NATIONAL UNIVERSITY OF ENGINEERING
COLLEGE OF GEOLOGICAL, MINING AND METALLURGICAL ENGINEERING

METALLURGICAL ENGINEERING PROGRAM

ME427 – EXTRACTIVE PROCESSES II

I. GENERAL INFORMATION

CODE	**:**	ME427 Extractive Processes II
SEMESTER	**:**	8
CREDITS	**:**	4
HOURS PER WEEK	**:**	6 (Theory–Practice–Laboratory)
PREREQUISITES	**:**	ME422 Extractive Processes I, ME413 Metallurgical Basics II.
CONDITION	**:**	Compulsory
DEPARTMENT	**:**	Metallurgical Engineering

II. COURSE DESCRIPTION

The course prepares students for understanding the physical-chemical factors affecting the extraction and aqueous recovery of metal and non-metal minerals, ore and metallic wasts.

III. COURSE OUTCOMES

At the end of the course, students:

1. Analyze and apply relations for hydrometallurgical equilibrium.
2. Recognize and analyze the heterogeneous kinetics that is relevant in hydrometallurgy.
3. Analyze metal, oxide and sulfur lixiviation, solution purification and metal production.

IV. LEARNING UNITS

1. HYDROMETALLURGICAL EQUILLIBRIUM

Introduction / Basics / Electrodes and cells / Electrode reactions / Electrochemical potential / Electrochemical equilibrium / Types of electrodes / Thermodynamic relations / Reversible and non-reversible transformations / Chemical reactions / Electrochemical reactions / Voltage-pH diagrams / Voltage-pH diagram of water / Construction of voltage-pH diagrams / Impact of stabilizer elements to voltage-pH diagrams.

2. MASS TRANSFER AND REACTION KINETICS

Introduction / Reactions classification / Reaction rate / Homogeneous kinetics / Mass action law and velocity laws / Reaction order / Activation energy / Heterogeneous kinetics / Interface presence, nature and geometry / Boundary layer / Fluid speed effects / Temperature effects / Reactive concentration effects / Electrochemical nature of some heterogeneous reactions / Characteristics of reaction products.

3. LIXIVIATION THEORY:

Metal lixiviation / Gold and silver / Cianydetion / Thiouretation. / Thiosulfate. / Chemical pre-refining / Platinum group metals / Copper and selenium / Oxides lixiviation / Absence of oxidizing agents / Presence of oxidizing agents / Presence of reducing agents / Sulfide lixiviation / Absence of oxidizing agents / Presence of oxidizing agents / Bacterial lixiviation.

4. SOLUTION PURIFICATION

Ionic exchange process / Resins properties and constitution / Exchange equilibrium / Ionic exchange of gold / Ionic exchange of copper / Sludge removal / Activated carbon adsorption process / Adsorption mechanism / Desorption / Gold and silver adsorption / Integrated process of lixiviation and adsorption / Carbon in pulp process / Copper solvent extraction / Gold solvent extraction.

5. REDUCTION PROCESS FOR RECOVERY AND SEPARATION

Chemical precipitation / Metallic sulfide precipitation / Metallic hydroxides precipitation / Other chemical precipitation processes / Chemical precipitation diagram as lixiviation data source / Reduction process / Reduction thermodynamic aspects / Cementation process / Hydrogen gas reduction / Other reduction processes / Metals recovery from waste water and effluents by precipitation processes / Chemical precipitation / Reductive precipitation.

6. ELECTROLYTIC PROCESSES

Introduction / Electrical obtaining of metals / Electrical obtaining electrodes / Electrolytic cells and electrodes configuration / Electrical obtaining of copper / Electrical obtaining of zinc / Electrical refining of metals / Electrical refining of copper / Electrical refining of silver / Electrical refining of gold / Electrical refining of lead.

V. LABORATORY

1. **Session 1:** Hydrometallurgical equilibrium
2. **Session 2:** Lixiviation process
3. **Session 3:** Solution purification
4. **Session 4:** Reduction process
5. **Session 5:** Electrolytic process

VI. METHODOLOGY

The course takes place in theory, practice and laboratory sessions. In theory, faculty presents and analyzes concepts and methods. In practice sessions diverse problems related to extractive processes are solved and analyzed. In laboratory sessions, students perform test on metallurgical extractive processes and verify expected outcomes and results. After each laboratory experience, students submit a report describing procedures and summarizing results and conclusions. Student's active participation is promoted.

VII. GRADING FORMULA

The Final Grade PF is calculated as follow:

PF = (EP + EF + PP) / 3

EP: Mid-term Exam EF: Final Exam
PP: Average of Practical Works.

VIII. BIBLIOGRAPHY

1. Habashi. F.
   Extractive Metallurgy, Hydrometallurgy, Ed. Gordon and Breach, 2006.

2. Wadsworth M.E.
   Introduction to Hydrometallurgy, Short course.