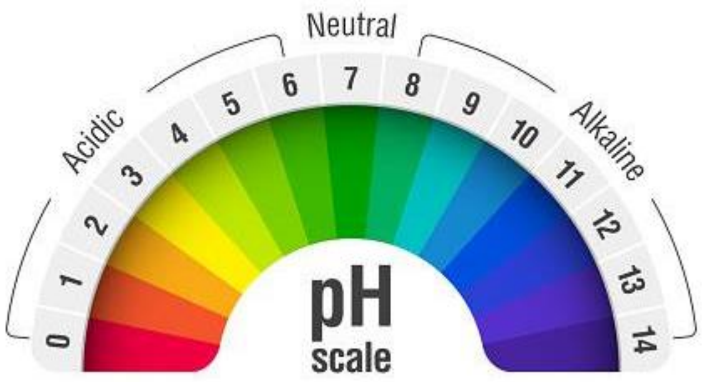
Determination of pKa value of a weak acid

Aim of the experiment:

To determine the pKa value of a weak acid potentiometrically using a pH meter



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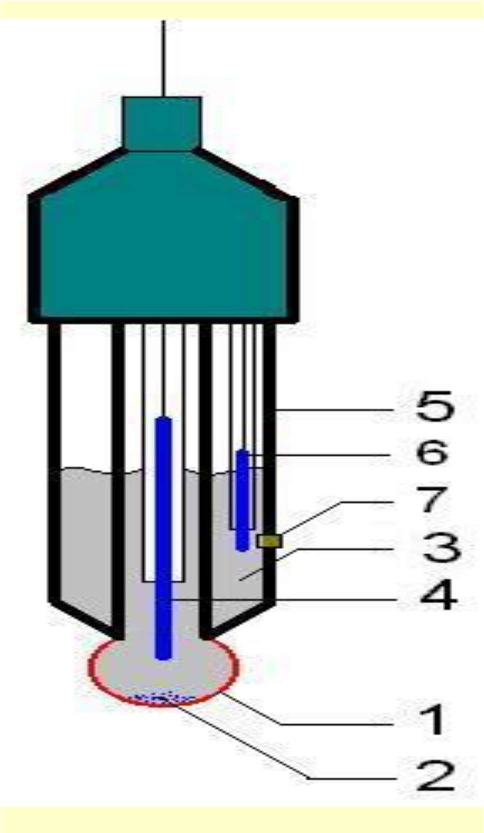
pH indicator electrode - Combined glass electrode



Scheme of typical pH glass electrode

1. a sensing part of electrode,
2. a bulb made from a specific glass sometimes electrode contain small amount of AgCl precipitate inside the glass electrode

3 internal solution, usually 0.1M HCl for pH electrodes

4.internal electrode, usually silver chloride electrode or calomel electrode

5.body of electrode, made from non-conductive glass or plastics.

6.reference electrode, usually the same type as 4

7.junction with studied solution, usually made from ceramics or capillary with asbestos or quartz fiber.

Principle and outline:

A weak acid, like acetic acid dissociates in its aqueous solution only slightly, as follows;

$$CH_3COOH + H_2O \rightleftarrows H_3O^+ + CH_3COO^-$$

The equilibrium constant of dissociation of the acid known as dissociation constant of the acid, Ka is given by:

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

The solution is considered to be very dilute and activity of water in very dilute solutions is assumed to be unity in the above equation.

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

From the above equation, taking – log on both sides:

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

$$\text{i.e. } pH = pKa + \log \frac{[CH_3COO^-]}{[CH_3COOH]}$$

This is Henderson's equation. When acetic acid (titrate) is titrated with NaOH solution (titrant), pH of the titrated solution increases in accordance with the above equation; since concentration of sodium acetate, $[CH_3COO^-]$ increases and concentration of unreacted acetic acid, $[CH_3COOH]$ decreases as the titration progresses. When the acid is half - titrated,

$$[CH_3COO^-] = [CH_3COOH]$$

and hence $pH \equiv pK_a$

That is, pK_a of the acid is pH of the half-titrated acid solution or pH of the titrated solution at half way to the equivalence point or end-point.

