# GCE AS/A Level Chemistry

# Specified Practical Work

# Exemplar results and analysis

## 1.6 Gravimetric analysis

### Identification of an unknown metal chloride

### Results

| | |
|---|---|
| Mass of unknown chloride / g | 0.305 |
| Mass of filter paper / g | 0.383 |
| Mass of dry filter paper and silver chloride / g | 0.957 |
| Mass of silver chloride formed / g | 0.584 |

### Analysis

n(AgCl) = $\frac{0.584}{143.5}$ = 0.00407 mol

1 mol of AgCl formed for every 1 mol of $Cl^-$ ions in the unknown chloride

∴ 0.00407 mol of $Cl^-$ ions in 0.305 g of the unknown chloride

Molar mass of unknown chloride = $\frac{mass}{number\ of\ moles}$ = $\frac{0.305}{0.00407}$ = 74.94 g

This molar mass suggests that there must be only one chloride ion

Molar mass of metal = 74.94 – 35.5 = 39.44 g

∴ metal must be potassium and unknown chloride must be KCl

## 1.7 Back titration

### Determination of the percentage of calcium carbonate in limestone

**Results**

Mass of limestone = 0.54 g

| | Rough | Run 2 | Run 3 | Run 4 |
|---|---|---|---|---|
| Initial volume / $cm^3$ | 0.50 | 0.00 | 0.35 | 0.60 |
| Final volume / $cm^3$ | 34.50 | 33.70 | 34.15 | 34.30 |
| Titre / $cm^3$ | 34.00 | 33.70 | 33.80 | 33.70 |
| Mean titre / $cm^3$ | 33.73 | | | |

**Analysis**

33.73 $cm^3$ of NaOH needed to neutralise excess HCl added to the limestone

[NaOH] = 0.098 M

$n(\text{NaOH}) = cV = 0.098 \times \frac{33.73}{1000} = 3.31 \times 10^{-3}$ mol

$\text{NaOH} + \text{HCl} \rightarrow \text{NaCl} + \text{H}_2\text{O}$

1 mol NaOH : 1 mol HCl

$\therefore$ $3.31 \times 10^{-3}$ mol of HCl left over after reaction with $CaCO_3$ in limestone

25.00 $cm^3$ of 0.501 M HCl added initially

$n(\text{HCl}) = cV = 0.501 \times \frac{25.00}{1000} = 1.25 \times 10^{-2}$ mol

Number of moles of HCl that reacted with $CaCO_3$ = initial amount added – amount left over

= $9.19 \times 10^{-3}$ mol

$\text{CaCO}_3 + 2\text{HCl} \rightarrow \text{CaCl}_2 + \text{H}_2\text{O} + \text{CO}_2$

1 mol $CaCO_3$ : 2 mol HCl

$\therefore$ $4.595 \times 10^{-3}$ mol $CaCO_3$ present in limestone sample

$n(\text{CaCO}_3) = \frac{mass}{M_r}$

mass = $n(\text{CaCO}_3) \times M_\text{r} = 4.595 \times 10^{-3} \times 100 = 0.4595$ g

Percentage of $CaCO_3$ in limestone sample = $\frac{0.4595}{0.54} \times 100 = 85.1\,\%$

## 1.7 Double titration

### To determine the concentration and the mass of sodium hydroxide and sodium carbonate in a mixed solution

**Results**

| | Rough | Run 2 | Run 3 | Run 4 | Mean |
|---|---|---|---|---|---|
| Initial volume / $cm^3$ | 0.50 | 0.10 | 0.25 | 0.15 | |
| First end-point volume / $cm^3$ | 30.80 | 29.95 | 30.05 | 29.90 | |
| Second end-point volume / $cm^3$ | 47.00 | 46.00 | 46.20 | 46.00 | |
| Titre 1 / $cm^3$ | 30.30 | 29.85 | 29.80 | 29.75 | 29.80 |
| Titre 2 / $cm^3$ | 16.20 | 16.05 | 16.15 | 16.10 | 16.10 |

