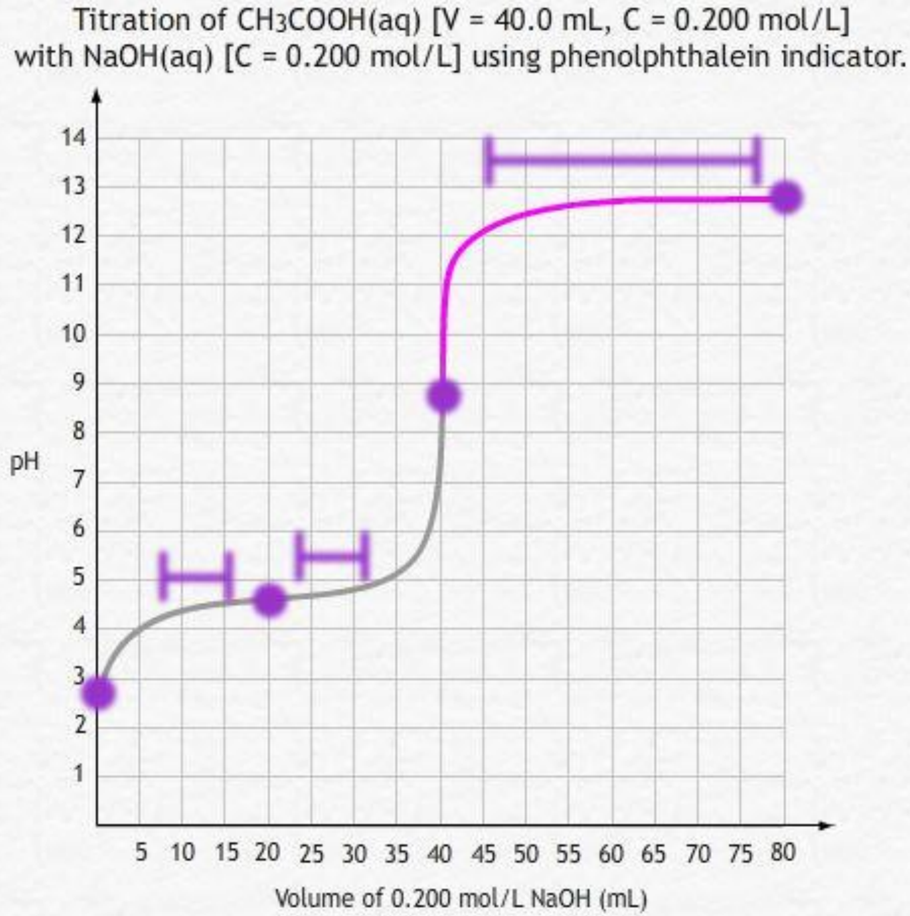




Chemistry AS 91392

Titration Calculations

Steps to drawing a titration curve

Question:
20.0 mL of 0.0896 mol L^{-1} ethanoic acid is titrated with 0.100 mol L^{-1} sodium hydroxide up to a total of 30mL
p*K*a (CH_3COOH) = 4.76

In order to graph a titration curve there are a number of points that need to be calculated in their specific order

1. The pH before any base is added
2. The volume of the base at equivalence point
3. The volume of base when pH = pKa
4. The pH at equivalence point
5. The pH after all of the base 30mL has been added

Step One: Start pH

Find the pH of:

0.0896 $molL^{-1}$ of $CH_3COOH_{(aq)}$ $pK_a = 4.76$

$$CH_3COOH_{(aq)} + H_2O_{(l)} \leftrightharpoons CH_3COO^-_{(aq)} + H_3O^+_{(aq)}$$

$$K_a = \frac{[CH_3COO^-]\ [H_3O^+]}{[CH_3COOH]} = 10^{-pKa}$$

$$= 10^{-4.76}$$

$$= 1.74 \times 10^{-5}$$

Assume
1. $[CH_3COO\text{-}] =$ $[H_3O^+]$
2. $[CH_3COOH] =$ 0.0896 $molL^{-1}$

Step One: Start pH

Equilibrium expression of acid dissociation in water

$$K_a = \frac{[CH_3COO^-]\ [H_3O^+]}{[CH_3COOH]}$$

$$1.74 \times 10^{-5} = \frac{[H_3O^+]^2}{0.0896 \text{ mol L}^{-1}}$$

Rearrange:

$$\sqrt{1.74 \times 10^{-5} \times 0.0896 \text{ mol L}^{-1}} = [H_3O^+]$$

$$1.25 \times 10^{-3} \text{ molL}^{-1} = [H_3O^+]$$

$$= -\log (1.25 \times 10^{-3} \text{ molL}^{-1})$$

Could also use 10^{-Pka} in formula

pH = 2.90

Step Two:
Volume of equivalence

Calculate the volume of NaOH at the endpoint.

