College of Science  **Department of Chemistry**

Course Code: CHEM-4437 *Course Title:* Electrochemistry

General Information

Number of Credits:	3
Instructional Format:	Lectures (2 h/w) + Tutorial (2 h/w)
Contact Hours/Week:	4
Prerequisite:	CHEM-3333 or CHEM-3330
Co-requisite:	NONE
Assessment:	Mid-term Exams (40%) + assignments (10%) + Final Exam (50%).
Grading:	(A–F)
Textbook:	Allen J. Bard and Larry R. Faulkner, Electrochemical methods: Fundamentals and Applications, 2nd edition, John Wiley, 2001
References (optional):	D. Brynn Hibbert, Introduction to Electrochemistry, MacMillan Physical Science Series, 1993.

1. Course Description

This course will introduce students to the fundamental and application of modern electrochemistry. Applying electrochemical theories to describe events occurred at the electrode surface. Using new electrochemical terminologies, new electrochemical methods and variety of electrodes employed for different applications. Introduce electrochemistry as an important tool in industrial, biological, medical and environmental applications.

2. Course Objectives

This course seeks to:

1. Set a firm foundation in modern electrochemistry
2. Present electrochemistry as an effective tool for analytical measurements
3. Describe chemical reactions according to electrochemical theories
4. Depict electrochemical methodology terms and methods
5. Evaluate some thermodynamic and kinetic parameters

3. Learning Outcomes

(a) Knowledge

On successful completion of this course, students will be able to:

1. Distinguish and define Faradaic and Non–Faradaic processes, double layer capacitance and charging current, ideal and non-ideal polarized electrodes.
2. Demonstrate the factors affecting the rates of electrode reactions and generalize mass transfer controlled reactions.
3. Generalize the importance of Tafel plot to evaluate the exchange current, the charge transfer resistance and the transfer coefficient.
4. Classify potential step under diffusion control and derive the diffusion current (Cottrell equation) for planar and spherical electrodes.
5. Summarize potential sweep voltammetry for reversible and totally irreversible processes, and predict the effect of scan rate, charging current and double layer capacitance on the peak current.

6. Apply the convective-diffusion (Levich and Koutechy-Levich) equations using RDE or/and RRDE to evaluate some thermodynamic and kinetic parameters.

(b) Skills and Attitudes

This elective course is offered without lab component. Therefore, the above subject specific skill may be considered as a general skill since the tutorial lecture will often be used to demonstrate a number of methods and used to demonstrate a number of methods and applications.
Also, students are involved in writing a single assignment on the application of electrochemistry in industrial, environmental, biological and clinical applications. This would broaden their knowledge and understanding for utilizing electrochemistry in the above applicable themes.

4. Assessment

Learning outcome:	**Assessment criteria**				
	A	**B**	**C**	**D**	**F**
(1) Electrochemical terminologies and definitions	Showing mastery understanding of various terminologies	Having a good understanding of various terminologies	Having a satisfactory understanding of various important terminologies	Having a less satisfactory understanding of various important terminologies	Demonstrating a very weak in understanding of various important terminologies
(2) Generalize mass transport modes and factor affecting the rate of electrode reaction	Showing mastery understanding of mass transport controlled reactions and excellently demonstrate the surface concentration profile as a function of time.	Having a good understanding of mass transport controlled reactions and a good ability to demonstrate the surface concentration profile as a function of time.	Having a satisfactory understanding of mass transport controlled reactions and an average ability to demonstrate the concentration profile as a function of time.	Having a less satisfactory understanding of mass transport controlled reactions and an average ability to demonstrate the concentration profile as a function of time.	Showing a weak understanding of mass transport controlled reactions and an average ability to demonstrate the concentration profile as a function of time.
(3) Electrode kinetics using well-known electrochemical theories.	Demonstrating a mastery understanding of electrode kinetics and ability to evaluate a range of chemical parameters.	Showing a good understanding of electrode kinetics and ability to evaluate some reaction parameters.	Having an average understanding of electrode kinetics and average ability to evaluate reaction parameters.	Having a less satisfactory understanding of electrode kinetics and less ability to evaluate a range of chemical parameters.	Showing a weak understanding of electrode kinetics and weak ability to evaluate a range of chemical parameters.
(4) & (5) Potential step and potential sweep methods and their applications for planar and spherical electrodes.	Demonstrating a mastery understanding of both potential techniques, applied their mathematical equations, excellently figure out the difference between reversible and irreversible processes and evaluate diffusion coefficient.	Demonstrating a good understanding of both potential techniques, applied their mathematical equations, describe the difference between reversible and irreversible processes, evaluate diffusion coefficient.	Demonstrating an average understanding of both potential techniques with their applied mathematical equations, figure out the difference between reversible and irreversible processes, evaluate diffusion coefficient.	Demonstrating a less satisfactory understanding of both potential techniques with their applied mathematical equations, a lack of describing the difference between reversible and irreversible processes, and weakly evaluate diffusion coefficient.	Demonstrating a weak understand--ing of both potential techniques with their applied mathematical equations, a lack of describing the difference between reversible and irreversible processes, and hardly evaluate diffusion coefficient.

