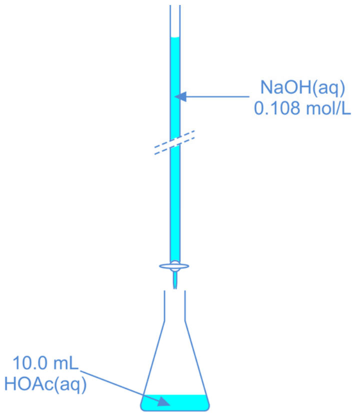
#5

Titration of 10.0 mL HOAc-solution (with unknown concentration) with 0.108 mol/L NaOH(aq). The equivalence point is reached after adding 10.4 mL NaOH.



1. Calculate the original HOAc-concentration.
2. Calculate the pH at the start of the titration (0 mL added).
3. Calculate the pH after adding 5.0 mL NaOH.
4. Calculate the pH after adding 10.4 mL NaOH (EP).
5. Calculate the pH after adding 15.0 mL NaOH.

Solutions

Reaction: **1** HOAc(aq) + **1** NaOH(aq) $\longrightarrow$ H_2O + NaOAc(aq)

1. At the EP the total amount of HOAc has reacted.

   10.4 mL 0.108 mol/L NaOH(aq) contains $10.4\times10^{-3}\text{L}\times0.108\ \frac{\text{mol}}{\text{L}}=1.12\times10^{-3}\ \text{mol}$ of NaOH.

   So the original HOAc-solution also contained 1.12×10^{-3} mol of HOAc.

   The unknown HOAc-concentration was $\frac{1.12\times10^{-3}\ \text{mol}}{10.0\times10^{-3}\ \text{L}}=0.112\ \frac{\text{mol}}{\text{L}}$.

2. At the start we have a HOAc-solution 0.112 mol/L.
   HOAc is a weak acid, partially reacting with water:
   HOAc $\rightleftharpoons$ H^+ + OAc^-

mol/L	HOAc	H^+	OAc^-
Before reaction	0.112	0	0
Δ	−x	+x	+x
After reaction	0.112 – x	x	x

$$K_{a_{HOAc}}=\frac{[H^+]\times[OAc^-]}{[HOAc]}=1.8\times10^{-5}$$

$$\frac{x^2}{0.112-x}=1.8\times10^{-5}$$

$$x^2+1.8\times10^{-5}x-2.0\times10^{-6}=0$$

$$x=0.0014$$

mol/L	HOAc	H^+	OAc^-
After reaction	0.111	0.0014	0.0014

pH = −log 0.0014 = 2.85.

3. After adding 5.0 mL NaOH, containing $5.0\times10^{-3}\text{L}\times0.108\ \frac{\text{mol}}{\text{L}}=5.40\times10^{-4}\ \text{mol}$ of NaOH:

mole	HOAc	NaOH	NaOAc
Before reaction	1.12×10^{-3}	5.40×10^{-4}	0
Δ	-5.40×10^{-4}	-5.40×10^{-4}	$+5.40\times10^{-4}$
After reaction	5.80×10^{-4}	0	5.40×10^{-4}

At this moment, we have a buffer solution: HOAc / OAc^{-}.

$$pH_{buffer}=pK_{a_{HOAc}}+\log\frac{[B]}{[A]}=4.75+\log\frac{\frac{5.40\times10^{-4}\text{mol}}{0.015\ \text{L}}}{\frac{5.80\times10^{-4}\text{mol}}{0.015\ \text{L}}}=4.72\,.$$

4. After adding 10.4 mL NaOH (EP), containing $10.4\times10^{-3}\text{L}\times0.108\ \frac{\text{mol}}{\text{L}}=1.12\times10^{-3}\ \text{mol}$ of NaOH:

mole	HOAc	NaOH	NaOAc
Before reaction	1.12×10^{-3}	1.12×10^{-3}	0
Δ	-1.12×10^{-3}	-1.12×10^{-3}	$+1.12\times10^{-3}$
After reaction	0	0	1.12×10^{-3}

$(Na^{+})OAc^{-}$ (basic salt) reacts partially with water:

$OAc^{-} + H_2O \rightleftharpoons HOAc + OH^{-}$

mol/L	OAc^{-}	HOAc	OH^{-}
Before reaction	0.0467	0	0
Δ	−x	+x	+x
After reaction	0.0467 – x	x	x

$$K_{b_{OAc^-}}=\frac{[HOAc]\times[OH^-]}{[OAc^-]}=5.6\times10^{-10}$$

$$\frac{x^2}{0.0467\ -\ x}=5.6\times10^{-10}$$

$$x^2+5.6\times10^{-10}x-2.6\times10^{-11}=0$$

$$x=5.1\times10^{-6}$$

mol/L	OAc^{-}	HOAc	OH^{-}
After reaction	0.0467	5.1×10^{-6}	5.1×10^{-6}

pOH = $-\log 5.1\times10^{-6}$ = 5.29 $\Rightarrow$ pH = 8.71.

5. After adding 15.0 mL NaOH, containing $15.0\times10^{-3}\text{L}\times0.108\ \frac{\text{mol}}{\text{L}}=1.62\times10^{-3}\ \text{mol}$ of NaOH:

mole	HOAc	NaOH	NaOAc
Before reaction	1.12×10^{-3}	1.62×10^{-3}	0
Δ	-1.12×10^{-3}	-1.12×10^{-3}	$+1.12\times10^{-3}$
After reaction	0	5.00×10^{-4}	1.12×10^{-3}

NaOAc is a weak basic salt and can be neglected.
So the pH is determined by the strong base NaOH: completely dissociated. So the pOH = 1.70 and pH = 12.30.