Electro-chemical conductivity

Resistance R of electrolytic solution

This is the drag force experienced by ions as they migrate towards the respective electrodes. Resistance of an electrolyte is proportional to the length l of an electrolyte between electrodes and inversely proportional to the square root of the cross section area A, of each electrode.

Thus, $R \propto \frac{l}{A}$

Or $R = \rho\frac{l}{A}$

ρ is called resistivity of an electrolyte and is the resistance of an electrolyte placed between electrodes each $1cm^2$ in area and 1cm apart.

In chemistry reciprocal terms are preferred.

That is, conductance, $\frac{1}{R} = \frac{1}{\rho\frac{l}{A}} = \frac{1}{\rho}\ x\ \frac{A}{l}$

The reciprocal of resistivity, $\frac{1}{\rho}$ is called conductivity, K.

It implies that conductance, $\frac{1}{R} = K\ x\ \frac{A}{l}$

And $K = \frac{1}{R} \times \frac{l}{A}\ \Omega^{-1}cm^{-1}$

Factors that affect the conductivity of electrolytes

1. **Concentration of Ions in Solution**
   The higher the concentration of ions in solution, the higher its conductivity due to high number of conducting ions.
2. **Weak/Strong Electrolyte**

Strong electrolyte have higher conductivity than weak electrolytes because they are completely ionized in water to produce many ions

Temperature

The solubility of the solute increases with the increase in the temperature. Therefore, the conductivity of the electrolyte increases. Secondly temperature increase the speed of ions in solution

Molar conductivity, Λ_c

This is the conductivity of a solution that contains 1 mole of an electrolyte.

$\Lambda_c = \frac{K}{C}$ $\Omega^{-1}cm^2mol^{-1}$

where C = moles of electrolyte in the solution between electrodes.

Example

The resistance of 0.1M KCl solution placed between electrodes each $1cm^2$ in area and 0.5 cm apart is 400Ω. Calculate the molar conductivity of the solution.

$K = \frac{1}{R} x \frac{l}{A} = \frac{1}{400} x \frac{0.5}{1} = 0.00125$ $\Omega^{-1}cm^{-1}$

Volume of electrolyte between the electrodes = 1 x 0.5 = $0.5cm^3$

Moles of the electrolyte between the electrodes

$1000cm^3$ contain 0.1mole

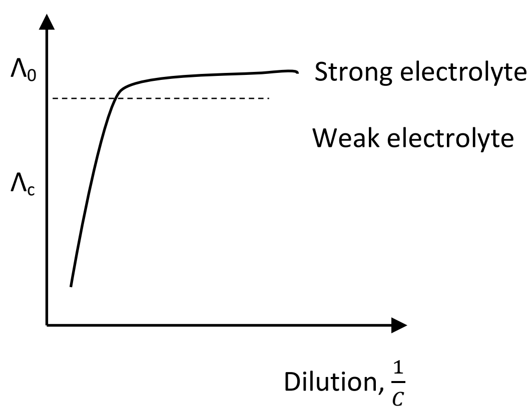
∴ $0.5cm^3$ contain $\frac{0.5 x 0.1}{1000}$ = 0.00005moles

$\Lambda_c = \frac{K}{C} = \frac{0.00125}{0.00005}$ = **25** $\Omega^{-1}cm^2mol^{-1}$

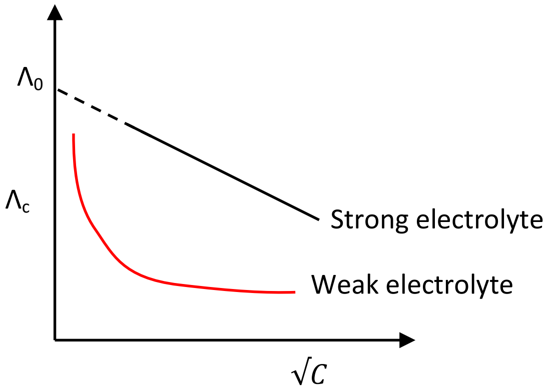
Variation of molar conductivity with concentration

Molar conductivity for both strong and weak electrolyte decrease as the concentration increase as shown by the graphs below

(i) A graph of molar conductivity, Λ_c, against dilution, $\frac{1}{C}$



(ii) A graph of molar conductivity, Λ_c, against root concentration, $\sqrt{C}$



Explanation

(a) Strong electrolyte

(i) **Strong electrolyte** are completely ionized in solution;

(ii) at high concentration the solution contains high density of ions

(iii) high density of ions lead ion interaction which reduce mobility of ions which lowers molar conductivity.

(iv) On dilution the tendency to form these interactions reduce lowering the drag force thus molar conductivity increases.

(b) Weak electrolyte

(i) Weak electrolytes are poorly ionized in solution which provides low concentration conducting ions which leads to low molar conductivity compared to strong electrolytes

(ii) At high concentration, the percentage ionization of weak electrolytes is very low leading to very few conducting ions per mole of electrolytes and low molar conductivity.

(iii) Percentage ionization of weak electrolytes increases with dilution leading to increase in the number of ions per mole of an electrolyte and molar conductivity.

