EMET 5830                                             Instructor: Dr. C.A. Young
Processing of Precious Metal Resources                  Office Hours, ELC 208A, Spring
Lecture: TR 3:30-5:30 p.m.                           12:1-1:00pm, TR
Room: ELC 202                                         or by appointment

2009-10 Catalog Description:
An introduction to the processing and hydrometallurgy of precious metal ores with a focus on gold. Lectures cover crushing, grinding, autoclaving, agglomeration, roasting, concentration, leaching, solution purification, recovery, cementation, electrowinning and recycling. Environmental concerns and industrial solutions are emphasized. The laboratory experience consists of visiting processing facilities, collecting processing data from each plant, and writing summary trip reports.

Credits: 3 Credit-Hours (2.5 Lecture; 1.5 Lab)
Designation: Elective
Prerequisite: Consent of Instructor
Lab: Arranged with MetE 5830 Lab (Corequisite). This 'hands-on' experience is provided without which the lecture material cannot be completely understood.

Handouts are on-line using Blackboard from notes and references.

Relationship of Course to Metallurgical & Materials Engineering Program Outcomes: This course is an elective that allows the student to broaden their background in mineral processing and extractive metallurgy to understand why specific unit operations are selected for a specific ore body, the chemistry and thermodynamics behind the processing stages, and the economic basis for precious metal processing. This course blends discussions of theory and practice to illustrate modern day precious metals recovery. The course continues to build the students background in unit operations so that he/she can enter the gold processing industry successfully and confidently. It provides a detailed study of modern precious metals unit operations and illustrates the application of chemistry and thermodynamics to real world precious metals recovery.

Objectives: The objectives of this course are four-fold and include introducing the student to the unit operations used in the processing of precious metals, mostly gold but also silver, platinum and palladium; exposing the student to a variety of industrial precious metals processing facilities; teaching the student the contemporary, social, and environmental issues faced by the industry due to cyanide and minor elements, namely arsenic, selenium and thallium; and engaging the student with life-long learning by having industrial guest lectures as well as industrial tours.

Outcomes: Graduates of this course will or will be able to:
1. Describe the mineral processing and extractive metallurgy unit operations used in the processing of precious metals.
2. Understand the chemistry and thermodynamics of the unit operations used in processing of precious metals.
3. Select the best unit operations for the processing of various types of precious-metal bearing materials (ores, sands, recyclables, etc.).
4. Be aware of the social and environmental constraints associated with the industry and know how to treat disturbances caused by cyanide and minor elements.
5. Have confidence to gain employment in the precious metal industry.
6. Meet **ABET Outcomes** a, c, h, i, and j (see below)

### Topics:

**Introduction**
- Gold (as well as silver and PGMs)
- Cyanide – Reality vs Hysteria
- History – Ancient to Current
- Markets and Consumption
- Primary and Secondary Resources

**Mineralogy**
- Mineral Occurrences
- Deposits
- Assaying/Characterization
  - Fire Assay
  - Diagnostic Leach
  - MLA – XRD - XRF

**Flowsheets**
- General Considerations
- Free Milling/Oxidized Ores
- Carbonaceous Ores
- Refractory Sulfidic Ores
- Pretreatment and Separations
- Commination and Liberation
- Gravity
- Flotation
- Biological
- Aeration (Low Pressure)
- Oxidation (High Pressure)
  - Acidic
  - Basic
- Autoclave (Wet High Temperature)
- Roasting (Dry High Temperature)
- Cyanidation (Leaching)
  - Reactions
  - Kinetics
  - Heap
  - Vat
  - Agitation
- Solution Concentration and Purification
  - Carbon Adsorption/Elution
  - Resin Adsorption/Elution
  - Solvent Extraction
  - Zinc Cementation
  - Electrowinning
- Chlorination
- Other Lixiviant

### Rong-Yu Wan Lecture Series:

**Weeks 1-3**
- Joe Rota (Exploration)
- Scott Rosenthal (Mine Operation)

**Week 4**
- Dave Brosnahan (Mineralogy and Automated Mineralogy Systems)
- Jaeheon Lee (Diagnostic Leach and lab testing simulations)

**Week 5**
- Jeff Snyder (Autoclave and POX)
- Brian Arthur (Overview and General)

**Week 6**
- Siedel (Comminution, Liberation; gravity)
- John Cole (Complex Flow Sheets and Engineering Flowsheets)

**Week 7**
- Jim Brierley (Biological)
- Sevket Acar (Roasting and Merrill-Crowe)
- Ronel Kappes (Flotation)

**Week 8**
- Meg Dietrich (Chemistry and Analysis)
- Marc LeVier (Heap, Vat and Agitation)

**Week 9**
- Matt Perry (Carbon)
- Larry Buter (Cementation; Refinery Op’s)

**Week 11**
- Lauren Hafla (Operations Planning)
Evaluations
Economics
Thermodynamics

Project Management and Development
Week 12: Adam House (Project M & D)

