Discipline Specific Elective Courses Applicable Specifically for B.Sc. Physical Sciences

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE

Discipline Specific Elective Courses –18 PS (DSE-18 PS): Introductory Interfacial Electrochemistry

COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Introductory Interfacial Electrochemistry **(DSE-18 PS)**	**04**	**02**	**--**	**02**	**Class 12th with Physics, Chemistry, Mathematics**	**--**

Course Objectives

The objectives of this course are as follows:

- To discuss the electrochemical cells and Faradaic and Nonfaradaic Processes.
- To develop an understanding of electrical double layer and various equivalent circuit models of electrical double layer.
- To enable learners to have an insight into electrode kinetics and evaluation of kinetic parameters.
- To explain nature of electrode processes using cyclic voltammograms.
- To provide hands-on experience with setting up of electrochemical cells, quantitative estimation and evaluation of important physical quantities.

Learning outcomes

By studying this course, the students will be able to:

- Develop an understanding of working, counter electrode and differentiate between various reference electrodes along with the nature of electrode process.
- Understand the concept of electrical double layer and various equivalent models of the electrical double layer.

- Understand kinetics parameters from Tafel plot and thus demonstrate understanding of electrode kinetics, Butler-Volmer equation; its physical implications and cyclic voltammograms.
- Understand various applications of electrochemistry i.e. electrocatalysis, transport in electrolyte solution, conversion and storage of electrochemical energy.
- Perform hands-on laboratory exercise and interpret results of important electrochemical techniques i.e. cyclic voltammetry.

Theory:

Unit 1 Electrochemical Cells and Reaction - (6 Hours)
Working and Counter Electrodes, Reference Electrodes: standard hydrogen electrode (SHE), or normal hydrogen electrode (NHE), saturated calomel electrode (SCE), silver-silver chloride electrode, potential of zero charge, open-circuit potential of the cell, overpotentials. Faradaic and Nonfaradaic Processes: ideal polarized (or ideal polarizable) electrode, Capacitance and Charge of an Electrode, supporting electrolyte.

Unit 2: Electrical Double Layer (8 Hours)
Description of the Electrical Double Layer: inner and outer compact layer Helmholtz, or Stern layer, Diffuse Layer, specifically and non-specifically adsorbed ions, Potential profile across the double-layer region in the absence of specific adsorption of ions, Equivalent circuit models of EDL, Gouy-Chapman Model, qualitative Graham-Devanathan-Mottwatts, Tobin, Bockris, Devanathan model.

Unit 3: Electrode Kinetics (8 Hours)
Electrode Kinetics: Formal and Equilibrium Potentials, Overpotentials, Derivation of Butler-Volmer equation and its physical implications, Exchange current density and transfer coefficient, Evaluation of kinetics parameters from Tafel plot. Explain reversible, quasireversible, irreversible and capacitive response using cyclic voltammograms.

Unit 4: Applications of Electrochemistry (8 Hours)
Electrocatalysis: Influence of various parameters on water splitting, HER and OER.
Corrosion: Introduction to corrosion, forms of corrosion, General description of Corrosion monitoring and prevention.
Transport in Electrolyte Solution: Qualitative discussion of Fick laws and equations of Einstein on diffusion.
Conversion and Storage of Electrochemical Energy: Fuel cells, Supercapacitors and Li ion batteries, Redox flow batteries.

Practicals: Credits: 02

(Laboratory periods:15 classes of 4 hours each)

1. Conductometric Titration of a Charge Transfer System, the formation of charge transfer complex between an electron donor and acceptor is studied and the stoichiometry of the complex is determined by following the variation of conductance of the solution with concentration of the donor and acceptor.
2. Effect of ionic strength on reaction rate (persulfate-iodine reaction).

3. Potentiometric determination of solubility and solubility product of AgCl(s) in water.
4. Potentiometric determination of mean ionic activity coefficient of HCl at different concentrations.
5. Potentiometric titration of Phosphoric acid vs NaOH.
6. Determination of dissociation constant of acetic acid from its potentiometric titration curve.

Hands-on/Demonstration/ Instruction Mode*: Demonstration/ Discussion of working principle/ Hands-on with substantial literature analysis/ Laboratory exercise.