Titration reaction is:

$$CH_3COOH_{(aq)} + NaOH_{(aq)} \rightarrow CH_3COONa_{(aq)} + H_2O_{(l)}$$

$n(CH_3COOH)$ = cV

= 0.0896 mol L^{-1} x 0.0200L

= 1.79 x 10^{-3} mol

n(NaOH) = $n(CH_3COOH)$

= 1.79 x 10^{-3} mol

Volume of acid at start

V(NaOH) = n / c

$$V(NaOH) = \frac{1.79 \times 10^{-3}\ mol}{0.100\ molL^{-1}}$$

From equation 1 mol acid = 1 mole base

V(NaOH) = 17.9mL

Step Three:
Mid-point of Buffer

Calculate the volume of NaOH when pH = pKa

The volume of NaOH at equivalence point is 17.9mL

17.9mL /2 = 8.96mL (x)

pKa = 4.76 (y)

These points intercept on the graph

The pH = pKa when **8.96 mL** of NaOH has been added

The buffer zone will be 1 pH point above and below pH 4.76

Once the curve is drawn this can be sketched as a circle around the area from 3.76 – 5.76 on the line.

Step Four:
pH of equivalence

Calculate the pH at equivalence point.
At the Equivalence point we will have:

1.79×10^{-3} mol of CH_3COONa in (20mL + 17.9mL = 37.9mL) of solution

$$C(CH_3COONa) = \frac{1.79 \times 10^{-3}\ mol}{0.0379L} = 0.0472\ molL^{-1}$$

c = n/V

We need to calculate the pH of a solution of CH_3COONa with this concentration: $0.0472\ molL^{-1}$

Use same mol of conjugate base as base calculated from step 2. as they are produced 1 mol = 1 mol

Step Four:
pH of equivalence

$CH_3COO^-_{(aq)} + H_2O_{(l)} \leftrightharpoons CH_3COOH_{(aq)} + OH^-_{(aq)}$

$$K_b = \frac{1 \times 10^{-14}}{K_a}$$

$$K_b = \frac{1 \times 10^{-14}}{1.74 \times 10^{-5}}$$

$$K_b = 5.75 \times 10^{-10}$$

$$K_b = \frac{[CH_3COOH]\,[OH^-]}{[CH_3COO^-]}$$

Assume

1 $[CH_3COOH] = [OH^-]$

2 $[CH_3COO^-] = 0.0472\ molL^{-1}$

Concentration calculated from previous step c=n/v

Step Four:
pH of equivalence

$$K_b = \frac{[OH^-]^2}{c(\text{conj base})}$$

$$5.75 \times 10^{-10} = \frac{[OH^-]^2}{0.0472\ molL^{-1}}$$

$$\sqrt{5.75 \times 10^{-10} \times 0.0472} = [OH^-]$$

$$5.21 \times 10^{-6}\ molL^{-1} = [OH^-]$$

$[H_3O^+] = K_w/[OH^-]$

$[H_3O^+] = 1 \times 10^{-14} / 5.21 \times 10^{-6}\ molL^{-1}$

$[H_3O^+] = 1.92 \times 10^{-9}\ molL^{-1}$

$pH = -\log (1.92 \times 10^{-9}\ molL^{-1})$

pH = 8.72

Step Five: Final pH

Calculate the pH after 30mL of NaOH has been added.