**Analysis**

At the first end-point the following reactions are just complete

$NaOH + HCl \rightarrow NaCl + H_2O$

$Na_2CO_3 + HCl \rightarrow NaHCO_3 + NaCl$

30.00$cm^3$ of 0.100M HCl has reacted

n(HCl) = $0.100 \times \frac{29.80}{1000} = 2.98 \times 10^{-3}$ mol

$\therefore$ total of $2.98 \times 10^{-3}$ mol of NaOH and $Na_2CO_3$ reacted

At the second end-point the following reaction is just complete

$NaHCO_3 + HCl \rightarrow NaCl + H_2O + CO_2$

16.10$cm^3$ of 0.100M HCl has reacted

n(HCl) = $0.100 \times \frac{16.10}{1000} = 1.61 \times 10^{-3}$ mol

$\therefore$ $1.61 \times 10^{-3}$ mol of $NaHCO_3$ reacted

$\therefore$ $1.61 \times 10^{-3}$ mol of $Na_2CO_3$ in 25.0$cm^3$ of the original solution

Total of $2.98 \times 10^{-3}$ mol of NaOH and $Na_2CO_3$ in 25.0$cm^3$ of the original solution

$\therefore$ $1.37 \times 10^{-3}$ mol of NaOH

Concentration of NaOH in mixed solution = $\frac{1.37 \times 10^{-3}}{\frac{25}{1000}}$ = 0.0548 M

Concentration of $Na_2CO_3$ in mixed solution = $\frac{1.61 \times 10^{-3}}{\frac{25}{1000}}$ = 0.0644 M

Mass of NaOH in 1 $dm^3$ of mixed solution = number of moles × molar mass

= 0.0548 × 40 = 2.19 g

Mass of $Na_2CO_3$ in 1 $dm^3$ of mixed solution = number of moles × molar mass

= 0.0644 × 106 = 6.83 g

## 2.1 Indirect determination of an enthalpy change of reaction

### Indirect determination of the enthalpy change of reaction of magnesium oxide and carbon dioxide to form magnesium carbonate

**Results**

Magnesium oxide

| | |
|---|---|
| Mass of MgO + weighing boat / g | 7.359 |
| Mass of weighing boat / g | 6.438 |
| Mass of MgO / g | 0.921 |

| Time / min | Temperature / °C |
|---|---|
| 0 | 23.4 |
| 0.5 | 23.3 |
| 1.0 | 23.2 |
| 1.5 | 23.2 |
| 2.0 | 23.2 |
| 2.5 | 23.2 |
| 3.0 | |
| 3.5 | 28.7 |
| 4.0 | 33.2 |
| 4.5 | 36.6 |
| 5.0 | 36.4 |
| 5.5 | 36.4 |
| 6.0 | 36.3 |
| 6.5 | 36.0 |
| 7.0 | 35.8 |
| 7.5 | 35.7 |
| 8.0 | 35.6 |
| 8.5 | 35.4 |
| 9.0 | 35.4 |

