Course Description and Syllabus

Welcome to Mineralogy! In this course you will learn about the structure and chemical makeup of Earth materials. We will concentrate on the physical and chemical properties of minerals, from macroscopic to microscopic. Since this is a geology course, we will investigate how geologic materials and processes influence mineral occurrence, stability, and composition.

The course is divided into five modules. The first reviews relevant chemistry, the second investigates how and why minerals are classified and introduces symmetry, the third presents optical mineralogy, the fourth introduces us to major rock-forming minerals in a systematic progression, and the fifth investigates crystal growth.

Course Information

Credits: 4
Semester: Fall 2015
Lecture : MWF 11:30 am- 12:20 pm POST 703
Lab: Tuesday 1:30 – 4:20 pm POST 703

Instructors:
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Required Texts:
Nesse *Introduction to Mineralogy* 1st Ed. (2nd Edition ok, but page numbers of assignments may differ)

Optional Texts and Resources available in POST 703:
Perkins *Mineralogy 2nd Ed.*
Klein *Manual of Mineral Science 22nd Ed.*
Perkins and Henke *Minerals in Thin Section 2nd Ed.*
Deer, Howie, and Zussman, *An Introduction to the Rock Forming Minerals*
Nesse *Optical Mineralogy, 2nd Ed.*

Prerequisites:

GG 200

CHEM 162 and CHEM 162L *or* CHEM 171 and CHEM 171L *or* CHEM 181A and CHEM 181L

Course Objectives and Components

Goals of this course include understanding:

(1) the characteristics of major mineral groups in hand specimen and thin section

(2) formation environments and associations of rock-forming minerals

(3) crystal symmetry, crystallography, and atomic structure

<u>Lecture</u>

Use of the **texts** and all supplemental reading is critical. Lecture will not be a forum where basic material from the text is reiterated. During lecture we will clarify parts of the reading that are not being understood, develop concepts from the text, and work together to solve problems. You are required, therefore, to read the assigned text *before* class.

Bring a **calculator** to class each day. We will work problems out in real-time together. Colored pencils or pens may be helpful.

<u>Lab</u>

Lab is scheduled for 3 hours on Tuesday afternoons. Several of the labs explore lecture material by directing your observations of mineral specimens. We will also use calculations, computer programs, and physical models to learn concepts. Labs will be integrated with lecture material to the greatest possible extent, usually following what we have discussed in lecture. Therefore, lab material will be incorporated with lecture material for the five quizzes. Quizzes will be in part "practical", that is, requiring microscopes and other lab materials.

All labs are designed to take 3-6 hours to complete. Students who arrive prepared, having read the lab assignment, read the associated text, and completed any pre-lab exercises, *may* finish the lab activity during the 3-hour session. Anticipate spending additional time on many of the labs. Labs should be handed to the TA on time. Unless there is a good excuse, late penalties apply! At the beginning of each lab, Elise will go over the weaker or less well understood points from the previous week. Students are encouraged to ask LOTS of questions!

You are required to obtain a **hand lens** for this course. You will use this tool frequently, not only in this class, but also in many of the upper division Geology courses. (A geologist always has a hammer, notebook, and a hand lens when going into the field!)

<u>Grading</u>

Labs	(30%)
Quizzes	(30%)
Homework	(20%)
Reading Questions	(10%)
Lecture preparedness (iClicker questions, knowledge surveys, etc.)	(10%)

GG301 MINERALOGY: LEARNING OBJECTIVES

Specific examples of the course learning objectives are described below for each of three modules.

Student Learning Objectives

Level of learning emphasis:

[1] Introduce topic [2] Develop knowledge [3] Achieve proficiency

1. Relevance
   1b) Impact to Understand Planet Earth *[2]*
2. Technical knowledge
   2a) Application of supporting disciplines (math, physics, chemistry, biology) *[3]*
   2b) Computer applications *[1]*
   2c) Laboratory methods *[3]*
3. Scientific method
   3a) Define a problem *[2]*
   3b) Critically analyze a problem *[3]*
   3c) Solve a problem *[3]*
4. Communicate geological knowledge
   4c) Use scientific ethics *[2]*
5. Evaluate, interpret and summarize basic principles.
   5a) Understand basic principles *[2]*
   5b) Understand relationships *[2]*
   5c) Explain complex phenomena *[3]*

1. Crystal Chemistry and Symmetry

Topics: Crystal chemistry (parts of the atom, abundance of elements, chemical bonding, sizes of atoms and ions, coordination), crystal structure (relationship between structure and bond types, application of Pauling's rules, polymorphism, mineral classification, compositional variation, formulas, graphical representation in binary and ternary diagrams). Symmetry includes translational symmetry, point symmetry, laws governing formation of crystal faces, Miller indices, definition of crystal forms, crystal habit.

