Course Design Document : Electrochemistry (210-312-DW)

Course identification		Course description
Course Name:	Electrochemistry	This course covers electroanalytical methods, focusing on interpreting instructions, operating equipment, and preparing reagents for accurate measurements. Students will learn to configure and calibrate instruments, select suitable electrodes, and establish proper operating parameters. The course also emphasizes maintaining equipment and recording data accurately for reliable results. Through hands-on practice, participants will develop confidence in executing procedures and following protocols. It prepares them for precise electroanalytical analysis in various laboratory settings.
Course Number:	210-312-DW	
Prerequisites:	General Chemistry 202-SN2-RE	
Corequisites:	Basic Circuits an Instrumentation 203-925-DW	
Prerequisite to:		
Ponderation:	2-2-2	
Instructional Hours:	60	
Credits:	2	

Complete Ministerial Competency Code : See Annex A
Specialization option B – Analytical Chemistry

Ministerial competency: **01DW**	Ministerial competency: **01ER**
To take electrometric measurements. (potential-based methods)	To perform electrochemical analyses (current/conductivity-based methods)
Elements of the competency:	Elements of the Competency:
E1. To interpret the instructions.	E1. To interpret the instructions.
E2. To prepare the reagents.	E2. To prepare the reagents.
E3. To prepare the equipment.	E3. To prepare the sample.
E4. To perform the analyses.	E4. To prepare the device or setup.
E5. To interpret the results.	E5. To apply the analysis protocol.
E6. To submit the results.	E6. To interpret the results.
E7. To maintain the equipment and electrodes.	E7. To submit the results.
	E8. To maintain the electrodes and equipment.

The two competency codes are either similar or complementary.

Competency Mapping Summary

Element of competency	01DW	01ER
E1. To interpret the instructions.	✓	✓
E2. To prepare the reagents.	✓	✓
E3. To prepare the equipment.	✓	
E3. To prepare the sample.		✓
E4. To prepare the device or setup.		✓
E4. To perform the analyses.	✓	
E5. To apply the analysis protocol.		✓
E5-E6. To interpret the results.	✓	✓
E6-E7. To submit the results.	✓	✓
E7-E8. To maintain the equipment and electrodes.	✓	✓

Course General Learning Outcomes (GLOs)

GLO1 – Interpret and apply technical instructions through a proper understanding of analytical methods, protocols, and equipment operation.

GLO2 - Apply knowledge of electroanalytical methods to select and prepare reagents at appropriate concentrations for accurate analytical measurements.

GLO3 - Prepare electroanalytical instrumentation for accurate analysis by selecting suitable electrodes, performing proper calibration, configuring equipment, and establishing operating parameters that meet analytical and sample requirements.

GLO4 - Demonstrate the ability to prepare and correctly configure equipment or experimental setups by following protocols and instructions.

GLO5 - Implement electrochemical analysis procedures through the proper setup and operation of equipment, selection of analytical techniques, and control of experimental parameters.

GLO6 – Maintain accurate laboratory records, evaluate data quality, and submit analytical results in compliance with organizational requirements.

GLO7 – Maintain and verify electroanalytical equipment and electrodes in accordance with manufacturer specifications and quality assurance requirements to ensure reliable analytical performance.

In this Course Design Document, it is important to distinguish between the information that is essential for understanding the core concepts and the supplementary topics (not compulsory) that, while not required for basic competency, are still considers valuable for a comprehensive grasp of the subject.

By focusing primarily on the essential equipment and core principles, (compulsory) the student will build a solid foundation in electrochemistry. The non compulsory topic, are highly recommended for those seeking a deeper and more nuanced comprehension of the field.

Compulsory:

Appropriate equipment:
various electrodes,
electrolysis cells,
DC current generator,
galvanometer/potentiometer,
automatic titration device,
Karl Fischer titration device,
trace voltage analyzer, (obsolete: using computer and software instead)
conductance device,
electrogravimetric measuring device,
amperometric or coulometric titration cell,
pH-meter and ion meter

Non-compulsory (not part of the required competency)

Equivalent Circuit of an Electrochemical Cell (Impedance spectroscopy)
Operational Amplifier

Thermodynamic
Heat and Work, The First Law of Thermodynamics
Entropy and the Second Law of Thermodynamics
Gibb's free energy, Spontaneity and equilibrium (K_{sp})