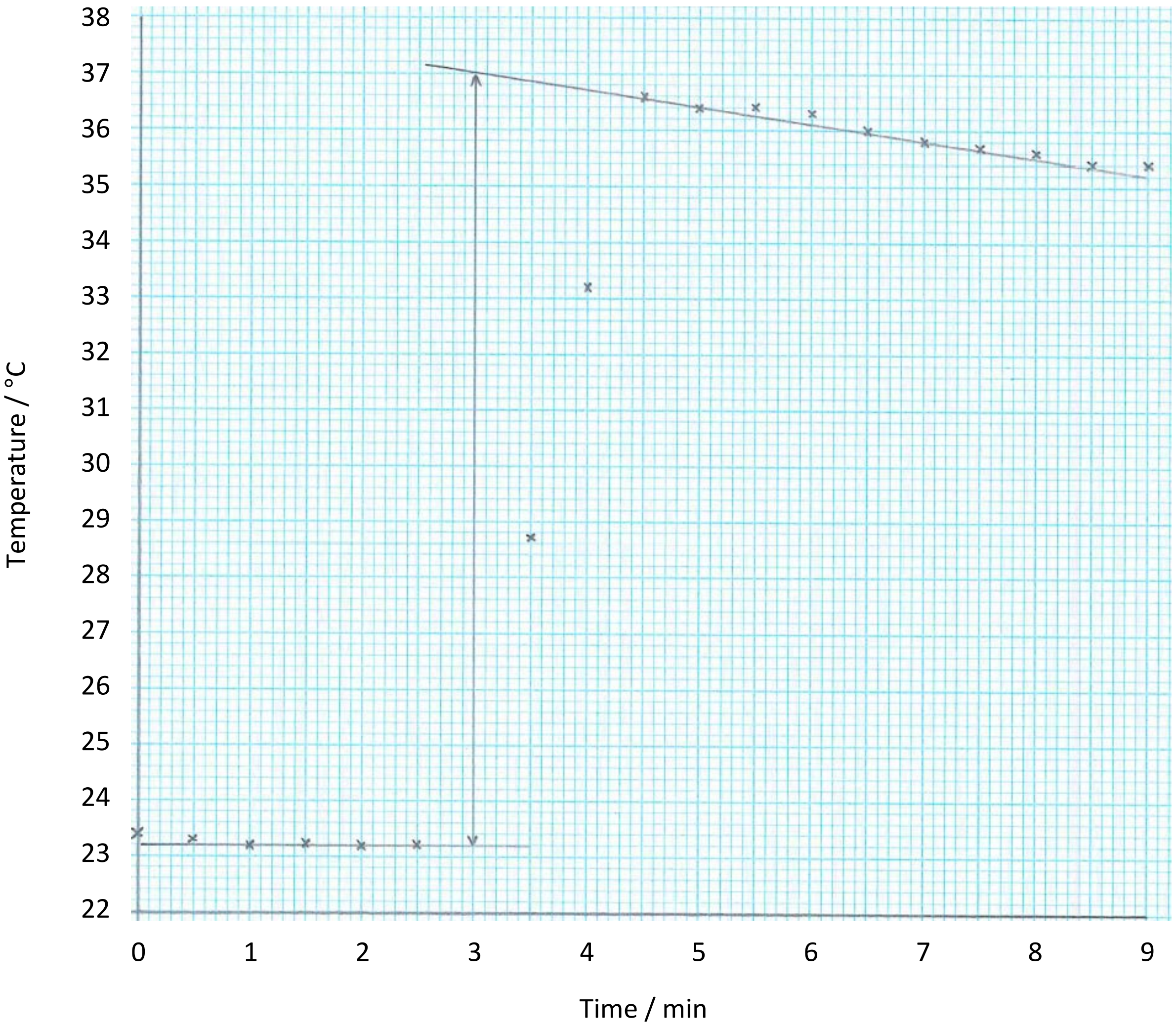
Magnesium carbonate

| | |
|---|---|
| Mass of $MgCO_3$ + weighing boat / g | 10.015 |
| Mass of weighing boat / g | 6.526 |
| Mass of $MgCO_3$ / g | 3.489 |

| Time / min | Temperature / °C |
|---|---|
| 0 | 24.2 |
| 0.5 | 24.1 |
| 1.0 | 24.0 |
| 1.5 | 24.0 |
| 2.0 | 24.0 |
| 2.5 | 24.0 |
| 3.0 | |
| 3.5 | 32.8 |
| 4.0 | 32.8 |
| 4.5 | 32.3 |
| 5.0 | 32.2 |
| 5.5 | 32.2 |
| 6.0 | 32.0 |
| 6.5 | 31.9 |
| 7.0 | 31.8 |
| 7.5 | 31.6 |
| 8.0 | 31.4 |
| 8.5 | 31.2 |
| 9.0 | 31.0 |