Contact time: Ten lectures and four labs

Learning resources:

1. Reading in Nesse: CH 2, 3, 4.
2. Demonstrations using specimens and interactive visualizations.
3. Homework assignments.
4. Guided laboratory exercises.

The student will:

1. Describe periodicity in the chemical characteristics of elements listed in order of increasing atomic number or mass. [2a, 5a, 5b]
2. Predict element substitutions in minerals using chemical characteristics (electronegativity, ionic size, valence, etc.), and define element substitutions in common solid solution series as simple, coupled, omission, or interstitial. [2a, 5a, 5b]
3. Hypothesize which minerals have similar characteristics (physical and optical properties) on the basis of their chemical formulas, thereby demonstrating understanding the importance of anionic groups. [2a, 3a, 3c, 5a, 5b]
4. Solve chemical word problems, demonstrating the ability to manipulate units and convert moles to mass and vice versa. [2a, 3c, 5a]
5. Demonstrate understanding of phase diagrams for any one-component system: anticipate reactions that occur due to a change in temperature or pressure, describe difference between displacive and reconstructive polymorphs, discuss element ordering on atomic sites in the formation of polymorphs. [2a, 5a, 5b, 5c]
6. Apply Pauling's rules to commonly occurring anionic groups to predict which groups form polymers. [2a, 5a, 5b, 5c]
7. Repeat a motif by applying symmetry operators in 2D and 3D and recognize symmetry operators in 2D patterns and 3D blocks. [2a, 5a, 5b]
8. Use symmetry content of 2D and 3D structures to identify the appropriate plane group or point group. [2a, 5a, 5b]
9. Define a lattice plane using Miller index notation, or conversely, use the Miller index to identify a set of parallel lattice planes. [2a, 5a, 5b]
10. Explain why planes having low-Miller index values dominate crystal shapes. [2a, 5a, 5b]
11. Identify primitive and non-primitive unit cells. [2a, 5a, 5b]
12. Identify by name common forms in isometric and non-isometric crystal systems. [2a, 5a, 5b]
13. Identify forms by name on wooden blocks and from perspective drawings of blocks/crystals. [2a, 5a, 5b]
14. Plot a mineral's composition in a ternary classification diagram. [2a, 5a, 5b]

2. Optical Mineralogy and X-ray diffraction

Topics: properties of polarized light, interaction of light with matter, petrographic microscope parts and purposes, isotropic and anisotropic materials, birefringence, the uniaxial and biaxial optical indicatrices, color and pleochroism, extinction angle and sign of elongation, optic sign, index of refraction.

Contact time: Eleven lectures and five labs.

Learning resources:

1. Reading: Nesse CH7 and 8.
2. Reading: RIMG vol. 78
3. Demonstrations of Becke line test, relief, and refractive index determination.
4. Optical properties demonstrations using plagioclase feldspar and tourmaline.
5. Guided laboratory exercises.
6. Homework exercises.

Student Learning Objectives

The student will:

1. Demonstrate understanding of the distinctions between light velocity, vibration direction, propagation direction, and wavelength. [2a, 5a, 5b]
2. Perform the Becke line test to determine which of two materials has a greater index of refraction. [2a, 2c, 5a, 5b]
3. Manipulate Snell's law, e.g., to compute angles of incidence and refraction given RI of materials separated by an interface. [2a, 5a, 5b]
4. Manipulate the birefringence equation to solve for retardation, thickness or birefringence. [2a, 5a, 5b]
5. Use the Michel-Levy chart to determine the birefringence of a mineral of given thickness and interference color when viewed under crossed polarizers. [2a, 2c, 5a, 5b]
6. Categorize a mineral's optical character as isotropic, uniaxial, or biaxial, given only its crystal system. [2a, 5a, 5b]
7. Demonstrate understanding of the uniaxial and biaxial indicatrices. [2a, 5a, 5b]
8. Use the petrographic microscope to determine a mineral's sign of elongation, birefringence, optic sign, pleochroic scheme, extinction angle, and relief. [2a, 2c, 5a, 5b]
9. Put into practice a time-conservative approach for identification of an unknown mineral using optical characteristics. [2a, 2c, 5a, 5b]
10. Develop understanding of crystallographic information describing mineral structures and know how it relates to physical properties. [2a, 5a, 5b, 5c]
11. Use crystallographic software to visualize crystal structures and analyze bonding and coordination. [2a, 2b, 5a, 5b]
12. Understand basic principles of X-ray diffraction experiment, learn to use software for evaluation of diffraction data, and be able to apply this knowledge to simple phase identification. [2a, 2b, 2c, 5a, 5b]

