Department of Chemistry
Indian Institute of Technology Kanpur

CHM671: Applied Electrochemistry: Electrodics and Electrocatalysis

Instructor: **Dr. Anantharaj Sengeni** (ananths@iitk.ac.in)
Prerequisites: None
Offered as: Open Elective to All

Course Description: This course introduces electrochemistry from a materials and molecular perspective, focusing on its role in energy conversion, storage, sensing, and molecular-scale catalytic systems. It connects fundamental principles with the design and behavior of materials and molecules in catalyzing reactions of batteries, fuel cells, electrolyzers, and related technologies. The course adopts a layered approach, moving from physical intuition to core equations and finally to materials- and molecular-level insights, with particular emphasis on kinetics, charge transfer, and interfacial phenomena. Electroanalytical techniques are taught through standardized frameworks to extract reliable mechanistic and kinetic information. Emphasis is placed on linking electronic structure, surface chemistry, and molecular architecture to electrochemical activity, selectivity, and stability, along with best practices in measurement, reproducibility, and data interpretation. Overall, the course trains students to connect structure to electrochemical behavior to mechanism to function across materials and molecular systems.

Course Contents:

S. No	Broad Title	Topics	No. of Lectures
1.	Fundamentals of Electrochemistry and Interfaces	• Electrochemical energy, potentials, and driving forces. • Nernst equation and thermodynamics in materials and molecular systems. • Electrochemical interfaces: solid–liquid and molecule–electrode interfaces. • Double-layer structure and interfacial fields. • Ion transport and mass transfer. • Summary: Linking thermodynamics to structure and interfaces.	4
2.	Electrodics and Charge Transfer	• Physical meaning of kinetics at material and molecular interfaces.	8

		• Butler–Volmer equation. • Tafel analysis and kinetic parameter extraction. • Electron transfer theories (adiabatic/non-adiabatic concepts). • Diffusion and transport in structured electrodes. • Multi-step reactions and rate-determining steps.	
3.	Electroanalytical Techniques for Materials and Molecular Systems	• Cyclic and linear sweep voltammetry (CV & LSV): Interpretation of current-voltage profiles. • Chronoamperometry and chronopotentiometry. • Electrochemical impedance spectroscopy (EIS): Basics and data fitting. • Rotating disk electrode (RDE) and rotating ring-disk electrode (RRDE) techniques. • In-situ and operando techniques in electrocatalysis. • Spectroelectrochemistry	6
4.	Electrocatalysis for Energy Conversion and Sensing Reactions	• Core principles: adsorption energy and reaction energetics. • Electrochemical sensing of glucose, vitamins and other relevant biomolecules and of environmental pollutants. • HER, OER, ORR, CO_2 reduction, N_2 reduction. • Descriptor-based catalyst design and scaling relations. • Structure–activity–stability relationships.	4
5.	Molecular Electrocatalysis and Interfaces	• Principles of molecular electrocatalysis: homogeneous vs heterogeneous systems. • Redox-active molecules and catalytic cycles. • Proton-coupled electron transfer (PCET).	3

		• SAM-based redox-active interfaces • Applications in sensing and catalysis.	
6.	Analytical Tools for Electrochemistry	• Fundamentals of pXRD, Raman, IR, UV-Vis, XAS, XPS, UPS, TEM, SEM, AFM, and STM. • Integration and operation of above techniques for *operando* electrochemistry • Spectroelectrochemistry	8
7.	Best Practices and Data Interpretation	• Reproducibility and benchmarking across materials and molecular systems. • Common pitfalls in electrochemical measurements. • Standard protocols: iR correction, ECSA, normalization. • Reporting metrics for catalysts, devices, and interfacial systems. • Case studies in misinterpretation and corrected analysis.	2
8.	Case Studies and Term Projects	• Guided analysis of selected research papers (materials and molecular systems). • Data interpretation exercises (CV, EIS, kinetics). • Mini projects: mechanism identification, catalyst benchmarking, or device analysis.	4

Recommended References:

a. Textbooks:

i. Electrochemical Methods: Fundamentals and Applications by A.J. Bard and L.R. Faulkner

ii. Modern Electrochemistry by J. O'M. Bockris and A.K.N. Reddy

iii. Fuel Cell Fundamentals by Ryan O’Hayre et al.

iv. Electrochemical Supercapacitors: Scientific Fundamentals and Technological Applications by B.E. Conway

v. Handbook of Batteries edited by David Linden and Thomas B. Reddy

भारतीय प्रौद्योगिकी संस्थान कानपुर
Indian Institute of Technology Kanpur

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No. A(P)/IITK/course approval/
July 21, 2026

The Convener, DPGC
Departments of **CHM, SEE, CHE, CE, MTH, ME**
IIT Kanpur

I am directed to communicate the concurrence of the SPGC (2025-26) in its 10th meeting held on June 22, 2026, for the approval of new/modification PG course proposal. After detailed discussion the following courses were approved.

Course No	Title	Credits	Instructor	SPGC Decision
CHM671	Applied Electrochemistry: Electrodics and Electrocatalysis	3-0-0-0 (9)	Dr. Anantharaj Sengeni	Approved
SEE638	Techno-Economic Assessment for Low Carbon Transition: Market, Policy, and Pathways	3-0-0-0 (9)	Dr. Deepika Swami	Approved
CHE671	Stochastic Simulations, Optimization, and Parameter Estimation in Chemical Engineering	3-0-0-0 (9)	Dr. Raj Ganesh S. Pala	Approved
CE731	Critical state theory for soil	3-0-0-0 (9)	Dr. Bipin Kumar Gupta	Approved
MTH756	Advanced ODE and PDE	3-0-0-0 (9)	Dr. Indranil Chowdhury	Approved
MTH744M	Iso-geometric Finite Element Analysis of Fluid Flows	3-0-0-0 (5)	Dr. B.V.R. Kumar	Approved
MTH757	Topology and Geometry	3-0-0-0 (9)	Dr. Debasis Sen	Approved
MTH758	Numerical Analysis	3-0-0-0 (9)	Dr. Mrinmay Biswas	Approved
ME628	Thermal Management of Electronic Systems	3-0-0-0 (9)	Dr. Umesh Madanan	Approved

22/07/2026
Assistant Registrar
Academic Affairs

CC: OARS (DOAA Office) for necessary action