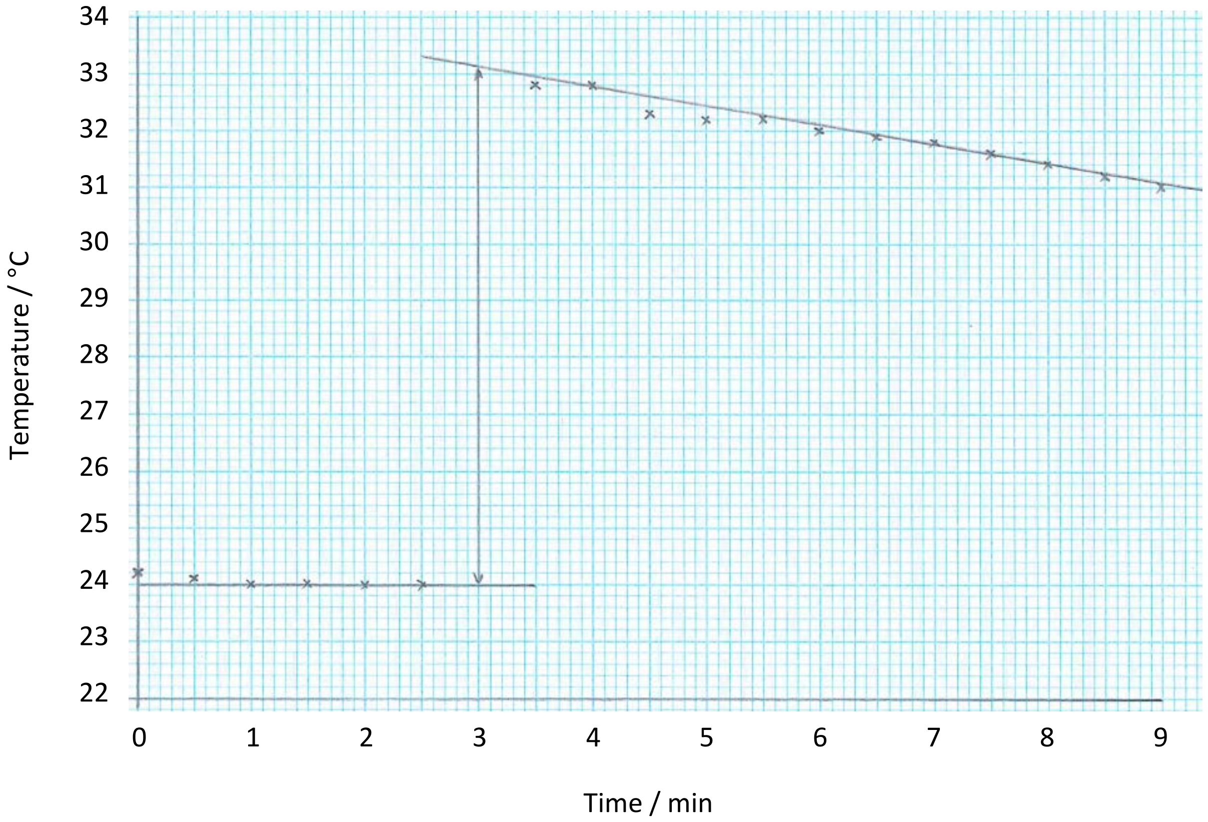
**Analysis**

Magnesium oxide

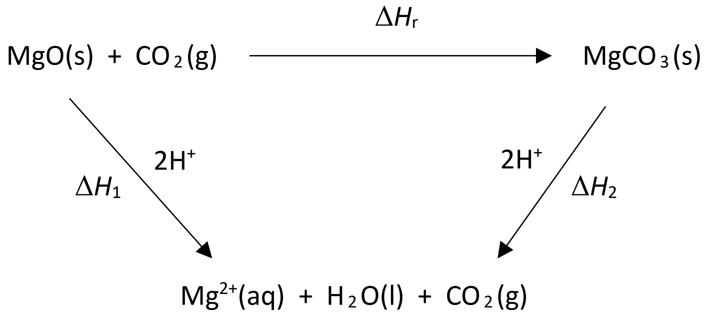


From magnesium oxide graph, the maximum temperature change $\Delta T$ = 13.8 °C

Magnesium carbonate



From magnesium carbonate graph, the maximum temperature change $\Delta T$ = 9.1 °C



Enthalpy of reaction of MgO, $\Delta H_1$

$$\Delta H_1 = -\frac{mc\Delta T}{n}$$

$\Delta T$ from graph = 13.8 °C

$n(MgO) = \frac{0.921}{40.3} = 0.0229$ mol

$$\Delta H_1 = -\frac{mc\Delta T}{n} = -\frac{50 \times 4.18 \times 13.8}{0.0229} = -126\ \text{kJ mol}^{-1}$$

