

MET 321 - HIGH TEMPERATURE EXTRACTION, CONCENTRATION, AND RECYCLING

(3-1) 4 credits. Prerequisite: MET 320. Thermodynamic principles involved in the winning of metals. Areas covered include calcination, oxidation, reduction processes, smelting, high -temperature refining, electrorefining, slags, and slag-metal interactions. This course is cross-listed with ENVE 321/321L.

TEXTS

- G. H. Geiger and D. R. Poirier, Transport Phenomena in Materials Processes, TMS, London, 1994.
- David R. Gaskell, Introduction to the Thermodynamics of Materials, 5th ed., Taylor & Francis, Washington DC, 1995.

INSTRUCTOR:

Dr. S. M. Howard MI 114 Ph. 394 -1282
Stanley.howard@sdsmt.edu Open Office Policy

REQUIRED/ELECTIVE:

MET 321 is required for all B.S. Metallurgical Engineering. It is a required course for B.S. Environmental Engineering students taking the Metallurgical Engineering emphasis.

COURSE OBJECTIVE:

Students who satisfactorily complete this course will be able to apply chemical thermodynamics to analyze chemical processes to metal production and performance and relate global resource distribution concepts of cost, conservation, cost, and creativity.

GLOBAL AWARENESS:

This course satisfies one-half of the Board of Regents requirements for General Education content in the area of globalization and global issues. Specifically, students will identify and analyze global issues from multiple scientific perspectives and explore how the science disciplines are involved in societal discourse on select issues. Student competency in the area of globalization and global issues will be assessed by writing assignments, homework assignments, and written exam questions. Student globalization and global issues competency achievement constitutes approximately 16 percent of the final course grade.

COURSE OUTCOMES:

Students who satisfy the following outcomes will receive a passing grade.

- The student will be able to correctly distinguish and discuss the following factors in global resources: the difference between deposits and ore, the relationship between ore grade and ore reserves, the role of creativity in the cost of materials, the role of substitution in markets, and the shift in material use as societies advance economically.
- Given sufficient but minimal mass flow information on an open process, the student shall calculate all unstated mass flows. Typical problems appear in Schuhmann's text in chapters 2, and 3.
- Given sufficient but minimal heat and mass flow information on an open process, the student shall calculate all unstated heat and mass flows. Typical problems appear in Schuhmann's text in chapter 4.
- Given isothermal activity data as a function of composition for a standard state, the student will be able to calculate ΔG° for a new standard state and the corresponding variation of activity coefficients in the new standard with respect to the new composition variable.
- Given liquidus temperature and composition data for a phase diagram in which a pure component A is in equilibrium with the liquid, the student will be able to derive the equation for finding the activity of the liquid component A in the solution relative to the pure, liquid A.
- Given the Fe-O-C phase diagram in which percent O₂ vs T is plotted, the student will be provided the underlying equations and cite the required data for calculating any equilibrium line on the diagram.

- The student will be able to calculate the cell potential for required for the reduction of any metal by molten salt electrolysis given ΔG^0 of formation for the salt. This includes combined reactions and reduction from molten salt solutions such as encountered in the Hall Cell.
- The student will be able to describe the fundamental problem of producing Zn from ZnO by carbothermic reduction and recommend at least two methods of affecting the recovery of metallic Zn.
- The student will sketch the silica slag network, show the effect of basic component additions on the network, and describe the effect such additions have on slag viscosity and conductivity. The student must be able to cite at least five basic slag components.
- Given a ternary phase diagram and the rules of interpretation, the student will determine the temperature and order of solidification from the liquid state at any specified bulk composition and will describe all phases present and their relative amounts at any given temperature.
- Given activity coefficient data for a component in a metal phase, the corresponding data for the component in the oxidized state in a slag in equilibrium with the metal, the standard Gibbs energy for the oxidation, and the chemical potential of the oxidation agent, the student will determine the slag-metal distribution ratio of the component.
- Given an Ellingham diagram, the student will provide the order of oxidation in a specified matte smelting process.
- The student will describe in detail all of the steps to performing a gold assay and the purpose of each step.
- The student will describe the differences in process in a mini steel mill and an integrated steel mill.
- The student will be able to determine the rate of free evaporation of liquid metals alloy components in vacuum using the Langmuir equation. The student will be given the solution composition, activity coefficient data for each component, their molecular weights, and the temperature.