Cottrell equation - Mass Transport: Diffusion - Migration - Convection

Pourbaix diagram: passivation, immunity and corrosion
Corrosion, galvanic corrosion and protections
Electrode Kinetics: Butler–Volmer model / Tafel plots

Ultramicroelectrodes, Modified electrodes and biosensors
Disposable electrodes (electrodes on a chip)

Commercial batteries cycling

ELEMENT AND PERFORMANCE CRITERIA (from the ministerial devis)	GENERAL & SPECIFIC LEARNING OUTCOMES
Statement of competency: 01DW / 01ER 1. To interpret the instructions. 1.1 Proper understanding of the documentation: - analysis protocol or standard method - operational mode of the equipment	GLO1 – Interpret and apply technical instructions through a proper understanding of analytical methods, protocols, and equipment operation. SLO1 - Explain the operating principle of the analytical instrument used. - Identify the purpose and sequence of the steps in an analytical protocol. - Interpret standard operating procedures (SOPs) and analytical methods. - Justify the choice of an analytical method based on the prescribed protocol.

Assessment strategies	Learning activities
Formative: - Lectures - in class and home video - in-class challenge problems - Troubleshooting - homework problems - group work **Summative**: Ponderation: check Course outline - class quiz - written class exam - lab activity - lab report	- Building galvanic and concentration cells using appropriate electrodes, solutions, and salt bridges. (Daniell cell) - Assembling electrochemical setups for studying redox reactions and cell potentials.(Voltametry) - Preparing samples and solutions to perform an electrochemical analysis

ELEMENT AND PERFORMANCE CRITERIA (from the ministerial devis)	GENERAL & SPECIFIC LEARNING OUTCOMES
Statement of competency: 01DW / 01ER 2. To prepare the reagents. 2.1 Proper choice of reagent for: - coulometric, amperometric or conductometric titration - trace analyses by voltammetry - electrogravimetry 2.2 Appropriate solution concentrations.	GLO2 - Apply knowledge of electroanalytical methods to select and prepare reagents at appropriate concentrations for accurate analytical measurements. SLO2 - Formulate an electrolytic solution containing iodide, starch, and supporting electrolyte - Select and use a supporting electrolyte - calculate standard solutions of known molality - Produce standard solutions by serial dilution - Formulate dilute acid solutions accurately - Prepare stock solutions of an unknown sample - Measure, transfer, and dilute samples accurately

Assessment strategies	Learning activities
Formative: - Lectures - in class and home video - in-class challenge problems - Troubleshooting - homework problems - group work **Summative**: Ponderation: check Course outline - class quiz - written class exam - lab activity - lab report	- Prepare KCl standard solutions of known molality using mass-based measurements. (conductometry) - Produce standard solutions by serial dilution using volumetric glassware. (Potentiometric Analysis) - Prepare dilute acid solutions accurately using volumetric techniques. (pH Electrode) - Prepare vitamin C stock solutions using appropriate volumetric techniques. (Coulometric Titration) - Prepare an electrolytic solution containing iodide, starch, and supporting electrolyte. (Coulometric Titration) - Prepare and use a supporting electrolyte to ensure constant ionic strength and minimize migration currents. (Voltammetry)

ELEMENT AND PERFORMANCE CRITERIA (from the ministerial devis)	GENERAL & SPECIFIC LEARNING OUTCOMES
Statement of competency: 01DW 3. To prepare the equipment. 3.1 Proper choice of electrode according to the type and nature of the sample. 3.2 Proper calibration of the electrode. 3.3 Proper preparation of the: - ion meter - automatic titrator - coulometric Karl Fischer titrator 3.4 If necessary, program the functions in accordance with the type of equipment and nature of the sample.	GLO3 - Prepare electroanalytical instrumentation for accurate analysis by selecting suitable electrodes, performing proper calibration, configuring equipment, and establishing operating parameters that meet analytical and sample requirements. SLO3 - Calibrate a pH meter - Calibrate a conductivity cell - Evaluate electrode performance - Configure and operate a computerized potentiostat - Set up and use a galvanostat - Correctly set up and operate conductivity instruments, coulometer and automatic titrator.