Materials Needed:
- pH meter
- Combined pH electrode
- Buffer solutions of known pH (e.g., pH 4)
- Beakers
- Weak acid solution (50 mL)
- Sodium hydroxide (NaOH) solution
- Semi-micro burette

Procedure:

I. **Standardization of pH Meter - Dipping in Buffer:**

- Dip the combined electrode into a beaker containing the buffer solution (e.g., pH 4).
- Connect the electrode to the pH meter.
- Observe the reading on the pH meter. It should correspond to the pH of the buffer solution (pH 4).
- If the reading does not match the known pH of the buffer, adjust the control knob on the pH meter until the display shows the correct pH value.
- Once standardized, the pH meter is ready for use.

II. Potentiometric titration

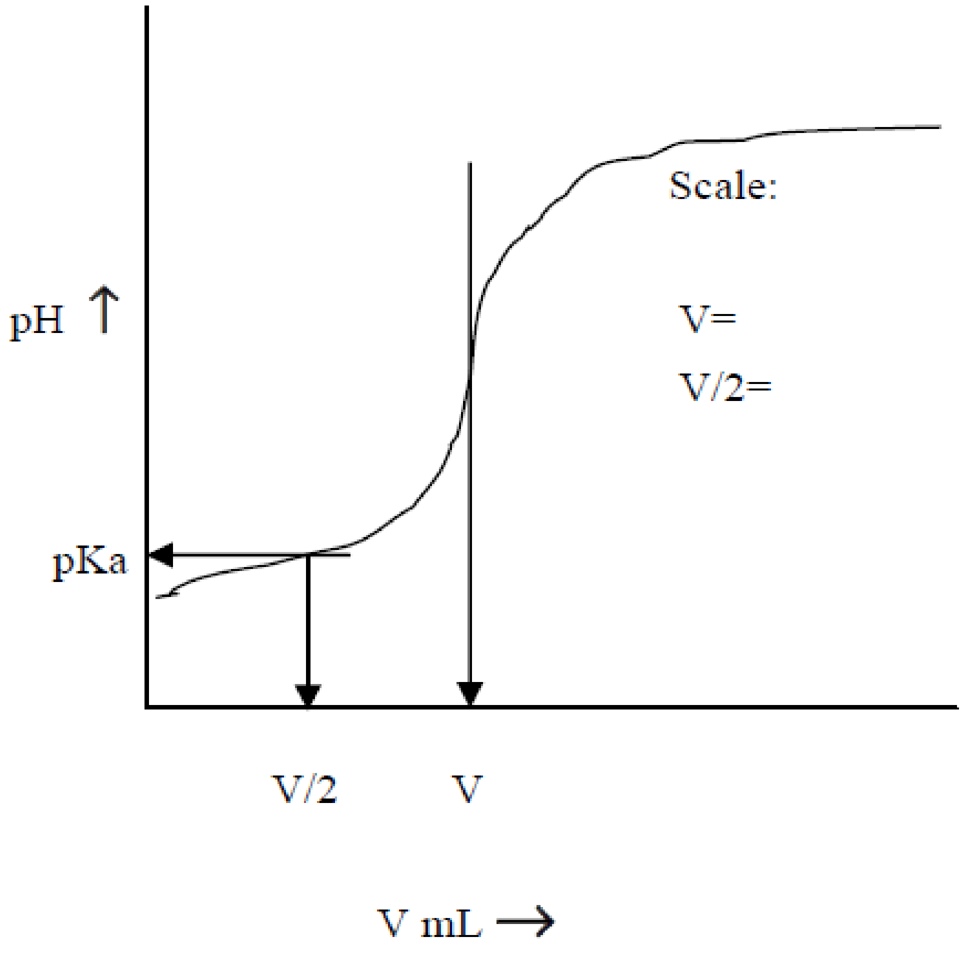
- Pipette 50 mL of the weak acid into a clean beaker.
- Rinse the combined electrode with distilled water and then dip it into the weak acid solution.
- Connect the electrode to the pH meter.
- Record the initial pH of the weak acid solution.
- Using a semi-micro burette, add exactly 1 mL of NaOH to the acid solution.
- Stir the solution gently to ensure proper mixing.
- Measure and record the pH after each addition of NaOH.
- Continue adding 1 mL increments of NaOH and recording the pH until a significant change in pH is observed.
- Continue the titration up to a total of 10 mL of NaOH.
- After reaching 10 mL, freshly pipette out another 50 mL of the weak acid.
- Record the pH after the addition of smaller increments (0.1 mL) of NaOH in the region where large changes in pH were previously observed.
- Continue this process until the change in pH becomes small again.
- Plot the data on a graph with the volume of NaOH on the X-axis and pH on the Y-axis.
- Analyze the graph to identify the inflection point, which corresponds to the pKa of the weak acid.