Molar conductivity at infinite dilution, Λ_0

This is the conductivity of 1 mole of electrolyte when the solution is very dilute that the ions experience no interaction from other ions.

For strong electrolyte, molar conductivity at infinite dilution is obtained by extra plotting of molar conductivity against root concentration to zero concentration.

For weak electrolyte, molar conductivity at infinite dilution is obtained by application of Kohrlrausch's law of independent migration of ions.

It state: "the molar conductivity of an electrolyte at infinite dilution is the sum of molar conductivity of the constituent ions at infinite dilution.

For example

Λ_0 NaCl = λ_0 Na^+ + λ_0 Cl^-

Λ_0 AB = Λ_0 AC + Λ_0 BD - Λ_0 CD

Example

The molar conductivity of nitric acid, potassium nitrate and potassium fluoride are 421, 145 and 129 $\Omega^{-1}cm^2mol^{-1}$ respectively at infinite dilution. Molar conductivity of hydrofluoric acid at infinite dilution.

Λ_0 HF = Λ_0 HNO_3 + Λ_0 KF – Λ_0 KNO_3

= 421 + 129 -145

= 405 $\Omega^{-1}cm^2mol^{-1}$

Factors affecting conductivity of an ion at infinite dilution

1. **Charge on the ion**: the bigger the charge the higher the conductivity because the ion caries bigger charge per ion
2. **The size of an ion**: small ions have high speed of movement leading to high conductivity. However, small ions with high charge have high density that may attract a big cloud of water of hydration that its effective mass may bigger than that of a big ion. That is why the small cations may have lower conductivity that big cation.

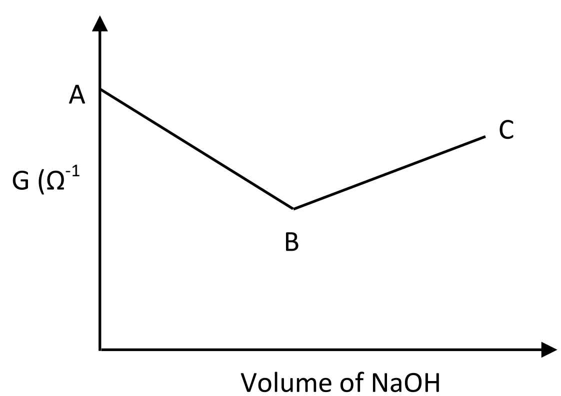
Example of conductivities of common ions at infinite dilution

ion	λ0 ($\Omega^{-1}cm^2mol^{-1}$)
Na^+	50.1
OH^-	198.6
H^+	349.8
Cl^-	76.4

Conductometric titrations

These are titrations in which ions are replaced by others of different conductivity, the titration followed by conductivity measurement.

(a) Titration of a strong acid with strong base



Explanation

Initially at A, conductivity is high due to presence of highly conducting H^+ from ionization of hydrogen chloride

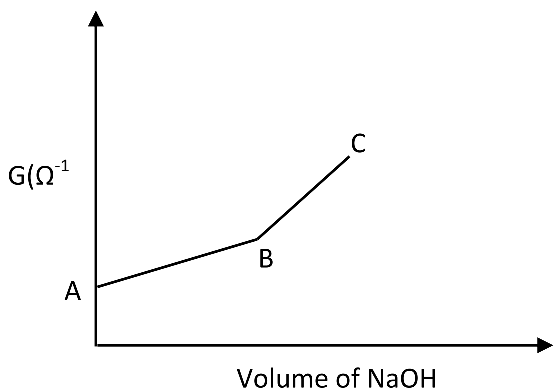
$HCl \rightarrow H^+(aq) + Cl^-(aq)$

Along AB conductivity decreases up to the end point due to removal of highly conducting hydrogen ions.

$H^+(aq) + OH^-(aq) \rightarrow H_2O\ (l)$

Along BC after the end point, conductivity increases due to excess OH^- ions that are relatively highly conducting.

(b) Titration of a weak acid e.g. CH_3COOH with strong base (e.g. NaOH)



Explanation

Initially at A conductivity is low due to small concentration of H^+ ions since the acid is partially ionized.

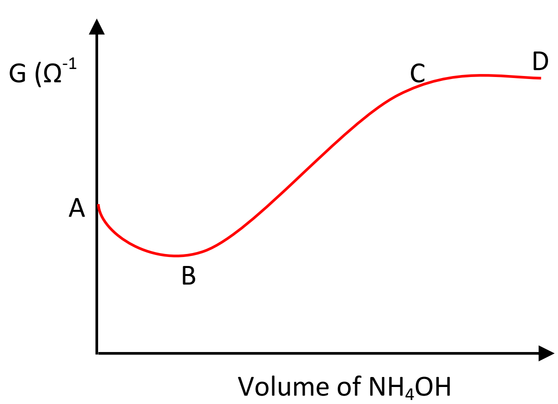
$CH_3COOH \leftrightarrow CH_3CO^- + H^+$

Along AB conductivity increases up to end point due to addition of salt ions and further ionization of the acid due to dilution.