Assessment strategies	Learning activities
Formative: - Lectures - in class and home video - in-class challenge problems - Troubleshooting - homework problems - group work **Summative**: Ponderation: check Course outline - class quiz - written class exam - lab activity - lab report	- Calibrate a pH meter using standard buffer solutions and evaluate electrode performance. (pH Electrode) - Calibrate a conductivity cell using KCl standards. (conductometry) - Configure and operate a computerized potentiostat. (Voltammetry) - Set up and use a galvanostat to deliver a constant current. (Coulometric Titration) - Correctly set up and operate conductivity instruments. (conductometry) - Configure and operate an automatic titrator / Karl-Fischer setup.

ELEMENT AND PERFORMANCE CRITERIA (from the ministerial devis)	GENERAL & SPECIFIC LEARNING OUTCOMES
Statement of competency: 01ER 3. To prepare the sample. 3.1 Observance of proper techniques for preparing samples.	GLO3 - Prepare samples correctly by applying appropriate preparation techniques. SLO3 - Make solutions at designated concentrations following proper laboratory procedures. - Transfer and dilute samples accurately employing calibrated pipettes and volumetric glassware. - Maintain optimal solution conditions (pH, oxygen removal, ionic strength adjustment) to reduce potential interferences.

Assessment strategies	Learning activities
Formative: - Lectures - in class and home video - in-class challenge problems - Troubleshooting - homework problems - group work **Summative**: Ponderation: check Course outline - class quiz - written class exam - lab activity - lab report	- Make dilute acid solutions accurately using volumetric techniques. (pH Electrode) - Produce vitamin C stock solutions using appropriate volumetric techniques. (Coulometric Titration) - Transfer and dilute samples accurately using calibrated pipettes and volumetric glassware. (Coulometric) - Control solution conditions (pH, oxygen removal, ionic conductivity) to minimize interferences. (Coulometric Titration) - Prepare samples according to prescribed analytical procedures and concentrations. - Maintain sample integrity and avoid contamination during preparation.

ELEMENT AND PERFORMANCE CRITERIA (from the ministerial devis)	GENERAL & SPECIFIC LEARNING OUTCOMES
Statement of competency: 01ER 4. To prepare the device or setup. 4.1 Observance of the protocol for using the equipment. 4.2 Proper setup according to instructions.	GLO4 - Demonstrate the ability to prepare and correctly configure equipment or experimental setups by following protocols and instructions. SLO4 - Assemble a three-electrode cell. - Configure potentiostat. - Set up galvanostat. - Demonstrate proper handling and cleaning of metal electrodes to avoid contamination. - Demonstrate correct handling, rinsing, and storage of conductivity and pH electrodes. - Demonstrate proper handling of a fragile pH electrode, including rinsing, equilibration time, and storage. - Assemble and use a salt bridge correctly to maintain electrical neutrality.

Assessment strategies	Learning activities
Formative: - Lectures - in class and home video - in-class challenge problems - Troubleshooting - homework problems - group work **Summative**: Ponderation: check Course outline - class quiz - written class exam - lab activity - lab report	- Assemble and use a salt bridge correctly to maintain electrical neutrality. (Daniell Cell) - Assemble and operate an electrochemical cell suitable for coulometric titration. (Coulometric Titration) - Assemble a three-electrode electrochemical cell identifying the working, reference, and auxiliary electrodes. (Voltammetry) - Prepare an Ag/AgCl reference electrode. (Voltammetry) - Demonstrate proper handling and cleaning of electrodes to avoid contamination. (Daniell Cell; pH Electrode)

ELEMENT AND PERFORMANCE CRITERIA (from the ministerial devis)	GENERAL & SPECIFIC LEARNING OUTCOMES
Statement of competency: 01DW 4. To perform the analyses. 4.1 Exact assay of the ionic concentration taking into account limitations due to electrochemical reactions. 4.2 Proper use of the Karl Fischer titrator.	GLO4 - Carry out quantitative analyses using electrochemical techniques and specialized instrumentation while ensuring the reliability and accuracy of analytical results. SLO4 - Explain the difference between concentration and activity in electrolyte solutions. - Describe the role of the activity coefficient (γ) in real electrochemical systems. - Assess the effect of constant vs. variable ionic strength on measured cell potentials. - Distinguish between concentration and activity in electrochemical calculations. - Recognize limitations in directly measuring the equivalence-point potential. - To be able to prepare, configure, and perform a Karl Fischer analysis