Since the equivalence point is at 17.9mL of NaOH, this results in an excess of 12.1mL of NaOH

Although the CH_3COONa formed hydrolyses slightly in water, the [OH-] from this reaction is very small compared to the [OH] from the NaOH so we assume all [OH-] comes from NaOH

Total volume of solution = 20mL + 30mL = 50mL

$$C(NaOH) = \frac{12.1mL}{50\ mL} \times 0.100 molL^{-1}$$

Original concentration

This is a dilution calculation

$$= 0.0242\ molL^{-1}$$

New concentration after dilution

(30mL - 17.9mL = 12.1mL)

Step Five: Final pH

NaOH is a strong base

Assume $[OH^-]$ = c(NaOH)

$[OH^-]$ = $0.0242\ molL^{-1}$

$[H_3O^+]$ = $K_w / 0.0242\ molL^{-1}$

$[H_3O^+]$ = $1 \times 10^{-14} / 0.0242\ molL^{-1}$

$[H_3O^+]$ = $4.13 \times 10^{-13}\ molL^{-1}$

pH = $-\log(4.13 \times 10^{-13}\ molL^{-1})$

pH = 12.4

Drawing Curve

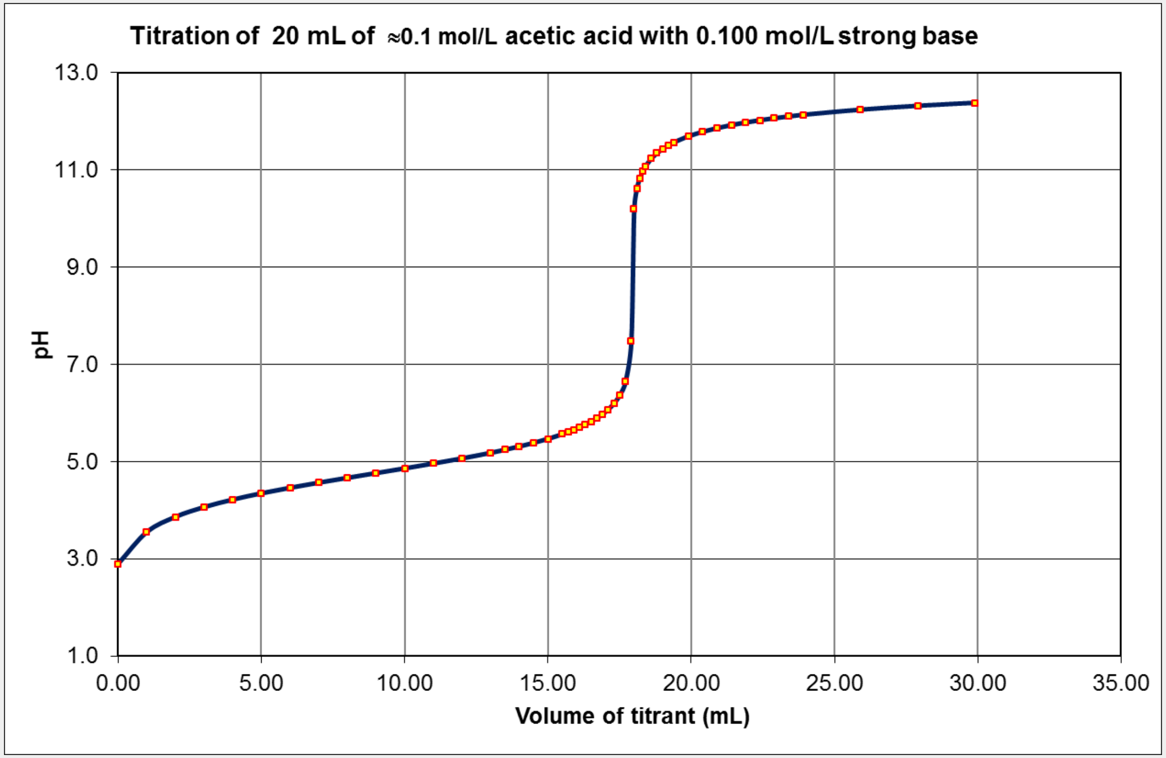
Now we have the key data points:

- ❑ The pH before any Base added = 2.90
- ❑ The volume of NaOH at equivalence point: 17.9 mL
- ❑ The volume of NaOH when pH = pKa: 8.96 mL
- ❑ The pH at equivalence point: 8.72
- ❑ The pH after 30mL of NaOH is added: 12.4

Drawing Curve

Plot these points on a graph

volume	pH
0.00 mL ,	2.90
8.96 mL ,	4.76
17.9 mL ,	8.72
30.0 mL ,	12.4



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