

**Discipline Specific Courses Applicable Specifically for
B.Sc. Life Sciences**

**DISCIPLINE SPECIFIC ELECTIVE COURSE – 23 LS (DSE-23 LS)
Bioelectrochemistry**

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical / Practice		
Bioelectro-chemistry (DSE-23 LS)	04	02	--	02	Class 12th with Physics, Chemistry	--

Course Objectives

The objectives of this course are as follows:

- To provide a conceptual understanding of the various types of electrodes and the electrochemical processes.
- To equip the students with conceptual understanding of the electrical double layer and Equivalent circuit models of EDL; Gouy-Chapman Model etc.
- To help build an insight into Interfacial Electron Transfer in Biological Systems.
- To provide an understanding of the concept of bio-electrocatalysis and electrochemical communication in biological organisms.

Learning outcomes

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

- Differentiate between different electro systems and account for the electrochemical processes at the electrodes.
- Demonstrate their understanding of the electrical double layer, membrane potential and the concept of interfacial electron transfer in biological systems.
- Exhibit their understanding of Chemical signalling, electrical signalling. Electrochemical mechanisms of the nervous system
- Develop an insight into Bioelectrocatalysis Using Enzymes electrodes.

Unit 1: Electrode and Electrochemical Processes (8 Hours)

Qualitative conceptual description of 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: Ideally polarizable electrode, Capacitance and Charge of an Electrode, supporting electrolyte, Nernst equation, Nernst potential and biological systems.

Description of the Electrical Double Layer: Stern Potential, Zeta potential. Membrane potentials, simplistic theories of membrane potentials, electrical conduction in biological organisms: electronics and protonics.

Unit 2: Electrical Double Layer (8 Hours)

Description of the Electrical Double Layer: inner and outer compact layer Helmholtz, 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 discussion only)

Brief qualitative discussion of basic principle and application of electrophoresis, Electrochemical impedance spectroscopy and cyclic voltammetry techniques.

Unit 3: Interfacial Electron Transfer in Biological Systems (6 Hours)

Electrode kinetics, Butler-Volmer equation, adsorption of proteins onto metals from solution, electron transfer from biomaterials to simple redox ions in solution, theoretical aspects of electron transfer from solid proteins to ions in solution.

Unit 4: Electrochemical Communication and Bio-Electrocatalysis (8 Hours)

Chemical signalling, electrical signalling. Electrochemical mechanisms of the nervous system, theory of the spike potential. Monitoring neurotransmitters in the intact brain and other single-cell studies.

Bio-Electrocatalysis, electrodes carrying enzymes, electrochemical enzyme-catalyzed oxidation of styrene.

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. To measure the Vitamin C content of commercial Orange Juice using Pencil Lead as a working electrode in cyclic voltammetry.
8. Synthesis and Cyclic voltammetry study of Nano-wood, prepared using household Chemicals.
9. 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 $K_4Fe(CN)_6 + K_3Fe(CN)_6 + 1.5 M NaNO_3$)
10. 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 10mM $Fe(NH_4)_2(SO_4)_2 + Fe(NH_4)(SO_4)_2 + 1 M HClO_4$)
 11. 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.

Essential/recommended readings

Theory:

1. Bockris, J. O' M. & Reddy, A. K. N. Modern Electrochemistry 2A: Fundamentals of Electrode Processes 2nd Ed., Springer (2001).
2. Bockris, J. O' M. & Reddy, A. K. N. Modern Electrochemistry 2B: Electrode Processes in Chemistry, Engineering, Biology and Environmental Science 2nd Ed., Springer (2001).
3. Bard, A. J. Faulkner, L. R. Electrochemical Methods: Fundamentals and Applications, 2nd Ed., John Wiley & Sons: New York, 2002.
4. Oldham, K. B., Myland, J. C. and Bond, A. M. Electrochemical Science and Technology: Fundamental and Applications, John Wiley & Sons, Ltd. (2012).
5. Brett, C. M. A. & Brett, A. M. O. Electrochemistry, Oxford University Press (1993).
6. Koryta, J., Dvorak, J. & Kavan, L. Principles of Electrochemistry John Wiley & Sons: NY (1993).
7. Bagotsky, V.S., Fundamentals of Electrochemistry 2nd Ed. Wiley – Interscience, (2006)
8. Hamann, Carl H., Hamneff, Andrew & Vielstich, Wolf., Electrochemistry, 2nd Ed. (2007)

Practical:

1. Khosla B. D., Garg V. C., Gulati A., Senior Practical Physical Chemistry, R. Chand & Co, New Delhi.
2. Holze R., (2019) Experimental Electrochemistry: A laboratory Textbook, Wiley-VCH.
3. Brabec V., Walz D., Milazzo G., Experimental techniques in Bioelectrochemistry, Springer.
4. Bartlett P. N., Bioelectrochemistry: Fundamentals, Experimental Techniques and Applications, John Wiley & Sons Inc.
5. 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.
6. Field, R. J.; Schneider, F. W. Oscillating Chemical Reactions and Nonlinear Dynamics, *J. Chem. Educ.* **1989**, *66*, 3, 195–204.
7. King D, Friend J., Kariuki J., *Measuring Vitamin C Content of Commercial Orange Juice Using a Pencil Lead Electrode*, *J. Chem. Educ.* **2010**, *87*, 5, 507–509.
8. Lima D, Singh V, Bulleeraz K, Lussier J. A., Kuss S., Electrifying Fruit Juice: Integrating Applied Electroanalytical Chemistry into the Undergraduate Curriculum, *J. Chem. Educ.* **2024**, *101*, 7, 2938-2946.

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