7. Record cyclic voltammogram for the electrochemical capacitors (electric double layer) response with varying scan rates,
   i) plot anodic and cathodic plateau currents vs scan rates.
   (Use aqueous solution of 1.5 M $NaNO_3$)
8. Record cyclic voltammogram for a reversible heterogeneous electron transfer system with varying scan rates,
   (i) Determine anodic and cathodic peak current ratio.
   (ii) Determine anodic and cathodic peak potential difference.
   (iii) Plot peak current vs square root of scan rates.
   (Use aqueous solution of 10 mM $K_4Fe(CN)_6 + K_3Fe(CN)_6$ + 1.5 M $NaNO_3$)
9. Record cyclic voltammogram for a quasi-reversible heterogeneous electron transfer system with varying scan rates,
   (i) Determine anodic and cathodic peak current ratio.
   (ii) Determine anodic and cathodic peak potential difference.
   (iii) Plot peak current vs square root of scan rates.
   (Use aqueous solution of 10 mM $Fe(NH_4)_2\ (SO_4)_2 + Fe(NH_4)(SO_4)_2$ + 1 M $HClO_4$)
10. Record the CV of aqueous solution of sulphuric acid (0.5 M) at Pt electrode as working electrode and counter electrode.
   (i) Interpret and explain various peaks and region of the CV and their significance.
   Determine the area and roughness factor of the electrode by Pt oxide region.

*[pre-recorded data for computer simulation may also be shared for visualization analysis and interpretation on MS-Excel]

Laboratory Activities

11. Assembling a simple electrochromic device from household materials and visualization of the colour change of curcumin.
   (https://pubs.acs.org/doi/10.1021/acs.jchemed.2c00176.)

12. Design concentration cells to demonstrate whether
   (i) Iron under the water surface has the same Corrosion Level at any part?
   (ii) Copper Sheets be Galvanized with Zinc without an External Power Supply?
   (https://pubs.acs.org/doi/10.1021/acs.jchemed.0c01408.)

Essential/recommended readings
Theory:

1. Bard, A. J. Faulkner, L. R. Electrochemical Methods: Fundamentals and Applications, 2nd Ed., John Wiley & Sons: New York, 2002.

2. Oldham, K. B., Myland, J. C. and Bond, A. M. Electrochemical Science and Technology: Fundamental and Applications, John Wiley & Sons, Ltd. (2012).
3. Bockris, J. O' M. & Reddy, A. K. N. Modern Electrochemistry 1: Ionics 2nd Ed., Springer (1998).
4. Bockris, J. O' M. & Reddy, A. K. N. Modern Electrochemistry 2B: Electrodics in Chemistry, Engineering, Biology and Environmental Science 2nd Ed., Springer (2001).
5. Bockris, J. O' M., Reddy, A. K. N. & Gamboa-Aldeco, M. E. Modern Electrochemistry 2A: Fundamentals of Electrodics 2nd Ed., Springer (2001).
6. Brett, C. M. A. & Brett, A. M. O. Electrochemistry, Oxford University Press (1993).
7. Koryta, J., Dvorak, J. & Kavan, L. Principles of Electrochemistry John Wiley & Sons: NY (1993).
8. Bagotsky, V.S., Fundamentals of electrochemistry 2nd Ed. Wiley – Interscience, (2006)
9. Hamann, Carl H., Hamneff, Andrew & Vielstich, Wolf., Electrochemistry, 2nd Ed. (2007)

Practical:

1. B. D. Khosla, V. C. Garg, A. Gulati, Senior Practical Physical Chemistry, R. Chand & Co, New Delhi.
2. Holze R., (2019) Experimental Electrochemistry: A laboratory Textbook, Wiley-VCH.
3. Elgrishi, N.; Rountree, K. J.; McCarthy, B. D.; Rountree, E. S.; Eisenhart, T. T.; Dempsey, J. L. A Practical Beginner's Guide to Cyclic Voltammetry, *J. Chem. Educ.* **2018**, *95*, *2*, 197–206.
4. Field, R. J.; Schneider, F. W. Oscillating Chemical Reactions and Nonlinear Dynamics, *J. Chem. Educ.* **1989**, *66*, *3*, 195–204.
5. Rozman M, Alif M, Bren U., Lukšič M., Electrochromic Device Demonstrator from Household Materials, *J. Chem. Educ.* 99, 10, 3595-3600.
6. Ling Y., Chen P., **2022**, Wang J., Chen K, Ren H. Design, Implementation, and Evaluation of a Scientific Modeling Course on Concentration Cells, *J. Chem. Educ.* **2021**, 98, 4, 1163-1173

Note: Minimum 6 hands-on exercise to be performed**.**

Assessment Methods: All examination and assessments methods shall be in line with the University of Delhi guidelines issued from time to time.