UNIVERSITÀ DEGLI STUDI DI PALERMO

DEPARTMENT	Ingegneria
ACADEMIC YEAR	2017/2018
MASTER'S DEGREE (MSC)	CHEMICAL ENGINEERING
SUBJECT	APPLIED ELECTROCHEMISTRY
TYPE OF EDUCATIONAL ACTIVITY	C
AMBIT	20911-Attività formative affini o integrative
CODE	02939
SCIENTIFIC SECTOR(S)	ING-IND/23
HEAD PROFESSOR(S)	SANTAMARIA MONICA Professore Ordinario Univ. di PALERMO
OTHER PROFESSOR(S)	
CREDITS	9
INDIVIDUAL STUDY (Hrs)	144
COURSE ACTIVITY (Hrs)	81
PROPAEDEUTICAL SUBJECTS	
MUTUALIZATION	
YEAR	1
TERM (SEMESTER)	1° semester
ATTENDANCE	Not mandatory
EVALUATION	Out of 30
TEACHER OFFICE HOURS	**SANTAMARIA MONICA** Monday 13:00 14:00 Studio personale Edificio 6 secondo piano previa conferma per e-mail Wednesday 12:30 14:00 Studio personale Edificio 6 secondo piano previa conferma per e-mail Friday 12:30 14:00 Studio personale Edificio 6 secondo piano previa conferma per e-mail

DOCENTE: Prof.ssa MONICA SANTAMARIA

PREREQUISITES	Genral chemistry and thermodynamics.
LEARNING OUTCOMES	Knowledge and understanding At the end of the course student is expected to have a deep understanding of the fundamental aspects of galvanic cells under equilibrium conditions as well as under current flow. The student will get a deep understanding of transport phenomena of charged species in solid and liquid electrolyte. He/She will understand the mechanism of charge transfer at the metal/electrolyte interface and the kinetic aspects of electrochemical reactions. These fundamental knowledge will be applied to the following technological fields: electrochemical energy conversion and storage, corrosion processes and electrolysis processes (Cl2 evolution, O2 evolution, electrorefining and electrowinning, etc.). Applying knowledge and understanding Student will be able to: - derive thermodynamic data from electrical measurement in galvanic cells under equilibrium conditions; - evaluate the influence of transport phenomena on electrochemical processes; - evaluate the kinetic parameters from polarization curves; - select the most appropriate electrodic materials and electrolytic solution to optimize the efficiency of electrochemical reactions in terms; - design devices for electrochemical energy conversion and storage; - prevent and/or hinder corrosion phenomena. Making judgments Staring from knowledge of the theoretical aspects of the electrochemical processes as well as from the laboratory experiences, the student is expected to understand the main issues about electrochemical reactions of technological interest. He/she will be able to select the operation conditions providing the highest efficiency. He/she will be also available to predict and hinder corrosion phenomena. Communication Student is expected to be able to work autonomously and collaborate with other team members involved in the same project (design and/or maintenance). He/she will be able to discuss about fundamental aspects of applied electrochemistry and related technological fields (electrocatalysis, electrometallurgy, corrosion, electrochemical energy conversion, etc.). Thanks to the laboratory experiences, the student will learn the suitable technological language and strategies to improve the efficiency of the electrochemical processes. Learning skills Following a deep understanding of the theoretical aspects and a after laboratory experience, student is expected to be able manage technical issues taking advantage of technical manuals, scientific literature updating frequently his/her knowledge.
ASSESSMENT METHODS	The assessment will be performed through an oral exam with questions focused on three main subjects: - thermodynamic and kinetic aspects of electrochemical processes; - transport of charged species; - electrochemical processes of technological relevance. The student must support the answers qualitatively and quantitatively taking advantage of the technical tools provided by the evaluation committee (Handbook of thermodynamic constants and kinetic parameters, etc.). The student will also discuss a case study (selected among three options) of practical relevance in the field of applied electrochemistry. The interview is aimed at determining the student abilities to process the knowledge gained by using them to solve problems and the ability to express the teaching content using a technically correct language. More specifically, the student must show how he/she is able to use the knowledge of thermodynamic and kinetic aspect of electrochemical reactions to design electrochemical energy conversion devices, to optimize electrolysis processes and to prevent and hinder corrosion phenomena. The vote is expressed in thirtieths with possible praise. A maximum of 24/30 will be attributed according to the student reply on the proposed questions, while the remaining 6/30 and praise will be attributed according to the discussion on the case study. In order to get the minimum score for a positive evaluation (18/30), the student must know the general aspects of the course content (correct selection of electro-catalysts, of electrolytic solutions, etc.). His/her command of technical language must be sufficient to clearly discuss with the evaluation committee about the main aspects of the course. Higher score will be attributed according to their ability in applying knowledge and skills learned in this course to practical and technical problems, according to what extent students are aware of the