$CH_3COOH\ (aq) + OH^-\ (aq) \rightarrow CH_3COO^-(aq) + H_2O(l)$

Along BC conductivity increase to due to excess OH^-.

(c) Titration of a weak acid (e.g. CH_3COOH) with weak base (e.g. NH_4OH)



Initially at A, conductivity is high due to presence of H^+ from partial ionization of the acid

$CH_3COOH \leftrightarrow CH_3CO^- + H^+$

Along AB conductivity decreases due to removal of H+.

$H^+(aq) + OH^-(aq) \rightarrow H_2O\ (l)$

Along BC conductivity increases due to addition of salt ion

$CH_3COOH\ (aq) + NH_4OH\ (aq) \rightarrow CH_3COO^-(aq) + NH_4^+(aq) + H_2O(l)$

Along CD conductivity remains almost constant due to attainment of equilibrium.

Exercise

Trial 1

(a) Define the term
   (i) Molar conductivity (1mark)
   (ii) Electrolytic conductivity (1mark)

(b) The table below shows molar conductivities, Λ, of potassium chloride and ethanoic acid at different concentrations.

(concentration)^{½} (moldm-3)½	0.01	0.02	0.03	0.04	0.74	0.106
Λ, for KCl ($\Omega^{-1}cm^2mol^{-1}$)	147.0	145.0	142.0	140.0	132.0	128.0
Λ, for ethanoic acid ($\Omega^{-1}cm^2mol^{-1}$)	70.0	49.0	33.0	24.0	10.0	6.0

(i) On the same axes draw graphs of molar conductivity against square root of concentration, for both potassium chloride and ethanoic acid. (3marks)

(ii) State the shapes of the graphs in (b)(i) and explain your answer. (5marks)

(c) The electrolytic conductivity of a solution containing 6.66g of ethanoic acid in one litre is 5.21 x 10^{-2} $\Omega^{-1}m^{-1}$ at 25^0C.
Calculate the dissociation constant Ka of ethanoic acid at 25^0C.
(the molar conductivities of hydrochloric acid, sodium chloride and sodium ethanoate are 426 x 10^{-4}, 126 x 10^{-4} and 91 x 10 $^{-4}$ $\Omega^{-1}m^2mol^{-1}$ respectively at infinite dilution). (06marks)

(d) To a solution of hydrochloric acid was added small amounts of sodium hydroxide solution at a time until in excess. State how the conductivity of the solution varied and explain your answer. (4marks)

Trial 2

(a) State **two** factors that can affect the molar conductivity of an electrolyte.

(b) The molar conductivity of potassium hydroxide at various concentrations are given in the table below.

Molar conductivity ($\Omega^{-1}cm^2mol^{-1}$)	238	230	224	217	210
Concentration of potassium hydroxide (mol/dm^3)	0.01	0.04	0.09	0.16	0.25
Square root of concentration of potassium hydroxide (mol/dm^3)^{½}					

(i) Complete the table above. (1mark)

(ii) Draw a graph of molar conductivity against the square root of the concentration of potassium hydroxide. (3marks)

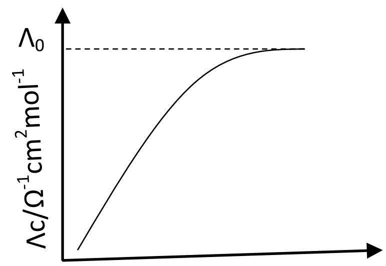
(iii) Explain the shape of the graph you have drawn in (b)(ii).

(iv) Determine the value of molar conductivity of potassium hydroxide at infinite dilution

Trial 3

(a) State three factors that can affect molar conductivity of electrolytes (1 ½ marks)

(b) The graph below shows the variation of molar conductivity of a strong electrolyte with dilution



Briefly explain the shape of the graph

(c) The molar conductivity of nitric acid, potassium nitrate and potassium fluoride are 421, 145 and 129 $\Omega^{-1}cm^2mol^{-1}$ respectively at infinite dilution
   (i) Molar conductivity of hydrofluoric acid at infinite dilution (02marks)
   (ii) Dissociation constant, Ka, of a 0.1M hydrofluoric acid solution. (The electrolytic conductivity of hydrofluoric acid is 3.15×10^{-5} $\Omega^{-1}cm^{-1}$)

Trial 4

(a) Define '**electrolytic conductivity'.**
(b) The molar ionic conductivity at infinite dilution of some ionic species are shown below

ion	λ0 ($\Omega^{-1}cm^2mol^{-1}$)
Na^+	50.1
OH^-	198.6
H^+	349.8
Cl^-	76.4

Calculate the electrolytic conductivies for:

(i) 0.01M sodium hydroxide solution
(ii) A solution made by mixing 50cm^3 of 0.01M sodium hydroxide and 50cm^3 of 0.02M hydrochloric acid

Trial 5

(a) The molar conductivity of sodium hydroxide solutions of different concentrations are shown in the table below:

Concentration/$moldm^{-3}$	0.01	0.04	0.09	0.16	0.25	0.36
Molar conductivity ($\Omega^{-1}cm^2mol^{-1}$)	238	230	224	217	210	202

