Kohlrausch Law Chemistry Questions with Solutions

Q1. Equivalent conductance of a strong electrolyte increases on dilution due to
(a) An increase in the number of ions and the ionic mobility of solution
(b) Complete dilution of the electrolyte at standard dilution
(c) An increase in the ionic mobility of solution
(d) None of the above
Answer: (c) Equivalent conductance of a strong electrolyte increases on dilution due to an increase in the ionic mobility of solution.

Q2. The molar conductivity of an ionic solution depends on
(a) Concentration of electrolytes in solution
(b) Distance between electrodes
(c) Surface area of electrodes
(d) None of the above
Answer: (a) The molar conductivity of an ionic solution depends on the concentration of electrolytes in solution.

Q3. The molar conductance of a solution ___________ with dilution while its specific conductance ________ with dilution.
(a) Decreases, Increases
(b) Increases, Decreases
(c) Decreases, Decreases
(d) Increases, Increases
Answer: (a) The molar conductance of a solution increases with dilution while its specific conductance decreases with dilution.

Q4. Kohlrausch's law states that at
(a) Infinite dilution, the equivalent conductivity of an electrolyte is equivalent to the sum of the conductances of the cations and anions
(b) Finite dilution, the equivalent conductivity of an electrolyte is equivalent to the sum of the conductances of the cations and anions.
(c) Both (a) and (b)
(d) None of the above
Answer: (a) Kohlrausch's law states that at infinite dilution, the equivalent conductivity of an electrolyte is equivalent to the sum of the conductances of the cations and the anions

Q5. Which of the following statements is correct for an electrolytic solution upon dilution?

(a) Conductivity increase on dilution
(b) Conductivity decrease on dilution
(c) Molar conductance decreases, but equivalent conductance increases on dilution
(d) Molar conductance increases, but equivalent conductance decreases on dilution
Answer: (b) When an electrolytic solution is diluted, it's concentration decreases. Due to this, the conductance increases, and the conductivity decreases.

Q6. What is Kohlrausch's law?
Answer: Kohlrausch's law states that at infinite dilution equivalent conductivity of an electrolyte is equivalent to the sum of the conductances of the cations and anions.

$$\Lambda^{\infty}_{m(Na_2SO_4)} = 2\Lambda^{\circ}_{m(Na^+)} + \Lambda^{\infty}_{m(SO_4^{2-})}$$

Q7. What are the applications of Kohlrausch's law?
Answer: Kohlrausch's law states that at infinite dilution equivalent conductivity of an electrolyte is equivalent to the sum of the conductances of the cations and anions. There are a lot of applications of Kohlrausch's law.
A few of them are mentioned below.
1. It can be used to calculate the molar conductance at infinite dilution for a weak electrolyte.
2. It can be used to calculate the degree of dissociation at infinite dilution for a weak electrolyte.
3. It can be used to calculate the dissociation constant at infinite dilution for a weak electrolyte.
4. It can be used to calculate the solubility of the sparingly soluble salt.

Q8. The $\Lambda_m°$ for sodium iodide, sodium acetate, and magnesium acetate solution are 12.69, 9.10 and 18.78 S cm^2 $mol^{-1,}$ respectively, at 298 K. Calculate $\Lambda_m°$ for magnesium iodide.
Answer:
We know that
$\Lambda_m°$ (NaI) = 12.69 S cm^2 mol^{-1}
$\Lambda_m°$ (CH_3COONa) = 9.10 S cm^2 mol^{-1}
$\Lambda_m°$ (MgI_2) = 18.78 S cm^2 mol^{-1}

According to Kohlrausch's law

$\Lambda_m°$ (MgI_2) = $\Lambda_m°$ $[CH_3(COO)]_2Mg$ + 2 $\Lambda_m°$ (NaI) - 2 $\Lambda_m°$ (CH_3COONa)
$\Lambda_m°$ (MgI_2) = (18.78 + 2 X 12.69 - 2 X 9.10) S cm^2 mol^{-1}
$\Lambda_m°$ (MgI_2) = (18.78 + 25.38 - 18.20) S cm^2 mol^{-1}
$\Lambda_m°$ (MgI_2) = (44.16 - 18.20) S cm^2 mol^{-1}
$\Lambda_m°$ (MgI_2) = 25.96 S cm^2 mol^{-1}

Q9. Calculate $\Lambda_m°$ for $CaCl_2$ and $MgSO_4$ from the following data:

$\Lambda_m^o (Ca^{2+})$ = 119.0 S cm^2 mol^{-1}, $\Lambda_m^o (Mg^{2+})$ = 106.0 S cm^2 mol^{-1}, $\Lambda_m^o (Cl^-)$ = 76.3 S cm^2 mol^{-1} and Λ_m^o $(SO_4^{\,2-})$ = 160.05 S cm^2 mol^{-1}