Enthalpy of reaction of $MgCO_3$, $\Delta H_2$

$$\Delta H_2 = -\frac{mc\Delta T}{n}$$

$\Delta T$ from graph = 9.1 °C

$n(MgCO_3) = \frac{3.489}{84.3} = 0.0414$ mol

$$\Delta H_1 = -\frac{mc\Delta T}{n} = -\frac{50 \times 4.18 \times 9.1}{0.0414} = -45.9\ \text{kJ mol}^{-1}$$

From Hess' cycle

$$\Delta H_r + \Delta H_2 = \Delta H_1$$

$$\Delta H_r = \Delta H_1 - \Delta H_2 = -126 - (-45.9) = -80.1\ \text{kJ mol}^{-1}$$

## 3.2 Estimation of copper in copper(II) salts

**To determine the percentage by mass of copper in copper(II) sulfate crystals**

**Results**

Mass of copper(II) sulfate = 6.01 g

Concentration of $Na_2S_2O_3$ = 0.0992 M

| | Rough | Run 2 | Run 3 | Run 4 |
|---|---|---|---|---|
| Initial volume / $cm^3$ | 0.50 | 0.15 | 24.35 | 0.10 |
| Final volume / $cm^3$ | 25.05 | 24.35 | 48.70 | 24.30 |
| Titre / $cm^3$ | 24.55 | 24.20 | 24.35 | 24.20 |
| Mean titre / $cm^3$ | 24.25 | | | |

**Analysis**

$$2Cu^{2+} + 4I^- \rightarrow 2CuI + I_2$$

$$I_2 + 2S_2O_3^{2-} \rightarrow 2I^- + S_4O_6^{2-}$$

$\therefore$ 2 mol $S_2O_3^{2-} \equiv$ 2 mol $Cu^{2+}$

$\therefore$ 1 mol $S_2O_3^{2-} \equiv$ 1 mol $Cu^{2+}$

$n(Na_2S_2O_3) = 0.0992 \times \frac{24.25}{1000} = 2.406 \times 10^{-3}$ mol

$\therefore$ $2.406 \times 10^{-3}$ mol $Cu^{2+}$ in 25.0 $cm^3$ of solution

$\therefore$ $2.406 \times 10^{-2}$ mol $Cu^{2+}$ in 250 $cm^3$ of solution

Mass of $Cu^{2+}$ ions in 250 $cm^3$ of solution = $2.406 \times 10^{-2} \times 63.5 = 1.528$ g

Percentage by mass of copper in copper(II) sulfate crystals = $\frac{1.528}{6.01} \times 100 = 25.4\%$

## 3.5 Determination of the order of a reaction

**To determine the order of reaction for the oxidation of iodide ions by hydrogen peroxide in acid solution**

**Results**

| Volume $H_2O_2$ / $cm^3$ | Volume $H_2O$ / $cm^3$ | *[$H_2O_2$] / M | Time / s |
|---|---|---|---|
| 5 | 0 | 0.010 | 26 |
| 4 | 1 | 0.008 | 32 |
| 3 | 2 | 0.006 | 42 |
| 2 | 3 | 0.004 | 64 |
| 1 | 4 | 0.002 | 126 |