   (i) Draw a graph of molar conductivity against the square root of concentration (4marks)
   (ii) Explain the shape of the graph (4 ½ marks)
   (iii) Determine the value of molar conductivity at infinite dilution of sodium hydroxide and indicate its units (2marks)

(b) Using the same conductivity cell, the resistance of 0.1M potassium chloride and 0.1M bromoethanoic acid solution were found to be 24.96 and 66.50 ohms respectively at 25^{0}C when determined using the same conductivity cell. [the conductivity of potassium chloride at 25^{0}C is 0.01164 $\Omega^{-1}cm^{-1}$ and the molar conductivity of bromoethanoic acid at infinite dilution is 389 $\Omega^{-1}cm^2mol^{-1}$]
   (i) Calculate the cell constant (2marks)
   (ii) Calculate the molar conductivity of the 0.1M bromoethanoic acid (3marks)
   (iii) Determine the pH of 0.1M bromoethanoic acid (4 ½ marks)

Trial 6

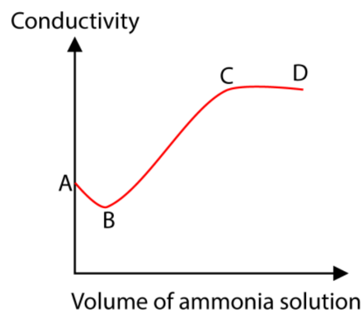
The molarity of a sample of hydrochloric acid about 0.1M was determined accurately by measuring the conductivity of solution as1.0M sodium hydroxide was added to 50cm^3 of the acid. The results were as follow:

Conductivity / $\Omega^{-1}cm^{-1}$	4.1	3.3	2.4	1.7	1.5	1.8	2.2	2.5
Volume of 1.0M NaOH/cm^3	1	2	3	4	5	6	7	8

(a) (i) Plot a graph of conductivity against the volume of 1.0M sodium hydroxide (3marks)
   (ii) Determine from the graph the volume of 1.0M sodium hydroxide used to reach the end point (1mark)
   (iii) Calculate the molarity of hydrochloric acid (02marks)
   (iv) Explain the shape of the graph (3marks)
(b) Name one other application of conductivity measurement (1mark)

Trial 7

(a) Define the following terms
   (i) Conductivity
   (ii) Molar conductivity (3marks)
(b) The graph below shows the change in conductivity when 0.01M methanoic acid is titrated with 0.1M ammonium solution



Explain the shape of the graph.
(c) At 25^{0}C, the molar conductivity of silver nitrate, potassium nitrate and potassium chloride are 133.4, 145.0 and 149.9$\Omega^{-1}cm^2mol^{-1}$ respectively.

At the same temperature, the conductivity of a saturated solution of silver chloride is 3.41 x10^{-6} $\Omega^{-1}cm^{-1}$ while that of pure water is 1.6 x 10^{-6} $\Omega^{-1}cm^{-1}$

(i) Calculate the solubility of silver chloride in moles per dm^3 at 25^0C. (4marks)

(ii) Determine the solubility product of silver chloride at 25^0C. (3marks)

(d) The ionic conductivities of rubidium and sodium ions are 73.3 and 50.1 $\Omega^{-1}cm^{-1}$ respectively. Explain why the ionic conductivity of rubidium ion is higher than that of sodium ions (3marks)

Trial 8

(a) (i) state Kohrlrausch's law of ionic conductivity at infinite dilution (1mark)

(ii) Calculate the molar conductivity of methanoic acid at infinite dilution

(λ_0(HCOONa) = 9.5x $10^{-2}Sm^2mol^{-1}$, λ_0(NaCl) = 1.26x $10^{-1}Sm^2mol^{-1}$, λ_0(HCl) = 4.26x $10^{-1}Sm^2mol^{-1}$,) (2marks)

(b) Ionic conductivities of Ag^+ and Cl^- ions at infinite dilution are 6.2 x 10^{-2} and 7.6 x 10^{-2} Sm^2mol^{-1} respectively at 298K. The electrolytic conductivity of silver chloride at 298K is 1.22 x$10^{-4}Sm^{-1}$. Calculate the solubility, in $moldm^{-3}$, of silver chloride at 298K. (5marks)

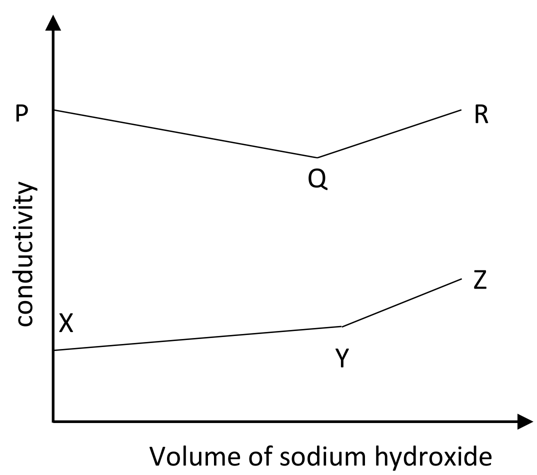
(c) Name one practical application of ionic conductivity apart from the determination of solubility of electrolytes.

