MET 624 - ADVANCED CHEMICAL METALLURGY

Credits: (3-0) 3 Prerequisites: MET 320, MET 321/321L and MET 422
Application of metallurgical thermodynamics and transport phenomena to extractive metallurgical processes.

REFERENCE 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

COURSE OBJECTIVE

Students who satisfactorily complete this course will be able to use chemical thermodynamics and kinetics to analyze chemical metal production processes, vapor transport processes, and chemical deterioration of metals at high temperatures.

TOPICS

- Predominance (stability, Kellogg) diagrams, Phase equilibrium diagrams, etc.
- Vaporization chemistry, Vapor transport reactions
- Gas-solid reaction kinetics
- Thermochemical databases and computational engines
- Advanced thermodynamic relationships, for example, Cp= f(alpha), Conc= f(gravitational field), etc.
- Rare earth resources and Processing
- Alternative standard states
- Lectures on Solvent Extraction by Drs. Cross/Safarzadeh - Feb 14-20
- Ternary Phase Diagram interpretation
- Tests (3 classes)

the relative emphasis may be modified to meet student needs.

CLASS SCHEDULE

1:00 – 2:15 WF (MI 320/220)

COURSE OUTCOMES

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

- Given the required thermodynamic data for the pertinent reactions, the student will calculate predominance diagrams for a specified M-O-X system.
- Given the required thermodynamic data for the pertinent reactions for a predominance diagram, the student will calculate diagrams showing phases present as a function of temperature and selected process variables such as oxygen pressure for a specified M-O-X system.
- 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 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.
- 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.
- The student will site at least ten vapor transport reactions and the effect of temperature on the reactions
- The student will locate the required thermodynamic data and construct total vapor pressure vs diagrams for selected temperatures as a function of a specified process variable such as oxygen or chlorine pressure.

- The student will generate a solvent extraction flow sheet for rare earth processing and identfying the pertinent extraction conditions and reagents.
- The student will be compute standard Gibb's energy changes for the change in standard state for liquid and solid solutions and changes in gas pressure.
- The student will write and use a macro model of a reactor in which a shrinking core topochemical model describes the internal reactions so as to determine the length of the reactor for a specified reaction extent.

OTHER REFERENCES

- John Hastie, High Temperature Vapors, Academic Press, Waltham, MA, 1975.
- H. Schafer, Chemical Transport Reactions, Academic Press, NY, London, 1964.
- Michael Binnewies, Robert Glaum, Marcus Schmidt, and Peer Schmidt, Chemical **Vapor Transport Reactions,** isbn 3110254654, De Gruyter, 2012
- 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 Hour exam 100 points each (approx) 300
- Final exam (approx) 100
- 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 is typically between 3.25 and 3.75.
- Grade summaries and ranking are sent to each student periodically during the semester. Students may receive additional grade updates by request. Mid-term DEF grades are not always employed by the professor so students should not rely on such feedback for determining their progress. Typically, students in the upper 75 percentile are not in danger of failing the course.

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 or the campus ADA coordinator at 394-2416 at the start of the semester or earlier.

POLICIES

- All exams sheets provided by the instructor MUST be turned in on top of each exam.
- 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.
- Short quizzes may cover material from the lecture, homework, or reading.
- 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 policy is posted on the door to (MI 114. Students are welcome to call or email Dr. Howard at 394-1282. Always put "MET 624" first in the subject line of all emails
- Students are expected to attend class unless otherwise excused.
- Short quizzes will cover only material from the lecture.

ASSESSMENT AND EVALUATION

One Final Exam
Three Hour Exams
Homework

EXPECTATIONS

Metallurgical Thermodynamics and Kinetic Applications
Met Eng BS-level calculus, chemistry, and physics

COMPUTER USAGE

Excel, MathCad, and ThermoCalc® (TAB and POLY)

PREPARED BY

S. M. Howard (Jan 10, 2014)