	steps they go through in solving problems and how well can they explain their problem-solving steps.
EDUCATIONAL OBJECTIVES	The student will learn about fundamental aspects of galvanic cells under equilibrium and non equilibrium (current flow) conditions. He/She will add the knowledge of transport phenomena of other course with those involving charged species. The student will understand the mechanism of charge transfer at the electrode/electrolyte interface and kind of kinetic control occurring during electrochemical reactions. These fundamental aspects will be used for a deep understanding of devices for electrochemical energy conversion and storage, of corrosion processes, and of electrometallurgical processes.
TEACHING METHODS	Frontal lectures, Laboratory and Demonstration Sessions, Laboratory Practice Sessions
SUGGESTED BIBLIOGRAPHY	J.O'M. Bockris, A.K. Reddy, Modern Electrochemistry , Vol.I e II, Plenum Press N.Y.4(1a Ed. 1967- 2a Ed. 2001 M. Paunovic and M. Schlesinger, Fundamentals of Electrochemical deposition, J. Wiley Interscience, N.Y. (1998) G. Bianchi- T. Mussini, Fondamenti di Elettrochimica, Masson (1993) Dispenze ed appunti del corso.

SYLLABUS

Hrs	Frontal teaching
20	Brief introduction. Classification of energy conversion devices. Schematic representation of a galvanic cell. Thermodynamics of galvanic cells. Dependence of electromotive force on concentration (Nerst equation), on temperature and pressure. Thermal effect in a galvanic cell. Electrochemical equlibrium. Electrolytic solution and mean ionic activity coefficient. Alloys and activity coefficient of alloying elements. Daniell cell. Volta and Galvani potential. Electromotive forse as a function of electrochemical potential. Work function. Contact voltage. Classification of eletrochemical nterfaces. Reference electrodes. Fermi level in solution. Absolute potential. Pourbaix diagram.
5	doublr layer
10	Ion transport in solutions. Diffusion of ions. Fick's law of steady state diffusion. Diffusion coefficient: dependence on physical and chemical quantities. Relationship between diffusion coefficient and molecular quantities. Ion drift under an electric field: conduction. Kohlarausch's law. Atomistic picture of ions migration: mobility of ions. Transport numbers.Stokes - Eistenin relation, Nerst - Enstein relation. interdependence of ionic drifts. Planck-Henderson equation. Non aqueous solvents. Walden Rule. Liquid junction potentials: Henderson equation.
12	Kinetics of electrode reactions: Butler - Volmer model of electrode kinetics. Effect of potential barrier. One step one electronic process. The standard rate constant. The transfer coefficient. Exchange current density. Overvoltage. High and low field forms of Butler - Volmer equation. Tafel plots. Effect of mass transfer. Ideally polarizable and non polarizable interfaces. Diffusion overvoltage. Reaction overvoltage. Crystallization overvoltage. Multi steps reaction. H2 evolution mechanism and O2 evolution mechanism.
10	Influence of eletrodic materials on the kinetic of selected eletrochemical reaction: outer and inner sphere reactions. DSA. Electrochemical aspects of Cl2 production process. Electrowinning of Zn, Cu, Al. Electrorefining of Cu, Pb and Al. Water electrolysis.
8	Wet and dry corrosion. Electrochemical mechanism of corrosion. Corrosion reactions: anodic and cathodic half cell reactions. Mixed potential theory. Pourbaix diagrams for corrosion studies. Passivation conditions. Evans diagrams. Corrosion rate and polarization resistance. Influence of metal on corrosion processes. Influence of enviromental conditions on corrosion processes.

Hrs	Practice
4	Exercises on thermodynamic of galvanic cells. Nernst equation and estimate of electromotive force. Interactive discussions.
4	Excercises on kinetics and lab experience. Exchange current density and Tafel slope estimate. Estimate of charge transfer resistance and limiting diffusion current. Rotating disk eletrode and Levich equation. Interactive discussions.
2	Lab course on Impedance of RC circuit on bread board. Bode and Nyquist diagram. Reduction and oxidation of iron complexes under mass transfer control. EIS measurements with Au electrode during electrochemical reactions with rotating disk eletrode. Interactive discussions.
3	MEA preparation.Polarization curve recording with H2 fed and methanol fed fuel cell. Evaluation of fuel cell performance from the polarization curve. Diagnostic criteria. Interactive discussion.
3	Corrosion processes. Passivation curves for carbon steel and stainless steel. Aluminium anodizing process. Interactive discussion.