MET 320 SYLLABUS

MET 320 - METALLURGICAL THERMODYNAMICS

(4-0) 4 credits. Prerequisites: PHYS 211, CHEM 112, MATH 125. The principles of chemical thermodynamics and their application to metallurgical engineering processes. Topics covered include the zeroth, first and second laws of thermodynamics, the fundamental equations of state for open and closed systems, criterion of equilibrium, heat capacities, reaction equilibrium constants and their dependence upon temperature and pressure, chemical potential, standard and reference states, stability diagrams, and solution thermodynamics. This course is cross-listed with ENVE 320.

TEXTBOOK

Introduction to the Thermodynamics of Materials, 5th Ed. by David Gaskell (3rd or 4th ed is OK)

INSTRUCTOR

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

REQUIRED/ELECTIVE

MET 320 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 OBJECTIVES

Students who satisfactorily complete this course will be able to determine the effects of temperature, pressure, and concentration on chemical reactions.

COURSE OUTCOMES

Students who satisfy the following outcomes will receive a passing grade

- Given the initial state (i.e..- two of the following: T, P, V), the final state (i.e..- one of the following: T, P, V), and the path followed (isothermal, isochoric, isobaric, adiabatic, reversible, free expansion) by an ideal gas, the student will be able to calculate ΔU, ΔH, ΔS, q, and w.
- The student will be able to calculate ΔS_{total} when a body of given mass, heat capacity, and initial temperature equilibrates with a heat sink of specified temperature.
- The student will be able to calculate ΔS^{Mixing} when two or more pure components at the same temperature, pressure, and state form an ideal solution.
- Given a chemical reaction where the temperatures and amounts of reactants, the final temperature and amounts of the products, and corresponding enthalpies of formation at 298 K and the heat capacities are specified, the student will determine the heat added to or removed from the system.
- The student will be able to integrate the Clausius and the Clausius-Clapeyron Equations and, given all but one of the variables in the equation, solve for the remaining variable using the equation. The student must recognize that melting or boiling point information constitutes a (T, P) set.
- The student will be able to calculate ΔG for a condensed-phase reaction at constant temperature as a function of pressure given the molecular weights and densities of the reactants and products and the ΔG at a specified pressure.
- The student will be able to determine the equilibrium constant for a reaction from $\Delta G°$ of formation data for the reaction and to correctly describe the standard state for each component involved in the reaction.
- The student will calculate the equilibrium state (partial pressures, moles) for a reaction involving known initial amounts of gases and pure condensed phases occurring at a given temperature and pressure. The student will be provided either the $\Delta G°$ or K_{Equil} for the reaction.
- The student will determine activities and activity coefficients for component i from the integral molar Gibbs energy of mixing and from the partial molar Gibb's energy of mixing for component i.
- The student will derive the Fundamental equations for an open system, the Maxwell Relations, the "Other" Thermodynamic relationships, the criterion of equilibrium for systems at constant temperature and pressure.
- The student will calculate the cell potential for electrolytic cells involving dissolved components in non-aqueous systems.
- The student will determine using the Ellingham Diagram relative oxide stabilities, equilibrium oxygen pressures, equilibrium H_2/H_2O and CO/CO_2 ratios for any reaction on the Ellingham Diagram.