3. Systematic Mineralogy

Topics: framework silicate minerals (silica group, feldspar group, zeolite group), sheet silicates (classification of layer silicates, clay minerals), chain silicates (pyroxene group, amphibole group), disilicates and ring silicates (zoisite group, beryl, cordierite, tourmaline), orthosilicates (olivine group, garnet group, aluminum silicates), carbonates, sulfates, oxides, hydroxides, halides, sulfides, native elements). We will also discuss mineral stability, kinetic theory, crystal nucleation, effects of rate on crystal morphology and zoning, defects, subsolidus processes (ordering, twinning, recrystallization, exsolution, pseudomorphism)

Contact time: Seventeen lectures and six labs

Learning resources:

1. Reading in Nesse: CH 5, 6, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, and 20 (selected pages)
2. Supplemental discussions of pyroelectricity, magnetism, mineral breakdown reactions, color, economic ore bodies, and geochronology, focusing on fluorite, Fe-Ti oxides, hornblende, azurite, malachite, zircon, water ice and clathrates.
3. Guided laboratory exercises.
4. Homework exercises.

Student Learning Objectives

The student will:

1. Demonstrate understanding of crystal aggregate types in classifying microcrystalline silica minerals. [2b, 5a, 5b, 5c]
2. Explain geologic formation environments of silica polymorphs using a P-T diagram. [1b, 5a, 5b, 5c]
3. Use a silicate mineral's formula to form a hypothesis about its structure. [2a, 3a, 3b, 3c, 5a, 5b]
4. Explain, with the aid of a phase diagram, the process of compositional unmixing that typifies feldspar group minerals, including a discussion of cation ordering. [2a, 3a, 3b, 3c, 5a, 5b]
5. Identify types of mineral twins in feldspar thin sections, and use twin properties to estimate composition. [2a, 2c, 3a, 3b, 3c, 5a, 5b]
6. Relate the structural features of zeolites to their widespread utilization and synthesis in industrial applications. [1b, 2a, 5a, 5b]
7. Relate the microscopic structures of single and double chain silicates to their (macroscopic) diagnostic cleavage. [2a, 5a, 5b]
8. Utilize appropriate charts to infer compositional constraints on olivines, pyroxenes, and amphiboles from their optical properties. [2a, 5a, 5b]
9. Organize information regarding optical properties, physical properties, and chemical formulae into a table to be used for identification of unknown minerals. Augment the table with personal observations. [2a, 3a, 3b, 3c, 4c, 5a, 5b]
10. Determine whether a layer silicate is dioctahedral or trioctahedral in structure by inspection of mineral formula. [2a, 5a, 5b]
11. Explain how anisotropy of seismic wave propagation in olivine can be used to study mantle flow. [1b, 5a, 5b, 5c]
12. Explain how occurrence of aluminum silicate minerals in a metamorphic rock preserves the tectonic history of a terrane. [1b, 4c, 5a, 5b, 5c]
13. Give one example of how the distribution of valence electrons in different energy levels is related to mineral color. [2a, 5a, 5b, 5c]

14. Summarize the carbonate mineral group in terms of (a) geologic occurrences, (b) compositional classification and common substitutions, (c) shared physical and optical properties, and (c) polymorphism. [1b, 5a, 5b, 5c]
15. Determine the rate-limiting step in crystal growth by inspecting crystal morphology. [1b, 5a, 5b, 5c]
16. Explain why slow-growing faces inevitably dominate crystal shape, and discuss theories explaining why some faces grow more slowly than others. [2a, 4c, 5a, 5b, 5c]
17. Utilize a liquidus binary T-X phase diagram to describe evolution in crystal and liquid composition during cooling, considering two cases: equilibrium and fractional crystallization. [1b, 5a, 5b, 5c]
18. Distinguish between different types of crystal defects (point, line, planar, and surface) and discuss their roles in chemical substitutions, rock deformation, and physical properties of rocks. [2a, 5a, 5b, 5c]
19. Describe the process of compositional unmixing by drawing a subsolidus binary T-X diagram and tracing the fate of an initially homogeneous pyroxene during cooling. Explain how such a diagram can be used to constrain thermal history of a volcanic rock. [1b, 2a, 5a, 5b, 5c]