Assessment strategies	Learning activities
Formative: - Lectures - in class and home video - in-class challenge problems - Troubleshooting - homework problems - group work **Summative**: Ponderation: check Course outline - class quiz - written class exam - lab activity - lab report	- To prepare, configure, and perform a Karl Fischer analysis. - Determine the conductivity of an unknown electrolyte solution from experimental measurements. - Calculate the concentration of an unknown KCl solution using a calibration equation. - Calculate the chloride ion concentration in an unknown solution from titration data. - Apply the Nernst equation to predict how changes in ion concentration affect cell potential. - Experimentally verify the Nernst equation using a copper–copper concentration cell. - Relate measured cell potentials to reaction quotient (Q) and ion concentrations. - Apply the Nernst equation to interpret potential changes during a potentiometric titration. - Correctly set up and operate a pH meter as a high-impedance voltmeter for potentiometric measurements.

ELEMENT AND PERFORMANCE CRITERIA (from the ministerial devis)	GENERAL & SPECIFIC LEARNING OUTCOMES
Statement of competency: 01ER 5. To apply the analysis protocol. 5.1 Proper installation of: - working, reference and auxiliary electrodes - conductivity cell - electrolysis cell - potentiostat/galvanostat - multimeter 5.2 Precise adjustment of: - potential - current intensity - resistance 5.3 Choice of method for detecting the titration endpoint, if necessary. 5.4 Choice of voltammetry method, if necessary. 5.5 Appropriate use of any necessary parameter control software.	GLO5 - Implement electrochemical analysis procedures through the proper setup and operation of equipment, selection of analytical techniques, and control of experimental parameters. SLO5 - correct use of a multimeter to perform electrical measurements (voltage or current) in an electrochemical setup or electronic circuit. - Identify the equivalence point of a titration curve based on changes in electrode potential. - Determine the equivalence point using the Gran method. - Justify the choice of potentiometric detection over visual indicators. - Set up and use a galvanostat to deliver a constant current during an electrochemical analysis.

Assessment strategies	Learning activities
Formative: - Lectures - in class and home video - in-class challenge problems - Troubleshooting - homework problems - group work **Summative**: Ponderation: check Course outline - class quiz - written class exam - lab activity - lab report	- Perform cyclic voltammetric measurements on electroactive species. (Voltammetry) - Perform a potentiometric titration using appropriate indicator and reference electrodes. (Potentiometric Titration) - Perform a coulometric titration by electrochemically generating a titrant in situ. (Coulometric Titration) - Record electrode potential as a function of titrant volume during a potentiometric titration. (Potentiometric Titration) - Identify the endpoint of a coulometric titration using the iodine–starch color change. (Coulometric Titration)

ELEMENT AND PERFORMANCE CRITERIA (from the ministerial devis)	GENERAL & SPECIFIC LEARNING OUTCOMES
Statement of competency: E5 01DW / E6 01ER 5. To interpret the results. 5.1 Precise determination of the concentration. 5.2 Correct determination of the accuracy and precision of the results. 5.3 Verification of the results in terms of prescribed quality standards. 5.4 Appropriate statistical treatment of results. 6.1 Proper interpretation of titration curves. 6.2 Concentration precision. 6.3 Proper comparison of the results to the proper quality standards. 6.4 Appropriate statistical treatment of results.	GLO5 - Analyze and interpret analytical data to obtain reliable quantitative results and verify their conformity with prescribed quality requirements. SLO5 - Calculate the ion concentration in an unknown solution from titration data. - Determine the conductivity of an unknown electrolyte solution from experimental measurements. - Determine the equivalence point using the Gran method. - Compare repeated measurements and assess precision and reproducibility. - Perform replicate measurements to assess experimental precision.