Trial 9

(a) (i) State Faraday's laws of electrolysis. (4marks)

(ii) A current of 2A was passed for 30 minutes through a cell containing dilute sulphuric acid and the hydrogen produced at the cathode collected, calculate the volume of hydrogen, in cm^3, that was produced at 23^0C and 100kPa. (6marks)

(b)



Graphs PQR and XYZ show variation of conductivities of solutions formed when equal volumes of 0.1M hydrochloric acid and 0.1M ethanoic acid respectively were titrated with 1M sodium hydroxide. Account for the difference in the shapes of the graphs.

Trial 10

The ionic radii and molar ionic conductivities at infinite dilution at 18^{0}C of lithium and cesium ions are given in the table below

	Li^+	Cs^+
Ionic radius (nm)	0.06	0.17
Molar ionic conductivity ($\Omega^{-1}cm^2mol^{-1}$)	33.5	68.0

Explain why the molar conductivity of lithium ions is lower than that cesium ions.

Trial 11

During the electrolysis of dilute sulphuric acid using platinum electrodes, a current of 2A was passed for6.7minutes at room temperature.

Calculate the volume of the gas evolved at

(i) The anode

(ii) The cathode (6marks)

[1Faraday = 96500C, 1 mole of a gas occupies 24dm3 at room conditions)

(iii) Name one application of

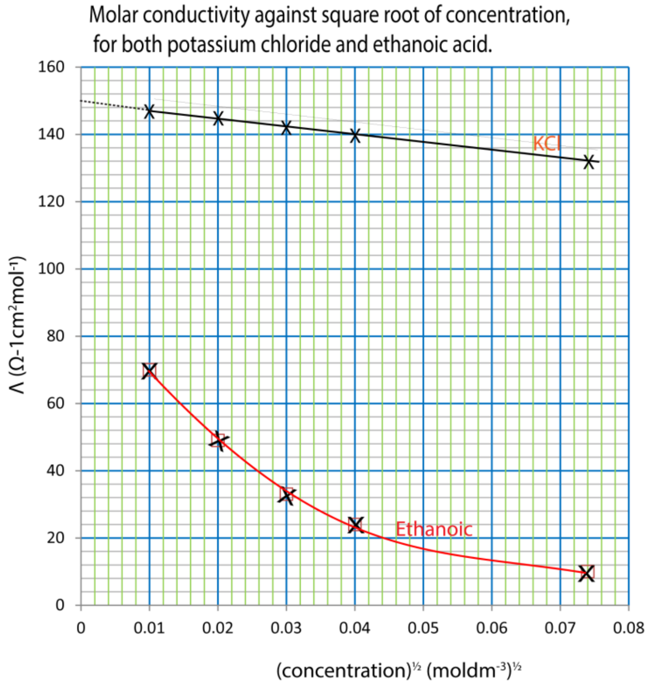
- Electrolysis
- Standard electrode potential.

Answers

Trial 1

(a) (i) Molar conductivity is a conductivity of solution that contains 1 mole of electrolyte.
(ii) Electrolytic conductivity is the reciprocal of resistance of a solution between electrodes each $1cm^2$ in area and 1cm a part.

(b) (i)



KCl is Strong electrolyte

- **It is** are completely ionized in solution;
- at **high** concentration the solution contains high density of K^+ and Cl^- ions
- high density of ions lead ion interaction that increases the drag force of ions which lowers molar conductivity.
- On dilution the tendency to form these interactions reduce lowering the drag force thus molar **conductivity** increases.

Ethanoic acid is weak electrolyte

- It is poorly ionized in solution which provides low concentration conducting CH_3COO^- and H^+ ions which leads to low molar conductivity compared to strong electrolytes
- At high concentration, the percentage ionization of ethanoic is very low leading to very few conducting ions per mole of electrolytes and low molar conductivity.
- Percentage ionization of ethanoic acid increases with dilution leading to increase in the number of ions per mole of an electrolyte and molar conductivity.

(c) Formula mass of ethanoic acid, CH_3COOH = 60

Moles of ethanoic acid per dm^3 = $\frac{6.66}{60}$ = 0.111 $moldm^{-3}$ ≡ $111molm^{-3}$.

Molar conductivity, $\Lambda_c = \frac{K}{C} = \frac{5.21 \times 10^{-2}}{111}$ = 0.000469 $\Omega^{-1}m^2mol^{-1}$

$\Lambda_0(CH_3COOH) = \Lambda_0(HCl) + \Lambda_0(CH_3COO^-Na^+) - \Lambda_0(NaCl)$

= 429 x 10^{-4} + 91 x 10^{-4} – 126 x 10^{-4}

= 391 x 10^{-4} $\Omega^{-1}m^2mol^{-1}$

The degree of ionization, $\alpha = \frac{\Lambda_c}{\Lambda_0} = \frac{0.000469}{391 \times 10^{-4}}$ = 0.012

Acid constant, Ka = α^2C = $(0.012)^2$ x 0.111 = 1.6 x 10^{-5}moldm^{-3}.