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TOPICS

- First Law of Thermodynamics (9 classes)
- Forms of Energy, Heat and Work, Joules Experiments, Conservation of Energy, Concept of Maximum Work, Isothermal Expansion, Reversible, Adiabatic Expansion, Constant Pressure Processes, Constant Volume Processes, Enthalpy
- Second Law of Thermodynamics (9 classes)
- 2nd Law Statement, Carnot Cycle, 4 Propositions
- Statistical Entropy (2 classes)
- Physical Meaning of Entropy, Boltzman Equation, Mixing Entropy, Stirling's Approximation
- Auxiliary Functions (3 classes)
- Fundamental Equations of State, Maxwell Relationships, Other Thermodynamic Relations, Chemical Potential, Gibbs-Helmholtz Equation, Criteria of Equilibria
- Heat Capacity and Entropy Changes (5 classes)
- Sensible Heats, Transformation Heats, Reaction Heats, ΔCp, $\Delta H=f(T)$, $\Delta S=f(T)$, Adiabatic Flame Temperatures, Heat Balances, JANAF Thermochemical Tables
- Phase Equilibria in One Component Systems (6 classes)
- Clausius-Claperyon Equation, Heats of Vaporization From Vapor Pressure Data, Shift in Transformation Temperature with Pressure
- The Behavior of Gases (3 classes)
- Compressibility Factor, Law of Corresponding States, Equations of State, Fugacity
- Reactions Equilibria (13 classes)
- Equilibria in Gaseous Systems, The Equilibrium Constant and $\Delta G°$, Reaction Extent Problems, Equilibria in Systems Containing Condensed Phases, Ellingham Diagram, Activities, F*A*C*T
- Solution Thermodynamics (9 classes)
- Absolute and Partial and Integral Molar Quantities, Relative and Partial Integral Molar Quantities, Ideal Solutions, Excess Quantities, Gibb's Duhem Equation, Tangent Intercept Method, a=f(T), Change in Reference State, 1 wt % Reference State Interaction Parameters
- Phase Equilibria and Electrochemistry (as time permits)
- Tests (5 classes)

CLASS SCHEDULE

9:00 – 9:50 MWRF MI 220

GRADING

Homework	10 points each	40 *
Short quiz every day	10 points each	450 *
3 or 4 Hour exams	100 points each	300 - 400
Final exam		150**

* These are approximate numbers based on previous sections.

** Sometimes the fourth hour exam is combined with the final.

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 such as an excellent homework file. The final grade section average is normally between 2.9 and 3.2.

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.

RELATIONS OF COURSE OUTCOMES TO PROGRAM OUTCOMES

a) Apply Knowledge of Math, Science, and Engineering

c) Optimally Select Material and Design Materials Treatment and Production Processes

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POLICIES

- Students who are ill should not attend class or enter the MI Building. Use email and the telephone.
- 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 wish to be excused should email the instructor before the absence. Excuses are allowed for sickness, emergencies, etc. Students who were unable to call before the absence occurred should discuss the absence with Dr. Howard.
- No quizzes or exams are thrown out.
- Requests for excused absences are to be emailed or submitted in writing before the absence unless this is not possible because of illness or other understandable circumstances in which case the written request must be submitted as soon as possible but not later than the first day of return to class.
- Students returning from an excused absence will receive an estimated short quiz grade determined by the professor and based on the student's normal relative performance.
- Students who return from an excused absence may elect on the first day of their return to class to either 1) take the normal short quiz or 2) submit an unworked copy of the short quiz stating that selection of the option to write a one-page summary paper on the missed day's lecture(s). The summary paper is due the second class day of the student's return and should include correctly-worked short quizzes for each day a normal short quiz grade was not submitted (one for each day missed and one for the first day returned to class if the student opted to submit written notes rather than take the short quiz that day).
- Unexcused absences will result in a zero for missed short quizzes and hour exams.
- 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. Students are expected to take makeup hour exams within three days after their return from an excused absence.
- Dr. Howard has an open door policy. His schedule is posted on the door to MI114. Students are welcome to call Dr. Howard at 394-1282 or email him at stanley.howard@sdsmt.edu. Appointments are discouraged unless there is a significant reason to make one. The 30 minute period before an hour exam is generally not a good time to ask questions since it is reserved for exam writing and printing.

LABORATORY

None

CONTRIBUTION OF COURSE TO MEETING THE PROFESSIONAL COMPONENT

- This course prepares students in the basics of resource recovery, concentration and recycling and therefore provides students with the necessary basis to design, operate, and optimize metallurgical processes taking place in practice.
- Ethical and professional conducts are emphasized throughout the course and also emphasized is global awareness in the field of extractive metallurgy.

ASSESMENT AND EVALUATION

One Final Exam – required by all students
Three or Four Hour Exams
Daily Short Quizzes

EXPECTATIONS:

College Calculus, Chemistry, Physics

COMPUTER USAGE

Know Elementary Excel

PREPARED BY

S. M. Howard