Answer:
We know that,
$\Lambda_m^o (Ca^{2+})$ = 119.0 S cm^2 mol^{-1}
$\Lambda_m^o (Mg^{2+})$ = 106.0 S cm^2 mol^{-1}
$\Lambda_m^o (Cl^-)$ = 76.3 S cm^2 mol^{-1}
$\Lambda_m^o (SO_4^{\,2-})$ = 160.05 S cm^2 mol^{-1}
According to Kohlrausch's law
$\Lambda_m^o (CaCl_2) = \Lambda_m^o (Ca^{2+}) + 2 X [\Lambda_m^o (Cl^-)]$
$\Lambda_m^o (CaCl_2)$ = [119.0 + 2 X 76.3] S cm^2 mol^{-1}
$\Lambda_m^o (CaCl_2)$ = [119.0 + 152.6] S cm^2 mol^{-1}
$\Lambda_m^o (CaCl_2)$ = 271.6 S cm^2 mol^{-1}
And
$\Lambda_m^o (MgSO_4) = \Lambda_m^o (Mg^{2+}) + \Lambda_m^o (SO_4^{\,2-})$
$\Lambda_m^o (MgSO_4)$ = [106.0 + 160.05] S cm^2 mol^{-1}
$\Lambda_m^o (MgSO_4)$ = 266.05 S cm^2 mol^{-1}

Q10. The Λ_m^o for sodium acetate, HCl, and NaCl are 91.0, 425.9 and 126.4 S cm^2 mol^{-1}, respectively, at 298 K. Calculate Λ_m^o for CH_3COOH.

Answer:
We know that,
$\Lambda_m^o (CH_3COONa)$ = 91.0 S cm^2 mol^{-1}
$\Lambda_m^o (HCl)$ = 425.9 S cm^2 mol^{-1}
$\Lambda_m^o (NaCl)$ = 126.4 S cm^2 mol^{-1}
According to Kohlrausch's law

$\Lambda_m^o\ CH_3COOH = \Lambda_m^o\ CH_3COONa + \Lambda_m^o\ HCl - \Lambda_m^o\ NaCl$
$\Lambda_m^o\ CH_3COOH$ = (91.0 + 425.9 - 126.4) S cm^2 mol^{-1}
$\Lambda_m^o\ CH_3COOH$ = 390.5 S cm^2 mol^{-1}

Q11. The molar conductivity of a 1.5 M solution of an electrolyte is found to be 138.9 S cm^2 mol^{-1}. Calculate the conductivity of this solution.
Answer: Molar conductivity (λ_m) = 138.9 S cm^2 mol^{-1}
Concentration = 1.5 M
Molar conductivity = Conductivity / Concentration
Conductivity = Molar conductivity X Concentration
Conductivity = (138.9 S cm^2 mol^{-1} X 1.5 M) / 1000 cm^3 L^{-1}
Conductivity = 0.208 S cm^{-1}

Q12. The resistance and conductivity of a cell containing 0.001 M KCl solution at 298 K are 1500 Ω and 1.46 X 10^{-4} S cm^{-1}, respectively. What is the cell constant of the cell?

Answer:

Resistance = 1500 Ω

Conductivity = 1.46 X 10^{-4} S cm^{-1}

Concentration = 0.001 M

Temperature = 298 K

We know that,

Conductivity = Cell constant / Resistance

1.46 X 10^{-4} S cm^{-1} = Cell constant / 1500 Ω

Cell constant = 1.46 X 10^{-4} S cm^{-1} X 1500 Ω

Cell constant = 0.219 cm^{-1}

Q13. The conductivity of the 0.20 M solution of KCl at 298 K is 0.0248 S $cm^{-1.}$ Calculate its molar conductivity.

Answer:

Conductivity = 0.0248 S cm^{-1}

Concentration = 0.20 M

Temperature = 298 K

Molar conductivity (λ_m) = (Conductivity X 1000) / C

Molar conductivity (λ_m) = (0.0248 S cm^{-1} X 1000) / 0.20 mol cm^{-3}

Molar conductivity (λ_m) = 24.8 S cm^{-1} / 0.20 mol cm^{-3}

Molar conductivity (λ_m) = 124 S cm^2 mol^{-1}

Q14. The molar conductivity of NaCl, HCl and CH_3COONa at infinite dilution are 126.45, 426.16 and 91 S cm^2 mol^{-1}, respectively. What will be the molar conductivity of CH_3COOH at infinite dilution?

Answer:

We know that,

Λ_m^o (NaCl) = 126.45 S cm^2 mol^{-1}

Λ_m^o (HCl) = 426.16 S cm^2 mol^{-1}

Λ_m^o (CH_3COONa) = 91 S cm^2 mol^{-1}

According to Kohlrausch's law

Λ_m^o CH_3COOH = Λ_m^o CH_3COONa + Λ_m^o HCl - Λ_m^o NaCl

Λ_m^o CH_3COOH = (91 + 426.16 - 126.45) S cm^2 mol^{-1}

Λ_m^o CH_3COOH = (91 + 426.16 - 126.45) S cm^2 mol^{-1}

Λ_m^o CH_3COOH = (517.16 - 126.45) S cm^2 mol^{-1}

Λ_m^o CH_3COOH = 390.71 S cm^2 mol^{-1}

Q15. Match the following.