* Concentration of $H_2O_2$ in total 50 $cm^3$ of solution

**Analysis**

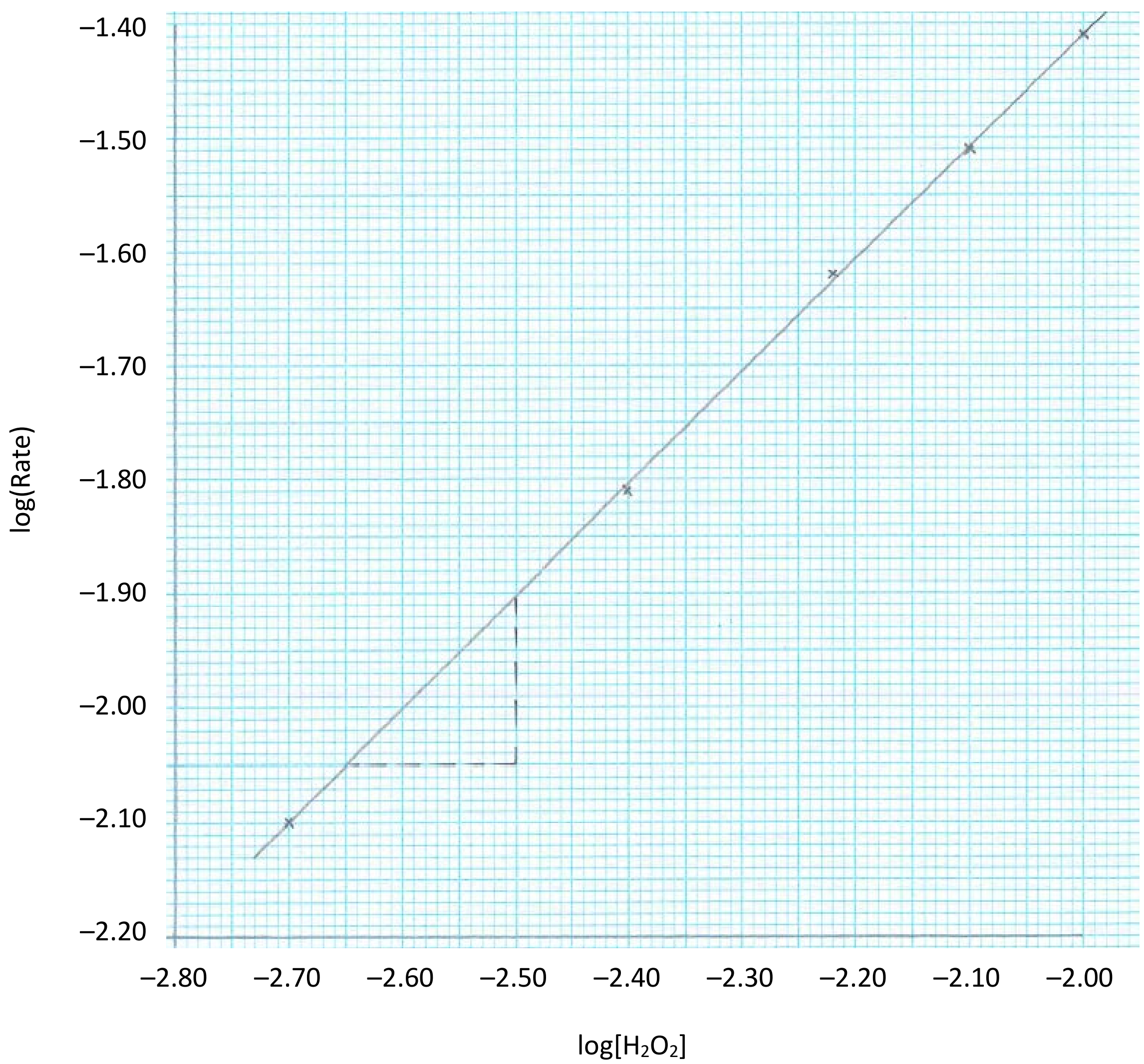
| [$H_2O_2$] / M | log[$H_2O_2$] | Time / s | Rate / $s^{-1}$ | log(Rate) |
|---|---|---|---|---|
| 0.010 | −2.00 | 26 | 0.0385 | −1.41 |
| 0.008 | −2.10 | 32 | 0.0313 | −1.51 |
| 0.006 | −2.22 | 42 | 0.0238 | −1.62 |
| 0.004 | −2.40 | 64 | 0.0156 | −1.81 |
| 0.002 | −2.70 | 126 | 0.0079 | −2.10 |

$\text{rate} = k \times [H_2O_2]^m$ where m is the order of reaction with respect to $H_2O_2$

$\therefore \log(\text{rate}) = \log k + m \log[H_2O_2]$

$y = c + mx$

For graph of log(rate) on y-axis against log[$H_2O_2$] on x-axis, gradient m is the order of reaction