Assessment strategies	Learning activities
Formative: - Lectures - in class and home video - in-class challenge problems - Troubleshooting - homework problems - group work **Summative**: Ponderation: check Course outline - class quiz - written class exam - lab activity - lab report	- Determine the conductivity of an unknown electrolyte solution from experimental measurements. (conductometry) - Calculate the concentration of an unknown KCl solution using a calibration equation. (conductometry) - Calculate the chloride ion concentration in an unknown solution from titration data. (Potentiometric Titration) - Determine the equivalence point using the Gran method. (Potentiometric Titration) - Compare repeated measurements and assess precision and reproducibility. (conductometry) - Perform replicate measurements and evaluate experimental precision. (Coulometric Titration)

ELEMENT AND PERFORMANCE CRITERIA (from the ministerial devis)	GENERAL & SPECIFIC LEARNING OUTCOMES (GLO & SLOs)
Statement of competency: E6 01DW / E7 01ER 6. To submit the results. 6.1 Observance of rules for keeping a laboratory notebook. 6.2 Submission of results according to company standards. 6.3 Proper evaluation of the reliability of the results. 7.1 Observance of rules for keeping a laboratory notebook. 7.2 Transmission according to company standards. 7.3 Evaluation of the reliability of the results.	GLO6 – Maintain accurate laboratory records, evaluate data quality, and submit analytical results in compliance with organizational requirements. SLO6 – - Observe and adhere to the rules for maintaining a laboratory notebook. - Compile and submit laboratory results in compliance with company standards. - Properly evaluate the reliability and accuracy of their laboratory results. - Ensure the credibility of their results before submission and transmission.

Assessment strategies	Learning activities
Formative: - Lectures - in class and home video - in-class challenge problems - Troubleshooting - homework problems - group work **Summative**: Ponderation: check Course outline - class quiz - written class exam - lab activity - lab report	- Document experimental data, calculations, and observations clearly in a laboratory report. (conductometry) - Accurately document raw data, calculations, and graphical analyses in a laboratory report. (Potentiometric Titration) - Accurately record raw data, corrected values, and calculated results in tables. (Coulometric Titration) - Record experimental conditions, raw data, and extracted peak values accurately. (Voltammetry) - Document calibration data, raw measurements, and calculated values clearly and accurately. (pH Electrode) - Compare repeated measurements and assess precision and reproducibility. (conductometry) - Evaluate the quality of a calibration by interpreting slope, intercept, and consistency of measurements. (conductometry)

ELEMENT AND PERFORMANCE CRITERIA (from the ministerial devis)	GENERAL & SPECIFIC LEARNING OUTCOMES (GLO & SLOs)
Statement of competency: E7 01DW / E8 01ER 7. To maintain the equipment and electrodes. 7.1/8.1 Maintenance in accordance with manufacturer's standards. 7.2 Verification of the equipment and electrodes. 8.2 Adherence to quality assurance standards.	GLO7 – Maintain and verify electroanalytical equipment and electrodes in accordance with manufacturer specifications and quality assurance requirements to ensure reliable analytical performance. SLO7 - Demonstrate correct handling, rinsing, and storage of conductivity and pH electrodes. - Evaluate the working condition of a pH electrode based on slope percentage and calibration results.

Assessment strategies	Learning activities
Formative: - Lectures - in class and home video - in-class challenge problems - Troubleshooting - homework problems - group work **Summative**: Ponderation: check Course outline - class quiz - written class exam - lab activity - lab report	- Demonstrate correct handling, rinsing, and storage of conductivity and pH electrodes. (conductometry) - Demonstrate proper handling of a fragile pH electrode, including rinsing, equilibration time, and storage. (pH Electrode) - Demonstrate proper handling and storage of a reference electrode to maintain a reliable potential. (Voltammetry) - Apply appropriate corrective actions when electrode performance is inadequate. (pH Electrode)

Annex – A MINISTERIAL COMPETENCY: Electrochemistry

Code 01DW	
Objective	Standard
Statement of competency: 01DW To take electrometric measurements.	**Achievement Context** ▪ Working in a quality control laboratory of a pharmaceutical, agro-food company or environmental agency. ▪ Based on: - instructions - protocol of analysis or standard methods - operating instructions for equipment ▪ With samples having undergone any necessary preliminary preparations. ▪ Using: - chemicals required - appropriate equipment, such as ion-specific and specialized electrodes, automatic titrator, coulometric Karl Fischer titrator, pH-meter and ion meter - a computer and appropriate software - documentation written in English or French ▪ Respecting: - health and safety regulations - Good Laboratory Practices (GLP), Good Manufacturing Practices GMP) or the standards of the International Organization for Standardization (ISO) ▪ Paying close attention to precision, minute detail and efficiency.
Elements of the Competency	**Performance Criteria**
1. To interpret the instructions.	1.1 Proper understanding of the documentation: - analysis protocol or standard method - operational mode of the equipment
2. To prepare the reagents.	2.1 Proper choice of chemicals. 2.2 Appropriate solution concentrations.
3. To prepare the equipment.	3.1 Proper choice of electrode according to the type and nature of the sample. 3.2 Proper calibration of the electrode. 3.3 Proper preparation of the: - ion meter - automatic titrator - coulometric Karl Fischer titrator 3.4 If necessary, program the functions in accordance with the type of equipment and nature of the sample.
4. To perform the analyses.	4.1 Exact assay of the ionic concentration taking into account limitations due to electrochemical reactions. 4.2 Proper use of the Karl Fischer titrator.