TOPICS:

Lectures

- Cost, conservation, creativity, and concentration of global mineral resources (2 classes)
 - Sampling
 - Process Outline
 - Library & Internet Resources
- Thermo Review (1 class)
 - Phase Rule
- Ternary Phase Diagrams (4 classes)
 - (Handout)
- Roasting (10 classes)
 - Stability Diagrams (M-O-S, M-X-Y)•Roaster Diagrams•Mo Roasting
- Sintering and Calcination (1 class)
- Solution Thermodynamics (7 classes)
 - Temperature Dependence of Activity
 - Alternative Standard States
 - Activities From the Phase Diagram (Handout)
 - Gibbs-Duhem Integration using the Alpha Function (Handout)
 - Derivation and Application of the Gibb's Phase Rule (Handout)
- Processes by elemental group
 - Oxidation - reduction reactions – global energy demand (8 classes)
 - Smelting and converting reactions – global commodity demands (6 classes)
 - Refining processes (3 classes)
 - Refractories and slags (2 classes)
 - Fused salt electrolysis (4 classes)
- Tests (3 or 4 classes)

Laboratory projects

- Calculations laboratory: Stoichiometric calculations; heat balances; and mass balances (6 classes)
- Globalization Module (1)
- Societal Context Module (1)
- High temperature laboratory exercises: calorimetry (1); slags (1); temperature measurement (1); gold assay (2); de-silvering of lead (1); phase diagram (1)

Writing Assignments

- Essay on Cost, Conservation, Concentration, and Creativity
- Laboratory Report Writing including the “Perfect Rewrite”

Societal Awareness

- Essay on Cost, Conservation, Concentration, and Creativity
- Faculty Coalition Module on Global-societal Context in Engineering

Know Global Contemporary Issues

- Essay on Cost, Conservation, Concentration, and Creativity
- Tour and analysis paper on Rapid City Recycling facility

CLASS SCHEDULE:

9:00 – 9:50 MWF MI 220

1:00 – 3:50 R MI 121

REFERENCES

- J. D. Gilchrist, Extraction Metallurgy, 3rd ed., Pergamon Press, New York, 1988.
- J. J. Moore, Chemical Metallurgy, 2nd ed., Butterworths, London, 1990.
- Robert D. Pehlke, Unit Process of Extractive Metallurgy, American Elsevier Publishing, New York, 1971.
- Y. A. Rao, Stoichiometry and Thermodynamics of Metallurgical Processes, Cambridge University Press, New York, 1985.
- Terkel Rosenquist, Principles of Extractive Metallurgy, McGraw Hill, New York, 1974.

GRADING

Homework 10 points each (approx)	150
Short quizzes 10 points each (approx)	50
3 or 4 Hour exam 100 points each (approx)	350
Final exam (approx)	150

- The final grade is based directly on the total points achieved. There is no additional weighting. On rare occasions a student's grade may be raised (but never lowered) for subjective considerations.
- The final grade section average will be between 2.9 and 3.2.

FREEDOM IN LEARNING

Students are responsible for learning the content of any course of study in which they are enrolled. Under Board of Regents and University policy, student academic performance shall be evaluated solely on an academic basis and students should be free to take reasoned exception to the data or views offered in any course of study. Students who believe that an academic evaluation is unrelated to academic standards but is related instead to judgment of their personal opinion or conduct should contact the dean of the college which offers the class to initiate a review of the evaluation.

ADA STATEMENT

Students with special needs or requiring special accommodations should contact the instructor, Dr. Howard at 394 1282 or the campus ADA coordinator at 394-2416 at the earliest opportunity.

POLICIES

- All exams sheets provided by the instructor **MUST** be turned in on top of each exam.
- Students must exercise safety in the high-temperature laboratory. Eye protection is required when hot liquids are being handled in the lab by anyone. No eating or drinking in MI 128B. These and other safety items will be discussed before each lab.
- Most homework is not graded but all homework must be kept in a bound notebook available for inspection.
- **Students who are ill should not attend class.**
- Excused absences from short quizzes will result in the assignment of an estimated grade for the missed quiz. Unexcused absences will result in a zero. No quizzes or exams are thrown out.
- Students are expected to take a short quiz on the day of their return after an absence.
- Short quizzes will cover only material from the lecture.
- Students who miss an hour exam for an excused reason will be given a make-up exam but it will probably be more difficult and longer than the missed exam.
- Office hours are posted on my door (MI 114). Students are welcome to call me at 394-1282.

RELATION OF COURSE OUTCOMES TO PROGRAM OUTCOMES: (a), (b), (c), (e), (h), (i), (j), (k)

CONTRIBUTION OF COURSE TO MEETING THE PROFESSIONAL COMPONENT:

LABORATORY: yes

ASSESSMENT AND EVALUATION:

One Final Exam – required by all students
 Three or Four Hour Exams
 Homework
 Laboratory Reports

EXPECTATIONS:

Metallurgical Thermodynamics
 College Calculus, Chemistry, Physics

COMPUTER USAGE:

Know Elementary Excel

PREPARED BY:

S. M. Howard