Column A	Column B
Kohlrausch's law	$K_\alpha = C\alpha^2 / 1 - \alpha$
Molar conductivity	$\alpha = \Lambda_m / \Lambda_m^\circ$
Degree of dissociation	$\Lambda_m = k / C$
Dissociation constant	$\Lambda_{eq}^\circ = \Lambda_c^\circ + \Lambda_a^\circ$

Answer:

Column A	Column B
Kohlrausch's law	$\Lambda_{eq}^\circ = \Lambda_c^\circ + \Lambda_a^\circ$
Molar conductivity	$\Lambda_m = k / C$
Degree of dissociation	$\alpha = \Lambda_m / \Lambda_m^\circ$
Dissociation constant	$K_\alpha = C\alpha^2 / 1 - \alpha$

Practise Questions on Kohlrausch Law

Q1. Why can Λ_m° for CH_3COOH not be determined experimentally?

Answer:

We can not determine the Λ_m° for CH_3COOH experimentally because the molar conductivity of weak electrolytes keeps increasing with dilution and does not become constant even at substantial dilution.

Q2. Why does the conductivity of a solution decrease with dilution?

Answer:

The conductivity of a solution decrease with dilution because the conductivity of a solution is dependent on the number of ions per unit volume. On dilution, the number of ions per unit volume decreases. Hence the conductivity of a solution decrease with dilution.

Q3. The conductivity of 0.00241 M acetic acid is 7.896 X 10^{-5} S $cm^{-1.}$ Calculate its molar conductivity, and if Λ_m° for acetic acid is 390.5 S cm^2 $mol^{-1,}$ what is its dissociation constant?

Answer:

Concentration = 0.00241 M
Conductivity = 7.896 X 10^{-5} S cm^{-1}
Λ_m° (Acetic acid) = 390.5 S cm^2 mol^{-1}

$$\Lambda^o_m = \frac{k \times 1000}{M}$$

$$= \frac{7.896 \times 10^{-5} \text{ S cm}^{-1} \times 1000 \text{ cm}^3 \text{ L}^{-1}}{0.00241 \text{ mol L}^{-1}}$$

= 32.76 S cm^2 mol^{-1}

$$\alpha = \frac{\Lambda_m}{\Lambda^o_m} = \frac{32.76}{390.5} = 8.39 \times 10^{-2}$$

$$K_a = \frac{C\alpha^2}{1-\alpha} = \frac{0.00241 \times \left(8.39 \times 10^{-2}\right)^2}{1 - 8.39 \times 10^{-2}}$$

K_a = 1.86 X 10^{-5}

Q4. Three electrolytic cells A, B, and C, containing a solution of $ZnSO_4$, $AgNO_3$ and $CuSO_4$, respectively all connected in series. A steady current of 1.5 amperes was passed through then until 1.45 g of silver was deposited at the cathode of cell B. How long did the current flow? What mass of copper and zinc were deposited?

Answer:

$Ag^+ + e^- \rightarrow Ag$ (s)
108 g of silver is deposited by 96500 C.

$$1.45 \text{ g silver is deposited by} = \frac{96500 \times 1.45}{108}$$

1.45 g silver is deposited by = 1295.6 C

Q = i X t
1295.6 = 1.5 X t

$$t = \frac{1295.6}{1.5} = 863 \text{ s}$$

In cell A, the electrode reaction is

$Zn^{2+} + 2e^- \rightarrow Zn(s)$

2 F of electricity deposit Zn = 65.3 g

$$1295.6 \text{ of electricity deposit Zn} = \frac{65.3 \times 1295.6}{2 \times 96500}$$

1295.6 of electricity deposit Zn = 0.438 g

In cell C, the electrode reaction is

$Cu^{2+} + 2e^- \rightarrow Cu(s)$

2 F of electricity deposit Cu = 63.5 g

$$1295.6 \text{ of electricity deposit Cu} = \frac{63.5 \times 1295.6}{2 \times 96500}$$

1295.6 of electricity deposit Cu = 0.426 g.

Q5. Suggest a way to determine the $\Lambda_m°$ of CH_3COOH.

Answer:

We can determine the $\Lambda_m°$ of CH_3COOH as follows.

$\Lambda_m° \, CH_3COO^- + \Lambda_m° \, H^+ = \Lambda_m° \, CH_3COO^- + \Lambda_m° \, Na^+ + \Lambda_m° \, H^+ + \Lambda_m° \, Cl^- - \Lambda_m° \, Na^+ - \Lambda_m° \, Cl^-$ ….. 1

$\Lambda_m° \, CH_3COOH = \Lambda_m° \, CH_3COONa + \Lambda_m° \, HCl - \Lambda_m° \, NaCl$