(d) Conductivity initially decreases with increasing volume of sodium hydroxide due to removal of highly conducting hydrogen ions up to the end point. It then increases due to excess OH^- ions.

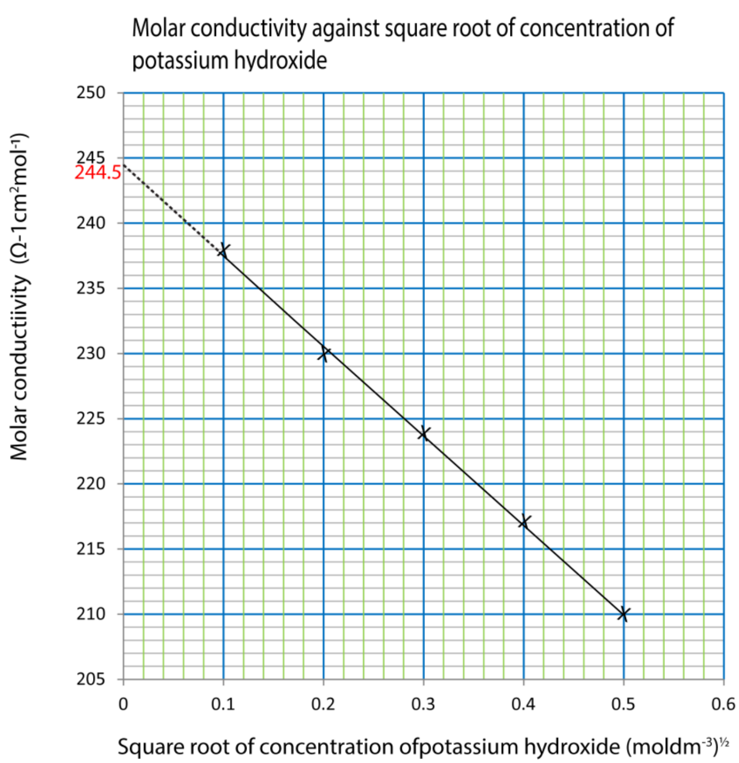
Trial 2

(a) – concentration and temperature

(b) (i)

Molar conductivity ($\Omega^{-1}cm^2mol^{-1}$)	238	230	224	217	210
Concentration of potassium hydroxide (mol/dm^3)	0.01	0.04	0.09	0.16	0.25
Square root of concentration of potassium hydroxide (mol/dm^3)^{½}	0.1	0.2	0.3	0.4	0.5

(ii)



(iii) KOH is Strong electrolyte: molar conductivity is decreases as concentration increase because

- It is are completely ionized in solution;
- at high concentration the solution contains high density of K^+ and Cl^- ions
- high density of ions lead ion interaction that increases the drag force of ions which lowers molar conductivity.
- On dilution the tendency to form these interactions reduce lowering the drag force thus molar conductivity increases.

(iv) 244.5 $\Omega^{-1}cm^2mol^{-1}$

Trial 3

(a) - concentration

- temperature

- whether weak or strong electrolyte

(b) molar conductivity increases with dilution because opposite ions get far apart which reduces ionic interference.

(c) (i) $\Lambda_0(HF) = \Lambda_0(HNO_3) + \Lambda_0(KF) - \Lambda_0(KNO^3)$

= 421 + 129 - 145

= 405 $\Omega^-1cm^2mol^{-1}$

(ii) Molar conductivity, $\Lambda_c = \frac{K}{C} = \frac{3.15 \, x \, 10^{-5}}{0.1 \, x \, 10^{-3}}$ = 0.001 $\Omega^{-1}m^2mol^{-1}$

Acid constant, Ka = $\alpha^2C = (0.001)^2 \times 0.1 = 1 \times 10^{-7} moldm^{-3}$.

Trial 4

(a) Electro conductivity is the reciprocal of resistance of an electrolyte placed between electrodes each $1cm^2$ and 1cm apart.

(b)(i) Electrolytic conductivity = $C(\lambda_0Na^+ + \lambda_0Cl^-)$

= 0.01(50.1 + 76.1)

=1.265 $\Omega^{-1}cm^2mol^{-1}$

(ii) Moles of sodium hydroxide = $\frac{50 \, x \, 0.01}{1000}$ = 0.0005 moles

Moles of hydrochloric acid = $\frac{50 \, x \, 0.02}{1000}$ = 0.001 moles

Moles of unreacted hydrochloric acid = 0.001 – 0.0005 = 0.0005 moles

Moles of sodium chloride formed = moles of sodium hydroxide that reacted

= 0.0005moles

Electrolytic conductivity = $C(\lambda_0Na^+ + \lambda_0Cl^-) + C(\lambda_0H^+ + \lambda_0Cl^-)$

