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3 (Sem-4/CBCS) CHE-HC 3

2025

## CHEMISTRY

(Honours)

Paper : CHE-HC-4036

**(Physical Chemistry-IV)**

Full Marks : 60

Time : Three hours

***The figures in the margin indicate full marks for the questions.***

1. Answer **any seven** of the following questions : 1×7=7
- (a) Define specific conductance of an electrolyte.
- (b) Under what conditions will a galvanic cell send no current in the outer circuit?
- (c) What is the charge in coulombs on  $\text{CO}_3^{2-}$  ion?
- (d) Define Wien effect.

(e) What is the relationship between molar conductivity and equivalent conductivity of an electrolyte  $A_xB_y$  ?

(f) The conductivity of  $N/10KCl$  solution at  $20^\circ C$  is  $0.0212 S cm^{-1}$  and the resistance of the cell containing this solution is 55 ohms. The cell constant in  $cm^{-1}$  is

(i) 4.6

(ii) 0.616

(iii) 2.17

(iv) 1.166

(Choose the correct option)

(g) Define magnetic susceptibility.

(h) Which of the following molecules would have zero dipole moment ?

(i) *m*-dichlorobenzene

(ii) *p*-dichlorobenzene

(iii)  $CH_3Cl$

(iv)  $NH_3$

(Choose the correct option)

(i) What is magnetic permeability ?

(j) Fluorine cannot be prepared from fluorides by chemical oxidation. Why ?

2. Answer **any four** of the following questions :

$2 \times 4 = 8$

(a) Explain why mobility of  $H^+$  ion is highest in aqueous solution.

(b) Write the reaction that takes place in  $Ag-AgCl$  electrode. Also write Nernst equation for the same.

(c) The molar conductances at infinite dilution of  $NaOH$ ,  $NaCl$  and  $BaCl_2$  are

$2.481 \times 10^{-2} Sm^2 mol^{-1}$ ,

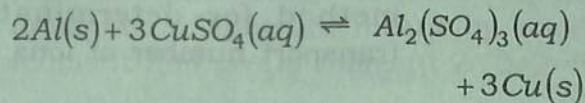
$1.265 \times 10^{-2} Sm^2 mol^{-1}$  and

$2.80 \times 10^{-2} Sm^2 mol^{-1}$  respectively.

Calculate molar conductance at infinite dilution of  $Ba(OH)_2$ .

(d) Given,  $E^\circ Cu^{2+} | Cu = 0.34V$  and

$E^\circ Al^{3+} | Al = -1.66V$ . Calculate the equilibrium constant of the following reaction at  $298 K$  :



- (e) Explain why mobility of  $Li^+$  is less than that of  $K^+$  ion aqueous medium.
- (f) Explain the terms 'induced polarization' and 'orientation polarization'.
- (g) What is dipole moment? What are its units?
- (h) The dipole moment of  $NH_3(g)$  is 1.46D. If the angle HNH is  $108^\circ$ , calculate the bond moment of N-H bond.

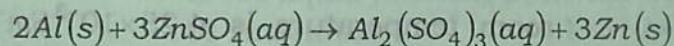
3. Answer **any three** of the following questions :  $5 \times 3 = 15$

- (a) Using Debye-Huckel theory discuss about different factors that affect the speed of ion when an electric field is applied.
- (b) Deduce an expression for the e.m.f. of the concentration cell with transference :
- $Pt(s) | H_2(1atm) | HCl(a_1) : HCl(a_2) | H_2(1atm) | Pt(s)$
- (c) (i) Explain the moving boundary method for determination of transport number of ions. 3

- (ii) Write the electrode reaction of calomel electrode when the cell acts as cathode. Give the expression for potential of a calomel electrode. 2

- (d) (i) Calculate the mean ionic activity coefficient of 0.01 M  $Na_2SO_4$  solution in water at 298 K. 3

- (ii) Calculate the standard free energy change associated with the reaction : 2



Given :

$$E_{Al^{3+}|Al}^0 = -1.66V \text{ and}$$

$$E_{Zn^{2+}|Zn}^0 = -0.76V$$

- (e) What is meant by polarizability of a molecule? Derive the Clausius-Mossotti equation.  $1+4=5$
- (f) What information regarding the structure of molecules can be obtained from the knowledge of their dipole moments? What are meant by bond moment and group moment?  $3+2=5$

(g) Give a brief account of Lorentz-Lorentz equation.

(h) Calculate the solubility product of the sparingly soluble salt  $\text{CaF}_2$  from the following data :

The molar ionic conductances (at infinite dilution) of  $\text{Ca}^{2+}$  and  $\text{F}^-$  ions are  $104 \times 10^{-4}$  and  $48 \times 10^{-4} \text{ Sm}^2 \text{ mol}^{-1}$  respectively. The specific conductance of the saturated solution of  $\text{CaF}_2$  at room temperature is  $4.25 \times 10^{-3} \text{ Sm}^{-1}$  and the specific conductance of water used for preparing the solution is  $2 \times 10^{-4} \text{ Sm}^{-1}$ .

