# *Florida Atlantic University*
## MINERALOGY -- FINAL EXAMINATION KEY

**True-False** - Print the letter T or F in the blank to indicate if each of the following statements is true or false.  Illegible answers are wrong.  (1 point each)

0    T    1. Powder X-ray photographs provide a "fingerprint" for an unknown mineral, which is very useful in identifying the mineral.

0    F    2. Z is the fast direction in a biaxial indicatrix.

0    T    3.  Interference colors for an anisotropic crystal will be brightest when viewed $45°$ off extinction.

1    F    4. In optical mineralogy, most of the work done is done in conoscopic mode.

1    T    5. $K_\beta$ peaks are always higher energy than $K_\alpha$.

2    T    6. A section through a uniaxial indicatrix perpendicular to the z axis will be circular, with a radius equal to omega.

1    F    7. Points plotted on the edge of a ternary diagram have three components.

2    F    8. The index of refraction is independent of the frequency of light used to measure it.

1    T    9. Solvus lines separate regions of a single solid phase from a region containing two solids.

0    T    10. The most common type of phase diagram for binary systems is a temperature-composition diagram.

2    F    11. If the slow direction of the crystal is parallel to the fast direction of the accessory plate, subtraction will occur. The new color is always less than the original color.

0    T    12. If $\tau = 0°$, a mineral will be extinct when viewed in crossed-nicols and its reference direction is aligned with the N-S or E-W crosshair.

2    _F_    13. For a uniaxial negative crystal, the optical indicatrix has the shape of a prolate ellipsoid.

0    _F_    14. In a biaxial crystal, $\beta$ is the numerical average of $\alpha$ and $\gamma$.

1    _T_    15. In plotting a phase diagram, it is assumed that the system is at equilibrium.

0    _T_    16. As pressure increases, a liquid will eventually cross a phase boundary and become a solid, if other factors are held constant. This helps explain why the outer core is liquid and the inner core is solid.

2    _F_    17. The sublimation curve separates a solid phase from a liquid phase.

1    _T_    18. For systems of fixed composition, as pressure increases the phase diagrams generally become simpler.

1    _T_    19. The more vibrations per second, the slower the light travels through the medium, if the dispersion is normal.

0    _T_    20. For a high power (40x) lens, the depth of focus is less than the thickness of the thin section, so the slide must be placed on the stage with the cover slip up, or it will be impossible to focus the microscope.

0    _F_    21. Natural color is measured in crossed-nicols.

2    _F_    22. The ellipsoid which represents the indicatrix of a biaxial mineral has two major axes.

3    _F_    23. If $B_{x_a}$ is over X, the mineral is biaxial positive.

2    _F_    24. Phase diagrams show the stable phase at any point in the diagram, and the stable phase always has the maximum value of G.

1    _T_    25. $\beta$ is normal to the OAP plane.

0    _T_    26. The plane known as OAP in a biaxial indicatrix shows the maximum possible birefringence.

0    _T_    27. X-rays have wavelengths corresponding to the energy-change involved in falling from a particular high level to a specific lower level. The energy values are different for each element. The resulting wavelengths, or lines, are characteristic lines of the atom producing it.

1    _F_    28. X-rays whose energy is insufficient to dislodge inner electrons will pass through the absorber will strong absorption.

4    _F_    29. Single crystal work is generally done with the aim of identifying an unknown mineral, whose crystal structure is known. This refers to powder X-ray work

1    _T_    30. The Reitveld refinement method allows an X-ray study of powder sample to determine a crystal structure. This is especially important for minerals whose habit is typically a fine powder, rather than discrete single crystals.

0    _T_    31. The mission of the National Minerals Information Center is to collect, analyze, and disseminate information on the domestic and international supply of and demand for non-fuel minerals and materials essential to the U.S. economy and national security.

2    _F_    32. There are always three components present at a triple point.

1    _T_    33. An X-ray tube operating at 40 keV will produce more intense radiation of shorter wavelength than a tube operating at 20 keV.

1    _T_    34. The 3d orbitals lie between the 4s and 4p orbitals in energy, so the 4s orbital is filled before the 3d.

2    _T_    35. Low-spin ferrous ion is larger than high-spin ferrous ion.