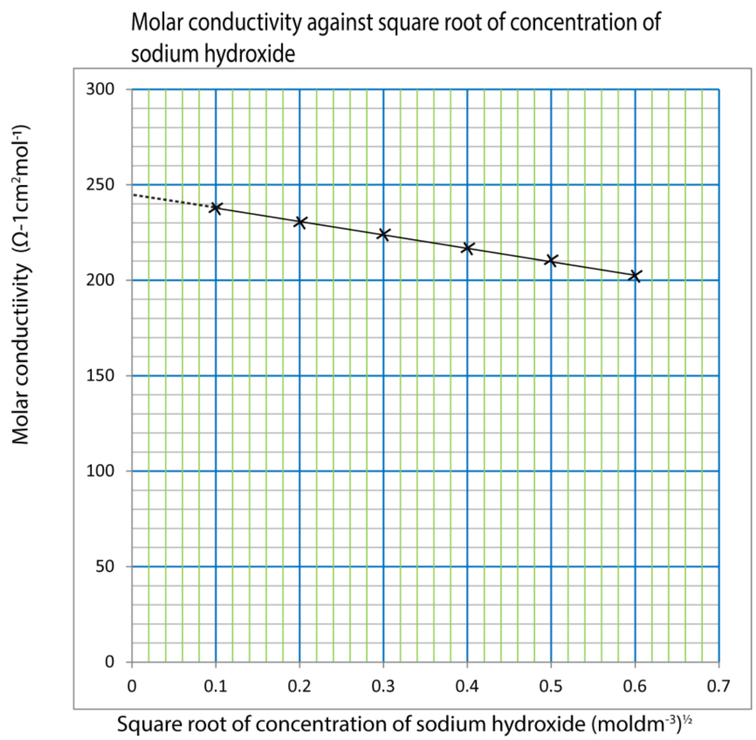
= 0.0005(50.1 + 76.1) + 0.0005(349.8 + 76.1)

= 0.06235 + 0.2122 = 0.27455 $\Omega^{-1}cm^2mol^{-1}$

Trial 5

(a)(i)

Concentration/moldm^{-3}	0.01	0.04	0.09	0.16	0.25	0.36
$Concentration^{\frac{1}{2}}/(moldm-3)^{\frac{1}{2}}$	0.1	0.2	0.3	0.4	0.5	0.6
Molar conductivity ($\Omega^{-1}cm^2mol^{-1}$)	238	230	224	217	210	202



(ii) NaOH is Strong electrolyte: molar conductivity is decreases as concentration increase because

- **It is** are completely ionized in solution;
- at **high** concentration the solution contains high density of K^+ and Cl^- ions
- high density of ions lead ion interaction that increases the drag force of ions which lowers molar conductivity.
- On dilution the tendency to form these interactions reduce lowering the drag force thus molar **conductivity** increases.

(iii) 245 $\Omega^{-1}cm^2mol^{-1}$

(c) (i) K = $\frac{1}{R}$ x cell constant

0.0116 = $\frac{1}{24.96}$ x cell constant

Cell constant = 0.29cm-1

(ii) K for bromoethanoic acid = $\frac{1}{66.5}$ x 0.29 = 4.36 x 10^{-3} $\Omega^{-1}cm^{-1}$

(iii) $\Lambda_c = \frac{K}{C} = \frac{4.36\ x\ 10^{-3}}{0.1\ x\ 10^{-3}}$ = 43.62 $\Omega^{-1}cm^2mol^{-1}$

(iii) $\alpha = \frac{\Lambda_c}{\Lambda_0} = \frac{43.6}{389}$ = 0.112

$[H^+]$ = αC = 0.112 x 0.1 = 0.0112moledm^{-3}

pH -= -log0.0112 = 1.95

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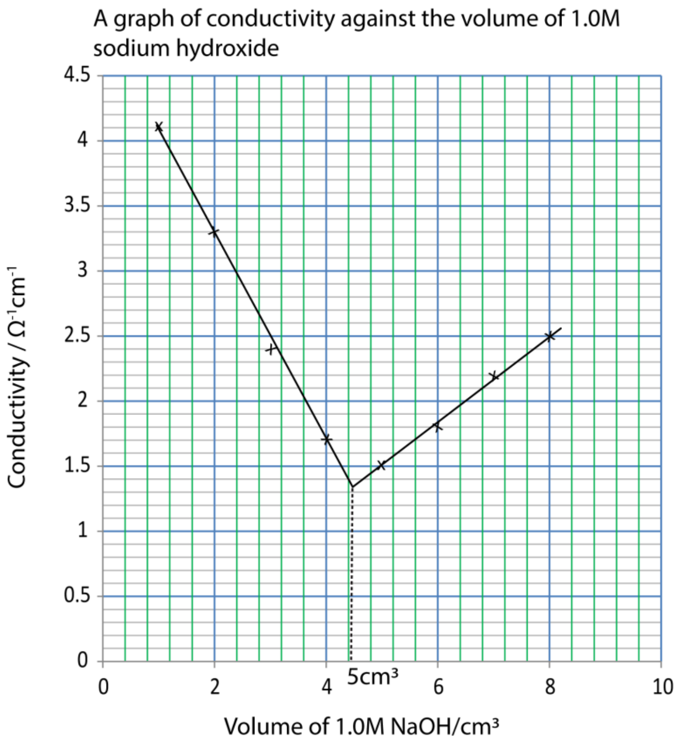
Trial 6 (a)(i)



(ii) $5cm^3$

(iii) moles of hydrochloric acid = moles of sodium hydroxide = $\frac{1\ x\ 5}{1000} = 0.005\ moles$

Molarity of hydrochloric acid = $\frac{1000\ x\ 0.005}{50} = 0.1M$

(iv) Conductivity initially decreases with increasing volume of sodium hydroxide due to removal of highly conducting hydrogen ions up to the end point. It then increases due to excess OH^- ions.