Water Treatment
Cyanide
Acid Rock Drainage
Arsenic
Selenium
Thallium
Weeks 13-14: Pragna Bhakta (Risk Assess Ethics Comply)

Thermodynamics
Charlie Bucknam (Environmental Character)
Larry Twidwell (As, Se and Th Treatment)

Field Trips (all Montana)
Weeks 15-16: (* definitely attend; $ maybe attend)

* Beal Mountain (former Heap Leach/current Se Treatment)
* Golden Sunlight (Agitation Leach/current expansion operations)
* Stillwater (Pt/Pd Flotation/Recycling/Smelting/Hydrometallurgical Refining)
$ Zortman-Landusky, Hays (former Heap Leach, current ARD treatment)
$ Kendall Mine, Lewistown (former Heap Leach, current Th treatment)

Homeworks: Required periodically and are normally due prior to the next class.

Quizzes: Generally intended to reinforce the learning process, quizzes will be given with or without (i.e. a “pop quiz”) advance notice. Subject matter covered during the previous and present lecture and/or the associated readings is considered fair game.

Reports and Computer Usage: The students will give oral and written presentations on a topic relevant to the precious metal industry. Normally the topic will chosen by drawing straws but can be changed with instructor approval. Students will also visit at least one precious metal processing facility and at least one environmental facility. They will collect data pertinent to each operating facility, summarize and evaluate the collected data, and write a summary report for each visit. The result is a final report that contains recommendations for alternative processing options (at each facility), a review of the current status of each facility, and the current economic health of each facility.

Examinations: No examinations are planned. However, excessive absence will result in a Final Closed Book and Comprehensive Examination which is scheduled for Monday, May 10, 11:30am-1:30pm.

Attendance: Roll is taken periodically and counted as approximately 15% of your grade. Excessive absence will result in lowering of the final grade possibly by two letter grades.

Grading: The final grade will be weighted from the above elements approximately as follows:
- Quizzes/Homeworks: 60%
- Oral and Written Reports: 25%
- Attendance: 15%

Disruptions: The pop quiz frequency correlates directly to the occurrence of classroom disruptions during lecture. Potential disruptions include but are not necessarily limited to: late arrivals or early departures by students, extraneous conversations, cell phone usage, text messaging, use of extraneous electronic devices (see below), etc. Each quiz question is graded on a 10-point basis and there is no limit to the number of quizzes that may be given during the semester. It goes without having to say that we have guests and they should be given the maximum of attention as well as respect.
**Academic Integrity:** Students enrolled in the Metallurgical and Materials Engineering courses are expected to maintain an integrity standard that is consistent with the applicable fundamental canons of the NSPE Code of Ethics for Engineers. Specifically, students are expected to conduct themselves honorably, responsibly, ethically, and lawfully so as to enhance the honor, reputation, and usefulness of the profession.

Academic dishonesty or cheating will not be tolerated. Acts of academic dishonesty include (but are not limited to):

- Plagiarism including on homework assignments and lab reports
- Copying from another student’s paper while taking a quiz or examination
- Using unlawful aids (books, notes, cell phones or other electronic devices, etc.) to pass an examination (unless the instructor has clearly stated that it is an open notes or open book exam)
- Assisting another student in an act of academic dishonesty

If it is determined that a student has deliberately cheated on a quiz, examination, or assignment, he or she will be dropped from the course with an “F” grade. In compliance with Montana Tech policy, cases of academic dishonesty will also be reported to the Office of the Vice Chancellor for Academic Affairs.

With one exception, the Department policy is that electronic devices are not to be activated or evident during lectures and examinations. This restriction includes but is not limited to programmable calculators, cell phones, I-pods, or entertainment devices. The exception is that students are permitted to use a calculator from the following list during lectures, quizzes, and exams:

- Casio – any model fx-115 calculator
- Hewlett-Packard – the HP33s and 35s models
- Texas Instruments – all TI-30X or TI-36X models

Students that possess unapproved calculators or other electronic devices during a quiz or exam are subject to dismissal from the classroom. Penalties for disregarding the policy during lecture will be enforced at the instructor’s discretion.

**Professional Component:**

- Engineering Topics – 100%
- Engineering Design – Yes
- Computer Usage – Yes (some - Microsoft)
- Ethics – Yes (some - environmental)
- Statistics – Yes (some – sampling and analysis)
- Safety – Yes (industrial and laboratory)

**ABET Outcomes Covered:** a, c, h, i, and j
- apply knowledge of mathematics, science and engineering,
- design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability and sustainability,
- understand the impact of engineering solutions in a global, economic, environmental and societal context,
- recognize the need for and engage in life-long learning, and
- understand contemporary issues.

**Prepared by:** C.A. Young  
**Date:** January 12, 2010