**Multiple-Choice** - Choose the best response to each statement or question. Print the letter corresponding to your choice in the blank. (1 point each)

1    _D_    1. If a sample is in continuous extinction:
         A. It is isometric
         B. It is viewed along an optic axis
         C. It is isotropic
         D. Any of the above

1    _D_    2. How many components are present in a ternary diagram?
         A. Zero
         B. One
         C. Two
         D. Three

2     _A_     3. If a system has only pressure as a variable, and there are two components and three phases present, the number of degrees of freedom is:
A. 0
B. 1
C. 2
D. 3

1     _D_     4. Parallel or straight extinction is not possible in what type of crystals?
A. Hexagonal
B. Monoclinic
C. Orthorhombic
D. Triclinic

1     _C_     5. What shape does an isotropic indicatrix have?
A. Oblate ellipsoid
B. Prolate ellipsoid
C. Sphere
D. Triaxial ellipsoid

2     _C_     6. Minerals from which of the following systems would be uniaxial?
A. Monoclinic
B. Orthorhombic
C. Tetragonal - the only one with a high-order axis
D. Triclinic

2     _B_     7. The L shell in x-ray crystallography corresponds to a shell whose n value is what?
A. 1
B. 2
C. 3
D. 4

4     _B_     8. A phase diagram for a unary system, such as silica, is of what type? The composition is silica, and is fixed, so composition is not needed as a variable
A. Temperature - Composition 2 thought it was this
B. Pressure - Temperature
C. Pressure - Composition 2 thought it was this
D. Pressure

2     _C_     9. In optical mineralogy, Δ is:
A. A measure of the change in the property which follows Δ (i.e. ΔT means a change in temperature)
B. Dispersion
C. Path difference
D. Refraction angle

3    _B_    10. The index of refraction associated with the circular section of a biaxial crystal is:
A. $\alpha$
B. $\beta$
C. $\gamma$
D. $\lambda$

4    _A_    11. What is the minimum birefringence possible in a biaxial mineral.
A. 0 In the circular section
B. $\gamma' - \beta$
C. $\gamma' - \alpha$
D. $\gamma - \alpha$

0    _A_    12. In order to filter $K_\beta$ an iron X-ray tube, which element should be used as a filter?
A. Mn
B. Co
C. Ni
D. Cu

2    _D_    13. Extinction which looks like a wave passing across a crystal as the stage is rotated is said to be:
A. Inclined
B. Parallel
C. Symmetric
D. Undulatory

0    _C_    14. The optic axis of a uniaxial crystal is coincident with which crystallographic direction?
A. X
B. Y
C. Z
D. It depends on whether the mineral is positive or negative

2    _C_    15. A system contains quartz, albite, and melt. How many components are present?
A. 0
B. 1
C. 2
D. 3

3    _D_    16. The system in question 5 has how many phases present?
A. 0
B. 1
C. 2
D. 3

1    C    17. What type of phase diagram is used to represent the olivine series?
A. Binary eutectic (temperature and composition)
B. Binary peritectic (temperature and composition)
C. Binary solid solution (temperature and composition)
D. Ternary (composition)

1    B    18. In order for extinction to occur, the privileged directions of two polaroids must be:
A. Parallel
B. Perpendicular
C. 45 to each other
D. The respective positions is irrelevant to extinction

4    A    19. In biaxial crystals, how many high-order axes are present? The lack of any high-order axis reduces symmetry elimates symmetry equivalences between axes
A. 0
B. 1
C. 2 2 thought it was this
D. 3 2 thought it was this

1    D    20. For a mineral classified as uniaxial positive, which of the following is true?
A. The ellipsoid that represents the indicatrix will have two major axes, whose magnitudes are $\varepsilon$ and $\omega$
B. There will be one optical axis, whose direction will be along the direction of the unique high-order symmetry axis in the tetragonal or hexagonal systems
C. The indicatrix will be a prolate ellipsoid
D. All of the above

0    C    21. Which of the following compensator plates has a variable retardation ($\Delta$)?
A. Quarter wave plate
B. Quartz sensitive tint
C. Quartz wedge
D. All of the above

0    B    22. A scanning electron microscope (SEM) has a resolution of approximately:
A. 1 $nm^2$
B. 2.5 - 5 nm
C. 1 $\mu m^2$

1    B    23. Which of the following single-crystal X-ray methods is NOT a moving film (or detector) technique?
A. Four circle Diffractometer
B. Laue
C. Precession
D. Weissenberg

1    _D_    24. Which of the following is an advantage of powder X-ray diffractometry?
A. Analysis is fast
B. Cost (per analysis) is low
C. Required sample size is small
D. All of the above

2    _D_    25. According to information in the video "Global Trends in Mineral Commodity Supplies", the number of elements used in a modern cell phone is:
A. 8
B. 15
C. 30
D. 75

1    _B_    26. What is the atomic number?
A. The number of electrons on an atom or ion
B. The number of protons in the nucleus of an atom or ion
C. The number of protons plus neutrons in an atom or ion
D. The number of protons plus neutrons plus electrons in an atom or ion

1    _D_    27. How many sides does an octahedral polygon have?
A. 2
B. 4
C. 6
D. 8

3    _C_    28. Three d electrons have what types contributions to magnetic moments?
A. Low orbital and low spin
B. High orbital and low spin
C. Low orbital and large spin
D. High orbital and large spin

2    _D_    29. The charge on Mo in Powellite, $CoMoO_4$, is:
A. -2
B. +2
C. +3
D. +6

**Fill-Ins** - Write in the word or words which best completes each statement or answers each question.  (1 point per blank)

7    1. In the Bragg equation what is $\theta$?