(6) Application of rotating disk electrodes (diffusion + convection) process and its importance to evaluate thermodynamic and kinetic parameters.	Demonstrating a mastery understanding of convective diffusional process, describe types of fluid flow in hydro-dynamic process, depicts excellently mass transport limitation (levich) and those associated with kinetic limitations (Koutecky-Levich) theories, apply these theories to evaluate kinetics and thermodyna-mic parameters.	Demonstrating a good understanding of convective diffusional process, describe types of fluid flow in hydro-dynamic process, depicts logically mass transport limitation (levich) and those associated with kinetic limitations (Koutecky-Levich) theories, apply these theories to evaluate kinetics and thermodyna-mic parameters.	Demonstrating an average understanding of convective diffusional process, describe types of fluid flow in hydro-dynamic process, fairly depicts mass transport limitation (levich) and those associated with kinetic limitations (Koutecky-Levich) theories, fairly apply these theories to evaluate kinetics and thermodyna-mic parameters.	Demonstrating a less satisfactory understanding of convective diffusional process, fairly describe types of fluid flow in hydro-dynamic process, fairly depicts mass transport limitation (levich) and those associated with kinetic limitations (Koutecky-Levich) theories, hardly apply these theories to evaluate kinetics and thermodyna-mic parameters.	Demonstrating a weak understand-ing of convective diffusional process, hardly describe types of fluid flow in hydrodynamic process, weakly depicts mass transport limitation (levich) and those associated with kinetic limitations (Koutecky-Levich) theories, hardly apply these theories to evaluate kinetics and thermodyna-mic parameters.

5. Instructional Methods:

Lectures and Tutorials

- Lectures will be primarily based on the material described in the textbook.
- A tutorial session will be conducted at the end of each chapter via solving some assigned problems.
- Other information (power point presentation, exam sample, model answer of some problems, etc) are provided through e-learning tools.

Assignments

During the period of this semester, each student should submit ***ONE*** report about the application of electrochemistry written in journal format described as below;

(i) ***Introduction:*** comprehensive literature review of the electrochemistry application theme accompanied by relevant references.

(ii) ***Experimental Conditions:*** state the type of reagents, instrumentation, preparation of samples, surface characterization, electrodes, etc.

(iii) ***Discussion:*** show the major results and achievements of that application accompanied with some figures, reaction schemes or/ and tables.

(iv) ***Conclusions:*** a brief description of the importance of the above application.

(v) ***References:*** list of references in ordered form as given in the body of the report.

Suggested topics:

(1) Chemical sensors for biological and pharmaceutical applications such as glucose, dopamine, ascorbic acid, uric acid, cholesterol, DNA, ephedrine, etc. ***(select one application)***

(2) Chemical sensors for environmental applications such as heavy metals, hydrogen sulphide, nitrogen oxides, etc. ***(select one application)***

(3) The chloro-alkali industry (the production of Chlorine, Hydrochloric acid and Sodium hydroxide).

(4) Metal winning and refining of ***copper*** or ***aluminium***.

(5) Photo-electrochemistry and its application.

(6) Electrochemistry and thermodynamic of corrosion.

(7) Potential–pH diagram (Pourbaix Diagram) and its application.

(8) Corrosion protection and inhibition.

(9) Lithium secondary Batteries.

(10) Hydrogen–Air Fuel Cells (Low temperature alkaline cell) and (High temperature cells).

6. Topics and Time Frame

Chapters	Topics	Sections	Weeks
CH. 1	**(1) Introduction and overview of electrode processes**		1 – 3
	1.1. Introduction.	1.1	
	1.2. Non-faradaic processes and the nature of the electrode/ solution interface.	1.2	
	1.3. Faradaic processes and factors affecting rates of electrode reactions.	1.3	
	1.4. Introduction to mass transfer controlled reactions.	1.4	
	1.5. Semi-empirical treatment of nernstian reactions with coupled chemical reactions.	1.5	
CH. 2	**(2) Potentials and thermodynamics of cells**		4 – 5
	(i) Reversibility	2.1	
	(ii) Reversibility and Gibbs free energy		
	(iii) Free energy and cell EMF		
	(iv) Half reactions and standard reduction potentials		
	(v) EMF and concentration, cell formal potentials		
	(vi) Reference electrodes		
	(vii) Interfacial potential differences	2.2	
	(viii) Liquid junction potentials	2.3	
CH. 3	**(3) Kinetics of electrode reactions**		6 – 8
	3.1. Review of homogeneous kinetics.	3.1	
	3.2. Essentials of electrode reactions.	3.2	
	3.3. Butler-Volmer model of electrode kinetics.	3.3	
	3.4. Implications of the Butler-Volmer model for the one step, one electron process.	3.4	
CH. 4	**(4) Mass transfer by migration and diffusion**		9
	4.1. Derivation of a general mass transfer equation.	4.1	
	4.2. Migration	4.2	
	4.3. Mixed migration and diffusion near an active electrode.	4.3	
	4.4. Diffusion and Fick's laws.	4.4	
CH. 5	**(5) Basic potential step methods**		10
	5.1. Overview of step experiments.	5.1	
	5.2. Potential step under diffusion control.	5.2	
	5.3. Diffusion controlled currents at ultra-micro-electrodes.	5.3	
	(6) Potential sweep methods		
	6.1. Introduction.	6.1	

CH. 6	6.2. Nerstian (reversible) systems.	6.2	11 – 12
	6.3. Totally irreversible systems.	6.3	
	6.5. Cyclic voltammetry	6.5	
	6.6. Multicomponent system and multistep charge transfer	6.6	
CH. 9	**(9) Methods involving forced convection (Hydrodynamic methods)**		13 – 14
	9.1. Introduction.	9.1	
	9.2. Theoretical treatment of convective systems.	9.2	
	9.3. Rotating disk electrode.	9.3	
	9.4. Rotating ring disk electrode	9.4	
CH. 11	**(11) Bulk electrolysis**		15
	11.7. Flow and thin layer electrochemistry	11.7	
	11.8. Stripping analysis.	11.8	