4. Answer **any three** of the following questions :  $10 \times 3 = 30$

(a) (i) A solution of  $\text{HCl}$  was electrolysed in a Hittorf cell using Pt electrodes. The analysis of the solution from the cathode compartment before and after electrolysis indicated the masses of  $\text{HCl}$  as  $1.82 \times 10^{-4} \text{ kg}$  and  $1.67 \times 10^{-4} \text{ kg}$  respectively. At

the same time the mass of  $\text{Ag}$  deposited at the cathode of the coulometer in the same circuit was

found to be  $2.52 \times 10^{-4} \text{ kg}$ .

Calculate the transport number of each ion. 4

(ii) Write what you mean by concentration cell. Taking the example of hydrogen electrode, explain how concentration cells are classified. Explain in which type of cell liquid junction potential will be maximum.  $1+3+2=6$

(b) What is the principle underlying conductometric titrations ? Discuss the titration curves obtained in the titration of :

(i) a strong acid with a strong base;

(ii) a strong acid with a weak base;

(iii) a mixture of  $\text{HCl}$  and  $\text{CH}_3\text{COOH}$  with  $\text{NaOH}$ ;

(iv)  $\text{AgNO}_3$  against  $\text{KCl}$ .

$2+2+2+2=10$

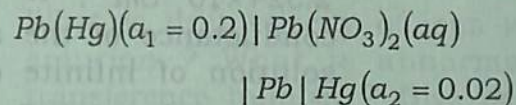
(c) (i) Write Nernst equations for the potentials of  $Zn$ -electrode and  $Cu$ -electrode in the Daniell cell. Hence find an expression for the e.m.f. of the Daniell cell at any given temperature.  $2+2=4$

(ii) For the reaction  $Fe^{3+} + 3e^- \rightleftharpoons Fe$ , standard electrode potential is  $-0.036 V$  and the standard electrode potential for the reaction  $Fe^{3+} + e^- \rightleftharpoons Fe^{2+}$  is  $0.771 V$ . Calculate the standard electrode potential for the reaction  $Fe^{2+} + 2e^- \rightleftharpoons Fe$ . Predict whether the reaction  $Fe + 2Fe^{3+} \rightleftharpoons 3Fe^{2+}$  is spontaneous or not.  $4+2=6$

(d) (i) Deduce the relationship between ion mobility and molar conductance of an electrolyte. 4

(ii) What do you mean by activity coefficient? Taking an example, discuss how mean ionic activity coefficient can be found out from e.m.f. measurement.  $1+3=4$

(iii) Calculate the EMF of the following electrode concentration cell at  $298K$ : 2



(e) (i) Discuss the principle underlying potentiometric titrations. Discuss the variation of potential with volume of  $NaOH$  added in the titration against  $HCl$ ? In what respect potentiometric titrations are better than simple volumetric titrations?  $2+2+2=6$

(ii) Explain a method of measurement of magnetic susceptibility of a substance. 4

(f) (i) Explain how the dipole moment of a gaseous molecule can be determined by using the Debye equation. 6

(ii) Estimate the refractive index of water, given that the polarizability volume of water molecule at optical frequencies is  $1.5 \times 10^{-24} cm^3$ . 4

- (g) (i) Conductivity of a  $0.02 \text{ mol ohm}^{-3}$  solution of acetic acid at  $298\text{K}$  is  $2.324 \times 10^{-2} \text{ Sm}^{-1}$ . If the molar conductance of the acetic acid solution of infinite dilution is  $387.9 \times 10^{-4} \text{ Smol}^{-1} \text{ m}^2$ , calculate the degree of dissociation of acetic acid in the solution at  $298\text{K}$ . 3
- (ii) The molar ionic conductance at infinite dilution of silver ions is  $61.92 \times 10^{-4} \text{ Sm}^2 \text{ mol}^{-1}$  at  $25^\circ\text{C}$ . Calculate the ionic mobility of silver ions at  $25^\circ\text{C}$  at infinite dilution. 3
- (iii) In an electrolysis experiment, a current was passed for 5 hours through two cells connected in series. The first cell contains a solution of gold salt and second cell contains copper sulphate solution.  $9.85\text{g}$  of gold was deposited in the first cell. If the oxidation number of gold is  $+3$ , find the amount of copper deposited on the cathode in the second cell. Also calculate the magnitude of the current in ampere. 4

- (h) (i) What are meant by electronic polarisation and atomic polarisation ? 2
- (ii) What is drift velocity of ions in solution ? What is abnormal transference number ? Give one example.  $2+3=5$
- (iii) The standard electrode potentials of  $\text{Pb}/\text{Pb}^{2+}$  and  $\text{Pt}/\text{I}^-/\text{I}_2$  are  $-0.126$  volt and  $+0.536$  volt respectively. When a galvanic cell is constructed using  $0.1$  molar concentrations of the respective ions,  $\text{Pt}$  is found to be the cathode. What is the voltage generated in the cell ? 3

the cell?

What is the voltage generated in ions, Pt is found to be the cathode. concentrations of the respective is constructed using 0.1 molar respectively. When a galvanic cell -0.125 volt and +0.536 volt of  $Pb/Pb^{2+}$  and  $Pt/V^{2+}$  are

(ii) The standard electrode potentials

example.  $2+3=5$  transference number? Give one solution? What is abnormal? What is drift velocity of ions in

(i) What are meant by electronic polarization and atomic polarization?