Code 01DW	
Objective	Standard
5. To interpret the results.	5.1 Precise determination of the concentration. 5.2 Correct determination of the accuracy and precision of the results. 5.3 Verification of the results in terms of prescribed quality standards. 5.4 Appropriate statistical treatment of results.
6. To submit the results.	6.1 Observance of rules for keeping a laboratory notebook. 6.2 Submission of results according to company standards. 6.3 Proper evaluation of the reliability of the results.
7. To maintain the equipment and electrodes.	7.1 Maintenance in accordance with manufacturer's standards. 7.2 Verification of the equipment and electrodes.

Annex – A MINISTERIAL COMPETENCY: Electrochemistry

Code 01ER	
Objective	Standard
Statement of competency To perform electrochemical analyses	**Achievement Context** ▪ Working in a trace analysis or quality control laboratory of a company in the environmental, agro-food, pharmaceutical, cosmetic, chemical, petrochemical or metallurgic sector. ▪ Based on: - instructions - protocol of analysis or standard methods - operating instructions for equipment ▪ Using: - raw samples - products required - appropriate equipment: various electrodes, electrolysis cells, DC current generator, galvanometer/potentiometer, automatic titration device, Karl Fischer titration device, trace voltage analyzer, conductance device, electrogravimetric measuring device, amperometric or coulometric titration cell, pH-meter and ion meter - a computer, appropriate software and the Internet - documentation written in English or French ▪ Respecting: - health and safety regulations - Good Laboratory Practices (GLP) and Good Manufacturing Practices (GMP) or the standards of the International Organization for Standardization (ISO) ▪ Paying close attention to precision, minute detail and efficiency.
Elements of the Competency	**Performance Criteria**
1. To interpret the instructions.	1.1 Proper understanding of the documentation: - analysis protocol or standard methods - operational mode of the equipment
2. To prepare the reagents.	2.1 Proper choice of reagent for: - coulometric, amperometric or conductometric titration - trace analyses by voltammetry - electrogravimetry 2.2 Appropriate solution concentrations.
3. To prepare the sample.	3.1 Observance of proper techniques for preparing samples.
4. To prepare the device or setup.	4.1 Observance of the protocol for using the equipment. 4.2 Proper setup according to instructions.

5. To apply the analysis protocol.	5.1 Proper installation of: - working, reference and auxiliary electrodes - conductivity cell - electrolysis cell - potentiostat/galvanostat - multimeter 5.2 Precise adjustment of: - potential - current intensity - resistance 5.3 Choice of method for detecting the titration endpoint, if necessary. 5.4 Choice of voltammetry method, if necessary. 5.5 Appropriate use of any necessary parameter control software.
6. To interpret the results.	6.1 Proper interpretation of titration curves. 6.2 Concentration precision. 6.3 Proper comparison of the results to the proper quality standards. 6.4 Appropriate statistical treatment of results.
7. To submit the results.	7.1 Observance of rules for keeping a laboratory notebook. 7.2 Transmission according to company standards. 7.3 Evaluation of the reliability of the results.
8. To maintain the electrodes and equipment.	8.1 Maintenance and minor repair of electrodes and equipment according to the manufacturer's standards. 8.2 Adherence to quality assurance standards.