Gradient m

$$m = \frac{change\ in \log(rate)}{change\ in \log[H_2O_2]} = \frac{0.145}{0.15} = 0.97$$

∴ reaction is first order with respect to $H_2O_2$

## 3.8 Determination of an equilibrium constant

### To determine the equilibrium constant for the reaction of ethanoic acid with ethanol

### Part 1

### Analysis

Initial number of moles of ethanoic acid, ethanol and water in the reaction mixture

ethanoic acid, $CH_3COOH$

mass = density × volume = 1.05 × 6.0 = 6.30 g

$M_r$ = 60

number of moles = $\frac{mass}{M_r}$ = $\frac{6.30}{60}$ = 0.105 mol

ethanol, $C_2H_5OH$

mass = density × volume = 0.79 × 6.0 = 4.74 g

$M_r$ = 46

number of moles = $\frac{mass}{M_r}$ = $\frac{4.74}{46}$ = 0.103 mol

water, $H_2O$ (6 $cm^3$ + 2 $cm^3$ from the HCl solution)

mass = density × volume = 1.00 × 8.0 = 8.00 g

$M_r$ = 60

number of moles = $\frac{mass}{M_r}$ = $\frac{8.00}{18}$ = 0.444 mol

## Part 2

### Results

Control mixture titration

| | Rough | Run 2 | Run 3 | Run 4 |
|---|---|---|---|---|
| Initial volume / $cm^3$ | 1.20 | 22.10 | 0.10 | 20.75 |
| Final volume / $cm^3$ | 22.10 | 42.85 | 20.75 | 41.45 |
| Titre / $cm^3$ | 20.90 | 20.75 | 20.65 | 20.70 |
| Mean titre / $cm^3$ | | 20.70 | | |

Reaction mixture titration

| | Rough | Run 2 | Run 3 | Run 4 |
|---|---|---|---|---|
| Initial volume / $cm^3$ | 0.00 | 0.85 | 0.25 | 0.40 |
| Final volume / $cm^3$ | 34.70 | 35.20 | 34.65 | 34.70 |
| Titre / $cm^3$ | 34.70 | 34.35 | 34.40 | 34.30 |
| Mean titre / $cm^3$ | | 34.35 | | |

### Analysis

Number of moles of HCl in the control mixture

concentration of NaOH = 0.0992 M

$n(\text{NaOH}) = c \times V = 0.0992 \times \frac{20.70}{1000} = 0.002053 \text{ mol}$

1 mol NaOH : 1 mol HCl

$\therefore$ 0.002053 mol of HCl in the control mixture

Number of moles of $H^+$ ions in 1 $cm^3$ of the reaction mixture

concentration of NaOH = 0.0992 M

$n(\text{NaOH}) = c \times V = 0.0992 \times \frac{34.45}{1000} = 0.00341744 \text{ mol}$

1 mol NaOH : 1 mol $H^+$ ions

$\therefore$ 0.00341744 mol of $H^+$ ions in 1 $cm^3$ of the reaction mixture

0.0683488 mol of $H^+$ ions in 20 $cm^3$ of the reaction mixture

$H^+$ ions come from original HCl which remains unchanged and the $CH_3COOH$ present at equilibrium

$\therefore$ $n(CH_3COOH) = 0.0683488 - 0.002053 = 0.0662958$ mol

This information is summarised as follows

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Initial concentration | 0.105 | | 0.103 | | 0 | | 0.444 |
| | $CH_3COOH$ | + | $C_2H_5OH$ | $\rightleftharpoons$ | $CH_3COOC_2H_5$ | + | $H_2O$ |
| Equilibrium concentration | 0.0662958 | | 0.0642958 | | 0.0387042 | | 0.4827042 |

For this equilibrium

$$K_c = \frac{[CH_3COOC_2H_5] \times [H_2O]}{[CH_3COOH] \times [C_2H_5OH]}$$

$$K_c = \frac{[0.0387042] \times [0.4827042]}{[0.0662958] \times [0.0642958]}$$

$$K_c = \frac{0.0186826799}{0.004262541498} = 4.383$$