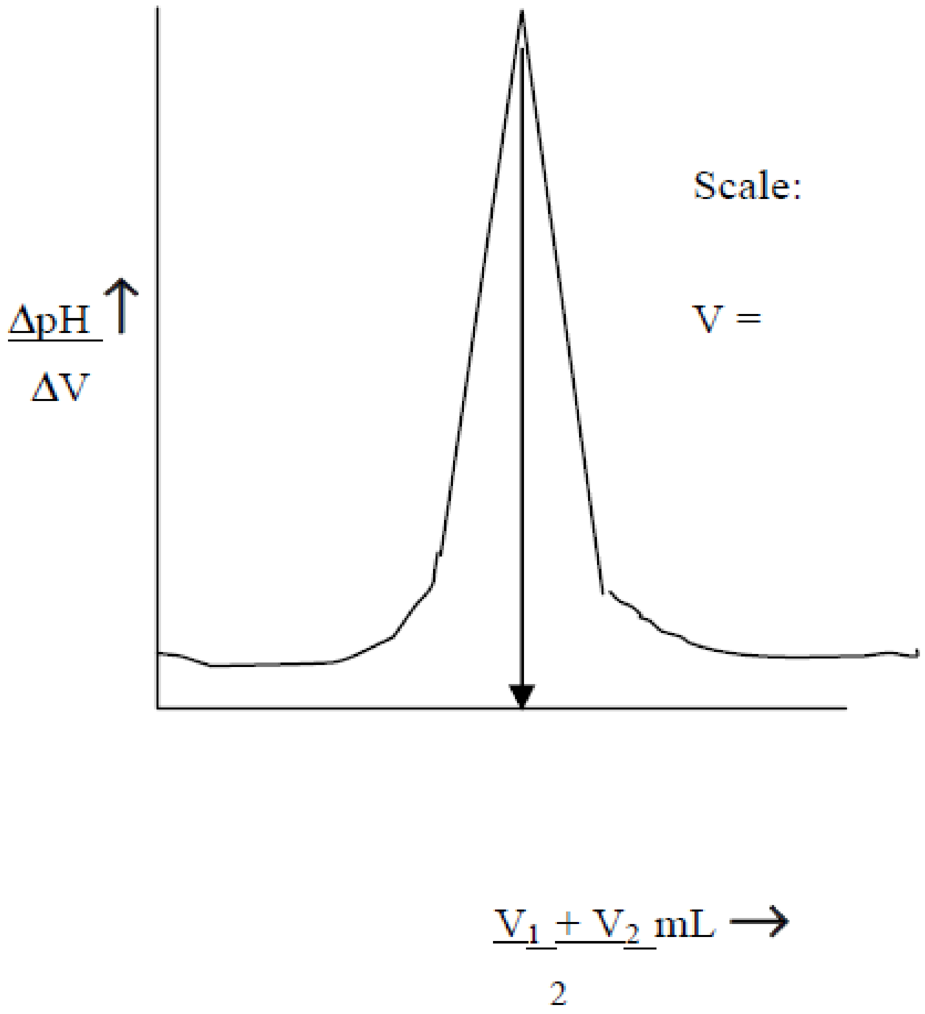
Observation and calculations:

V Vol NaOH mL	pH	ΔV mL	Δ pH	$\frac{\Delta pH}{\Delta V}$	$\frac{v_1 + v_2}{2}$ mL
0.0		--	--	--	--
1.0		1.0			0.5
2.0		1.0			1.5
3.0		1.0			2.5
4.0		1.0			3.5

V Vol NaOH mL	pH	ΔV mL	Δ pH	$\frac{\Delta pH}{\Delta V}$	$\frac{v_1 + v_2}{2}$ mL

Graph:





pKa value of acetic acid =

Applications of pH meter

1. Agriculture
•Soil testing for acidity/alkalinity.
•Optimizing fertilizer use.

2. Environmental Monitoring
•Assessing water quality in ecosystems.
•Detecting pollution levels.

3. Food and Beverage Industry
•Ensuring quality and safety in food products.
•Monitoring fermentation processes in brewing and winemaking.

4. Healthcare and Pharmaceuticals
•Measuring blood and urine pH for diagnostics.
•Controlling pH in drug formulation.

Instrument Calibration and Measurement of pH in water
by pen type pH Meter

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Thank you