Summary of competencies and laboratory techniques

	01DW	**01ER**
Interpret instructions	✓	✓
Prepare reagents	✓	✓
Prepare samples		✓
Select and calibrate electrodes	✓	✓
Prepare ion meters and Karl Fischer equipment	✓	
Prepare conductivity, electrolysis, and voltammetric systems		✓
Potentiometric analyses	✓	
Karl Fischer titration	✓	
Coulometric, amperometric, conductometric titration		✓
Voltammetry		✓
Electrogravimetry		✓
Data interpretation and statistics	✓	✓
Reporting results	✓	✓
Equipment maintenance	✓	✓
Quality assurance and troubleshooting		✓

Annex - B

Electrochemistry Syllabus: (210-312-DW)

Chapter 1 - Introduction to Electrochemical Technologies (1 LECTURE) *(note: a lecture is 2h)*

	Class topic	Suggested problems
1.1	The Alessandro Volta pile	
1.2	The Daniell cell (continuous and rechargeable cell)	
1.3	Electroplating and water electrolysis	
1.4	Faraday's Laws of Electrochemistry	
1.5	Galvanic cell	
1.6	Electrolytic cells	
1.7	Fuel cells and gaseous electrodes	

Chapter 2 - Fundamental Concepts and Principles in Electrochemistry (2 LECTURES)

	Class topic	Suggested problems
2.1	Electrochemical Reactions and Definitions	
2.2	Balancing Oxidation–Reduction Reactions	
2.3	Metal Reactivity - Beketov displacement / Electrochemical Series	
2.4	Cell notation and Electrochemical cells	
2.5	Equivalent Circuit of an Electrochemical Cell	
2.6	Commercial Batteries and cycling	
2.7	Salt Bridge: Diffusion and Electrochemical Migration	

Chapter 3 - Thermodynamic Foundations of Electrochemistry (2 LECTURES)

	Class topic	Suggested problems
3.1	Nature of Energy.	
3.2	Heat and Work, The First Law of Thermodynamics	
3.3	Entropy and the Second Law of Thermodynamics	
3.4	Gibb’s free energy, Spontaneity and equilibrium	
3.7	Relationship between ΔG and cell voltage	

Chapter 4 - Applications of Thermodynamics in Electrochemistry (2 LECTURES)

	Class topic	Suggested problems
4.1	Electrode potentials and cell voltage	
4.2	Standard potentials	
4.3	Nernst equation	
4.4	Ionic strength, concentration and activity coefficients	
4.5	Reference electrodes	
4.6	Pourbaix diagram: passivation, immunity and corrosion	

Chapter 5 – Potentiometric methods (2 LECTURES)

	Class topic	Suggested problems
5.1	Indicator electrodes	
5.2	Ion and selective electrodes	
5.3	pH electrode: operation and limitations	
5.4	Potentiometric titrations (redox titration)	
5.5	Conductometry	

Chapter 6 – Current based techniques (3 LECTURES)

	Class topic	Suggested problems
6.1	Electrode-solution interface: the double layer	
6.2	Mass Transport: Diffusion - Migration - Convection	
6.3	Electrode Kinetics: Butler–Volmer model / Tafel plots	
6.4	Overpotential	
6.5	Electrogravimetry / copper electrowinning	
6.6	Electrochemical Cell Design, two and three electrode cells	
6.7	Faradic and capacitive current	
6.8	Cottrell equation	
6.9	Chronoamperometry	
6.10	Electrochemical Cell Design, two and three electrode cells	
6.11	Polarography / Voltammetry	
6.12	Practical Measurement Considerations: Ohmic drop (iR drop)	
6.13	Anodic stripping voltammetry	
6.14	Specialized Applications: Karl Fischer titration	

Chapter 7 – Applications and modern Electrochemistry (3 LECTURES)

	Class topic	Suggested problems
7.1	Corrosion, galvanic corrosion and protections	
7.2	Industrial electrochemical processes: the chloro-alkali process	
7.3	Production of aluminum	
7.4	Energy conversion and storage: modern batteries	
7.5	Electrocoagulation (water treatment)	
7.6	Ultramicroelectrodes, Modified electrodes and biosensors	
7.7	Disposable electrodes (electrodes on a chip)	

Laboratories

Salt bridge and Reference electrode

Daniell Cell and the Nernst's law

conductometry analysis

pH electrode: verification, use and storage.

Selective ion electrode: Calcium in milk

Potentiometric titration of Cl^-

ORP electrode (redox titration)

Coulometric titration (Vitamin-C)

Chronoamperometry: diffusion analysis

Voltammetry: $K_4Fe(CN)_6$ and Vitamin C.

Potentiometric analysis using Op-amp electronic

Impedance Spectroscopy: electrochemical cell