(b) study of complexes

Trial 7

(a) (i) Electrolytic conductivity is the reciprocal of resistance of a solution between electrodes each $1cm^2$ in area and 1cm a part.

(ii) Molar conductivity is a conductivity of solution that contains 1 mole of electrolyte.

(b) Initially at A, conductivity is high due to presence of H^+ from partial ionization of the acid

$CH_3COOH \leftrightarrow CH_3CO^- + H^+$

Along AB conductivity decreases due to removal of H+.

$H^+(aq) + OH^-(aq) \rightarrow H_2O\ (l)$

Along BC conductivity increases due to addition of salt ion

$CH_3COOH\ (aq) + NH_4OH\ (aq) \rightarrow CH_3COO^-(aq) + NH_4^+(aq) + H_2O(l)$

Along CD conductivity remains almost constant due to attainment of equilibrium.

(c) Λ_0 AgCl = Λ_0 $AgNO_3$ + Λ_0 KCl – Λ_0 KNO_3

= 133.4 + 149.9 – 145

= 138.3 $\Omega^{-1}cm^2mol^{-1}$

KAgCl = 3.41 x 10^{-6} – 1.6 x 10^{-6}

1.81 x 10^{-6} $\Omega^{-1}cm^{-1}$

Λ_0 AgCl = $\frac{K}{C}$

C = $\frac{1.6\ x\ 10^{-6}}{138.3} = 1.3\ x\ 10^{-8}\ molcm^{-3}\ or\ \ 1.3\ x\ 10^{-5}moldm^{-3}$

Ksp = $[Ag^+][Cl^-]$ = $(1.3 \text{ x } 10^{-5})^2$ = 1.7 x $10^{-10}mol^2dm^{-6}$.

Trial 8

(a) (i) It state: "the molar conductivity of an electrolyte at infinite dilution is the sum of molar conductivity of the constituent ions at infinite dilution.

(ii) Λ_0 HCOOH = Λ_0 HCOONa + Λ_0 HCl – Λ_0 NaCl

= 0.095 + 0.426 – 0126

= 0.395 $\Omega^{-1}cm^2mol^{-1}$

(b) Λ_0 AgCl = λ_0 Ag^+ + λ_0 Cl^-

= 0.062 + 0.076 = 0.138 $\Omega^{-1}cm^2mol^{-1}$

Λ_0 AgCl = $\frac{K}{C}$

C = $\frac{1.22\ x\ 10^{-4}}{0.138} = 8.84\ x\ 10^{-4}\ molm^{-3}\ or\ \ 8.8\ x\ 10^{-7}moldm^{-3}$

(c) – study complexes

- Determine end point in titration

Trial 9

(a) (i) the mass of a substance liberated at an electrode is proportional to the quantity of electricity used.

the number of moles of electricity liberated by 1 mole of electricity is inversely proportional to the charge on its ions

(ii) Q = it = 2 x 30 x 60 = 3600C

$2H^+(aq) + 2e \rightarrow H_2(g)$

Volume of hydrogen liberated at stp.

96500 x 2 liberates 22400cm^3 of hydrogen

3600 liberate $\frac{3600\ x\ 22400}{96500\ x\ 2}$ = 417.8cm^3

Volume of hydrogen at 23^0C and 100KPa

From $\frac{PV}{T} + constant$

Then, $\frac{100000 \, x \, V}{273+23} = \frac{101325 \, x \, 417}{273}$

V = 459cm^3

(b) Graph PQR

- At P the conductivity is high due to presence of hydrogen ions from ionization of HCl.
- Along PQ conductivity decrease due to removal of hydrogen ions by OH^- ions.
- After the end point at Q, conductivity increase due to excess OH^- ions.

Graph XYZ

- At X conductivity is low due to presence of few hydrogen ions from partial ionization of ethanoic acid.
- Along XY conductivity increases due to addition of salt ions and further ionization of the acid on dilution
- After the end point at Y conductivity increases due to excess hydroxyl ions from sodium hydroxide

Trial 10

- Lithium ions have a large charge density.
- In aqueous solution they attract a big cloud of water molecules around themselves.
- This makes their effective size bigger than that of cesium.
- The big size of lithium ions the drag force that reduces its conductivity.

Trail 11

Q = it = 2 x 6.7 x 60 = 804C

(i) At the anode oxygen is liberated

$4OH^-(aq) + 4e \rightarrow 2H_2O(l) + O_2(gas)$

(4 x 96500)C liberate 24000cm^3

∴ 804 C liberate 50cm^3

(ii) At cathode hydrogen is liberated.

$2H^+(aq) + 2e \rightarrow H_2\,(g)$

(2 x 96500)C liberate 24000cm^3

∴ 804 C liberate 10cm^3