         Θ IS THE GLANCING ANGLE OF INCIDENCE  Most forgot the glancing angle

3    2. When light passes from a medium of high index of refraction to one of lower refractive index, the light will be refracted __AWAY FROM__ the normal.

2    3. In a phase diagram in which pressure is NOT shown as a variable, at what pressure is the system, unless it is explicitly stated otherwise on the diagram?   __ONE   ATMOSPHERE__

0    4. Melting accompanied by decomposition or by reaction with the liquid, so that one solid phase is converted into another, is known as __INCONGRUENT__ melting.

0    5. What are the dimensions of the index of refraction?

          __IT IS DIMENSIONLESS SINCE IT IS THE RATIO OF THE VELOCITY OF LIGHT__

          __IN A VACUUM TO THE VELOCITY OF LIGHT IN A MEDIUM__

0    6. The last name of the father-son team that discovered an equation for successful reinforcement of X-rays off different layers within a crystal structure is __BRAGG__

0    7. What does CN stand for? __CN = CROSSED NICOLS__   (COORDINATION # OK)

2    8. If n = 3, what are the possible values of m?   __±2, ±1, 0__

3    9. From his studies, __DMITRI IVANOVICH MENDELEEV__   was able to correct the atomic weights of indium, beryllium, and uranium in the 19th century.

3    10. __LINUS CARL PAULING__   said, "The number of essentially different kinds of constituents in a crystal tends to be small?

**Matching** - Match the discovery in column one with the person associated with the discovery in column two by writing the letter(s) corresponding to your choice in the blank. Answers may be used once, more than one, or not at all (One point each)

| Column 1 | Column 2 |
|---|---|

2    _O_ 1. He determined the law governing the bend of light passing between media of different refractive indices. That's why they call it Snell's Law

A. Roy G. Biv

B. Sir William Henry Bragg

1    _G_ 2. He discovered a basic property of electromagnetic radiation, $E = h\upsilon = hc/\lambda$

C. Sir William Lawrence Bragg

D. Sir David Brewster

1    _E_ 3. He invented the precession camera for single crystal X-ray work

E. Martin J. Buerger

0    _P_ 4. German physicist who won the Nobel Prize in Physics in 1914 for the discovery of diffraction of X-rays by crystals

F. Augustin Louis Cauchy

G. Albert Einstein

1    _D_ 5. The condition for maximum polarization of reflected and refracted rays is named for this Scottish physicist.

H. Sir Lazarus Fletcher

I. Steven M. Fortier

0    _L_ 6. Produced a color chart which plots the thickness of an isotropic specimen, its birefringence and its retardation in nanometers

J. Joseph von Fraunhofer

K. Josiah Willard Gibbs

L. Auguste Michel-Lévy

1    _Q_ 7. This Austrian physicist developed a rotating-crystal method which also translated the film, allowing unambiguous index of each refraction

M. William Nicol

N. Wilhelm C. Roentgen

3.5    _C_ 8. Shortly after Friedrich, Knipping, and von Laue demonstrated in 1912 that X-rays were diffracted in a crystal, he was able to show that X-rays behaved as though they were reflected from planes of atoms making up the crystal structure.

O. Willebrod Snellius

P. Max Theodore Felix von Laue

Q. Karl Weissenburg

0    _I_ 9. He was the speaker for the video "Global Trends in Mineral Commodity Supplies"

**Discussion questions** - Write a complete, concise answer to each of the following questions. Diagrams (labeled) may be used to supplement your written answers, where appropriate, and must be shown where requested. Points as shown

2.5     1. State the **general case** of the phase rule in a formula, and clearly define each symbol used. Just saying what the symbol stands for does not define it. (5 points)

$$f = c - p + x$$

where:

$f$ = # degrees of freedom. The number of intensive parameters that must be specified in order to completely determine the system. Intensive variables usually include pressure, temperature, and composition, and may include magnetic and/or electric fields, that can be changed independently without loss of a phase.

$p$ = number of phases - phases are mechanically separable constituents

$c$ = minimum number of components, which are chemical constituents that must be specified in order to define all phases

$x$ is the number of intensive variables, pressure, temperature, composition, and possibly magnetic and electric fields, that can be changed independently without loss of a phase.

0.5     2. Dolomite belongs to the hexagonal crystal system, with $\varepsilon = 1.500$ and $\omega = 1.681$.

What is the optical class and sign of dolomite? (2 points)    Uniaxial negative

7.5     3. Why are the ports of X-ray tubes covered by beryllium windows? (2 points)
      THE INTERIOR OF THE X-RAY TUBE OPERATES IN VACUUM SO THE PORT MUST BE COVERED IN ORDER TO MAINTAIN THE VACUUM.  X-RAYS ARE ABSORBED BY MATTER.  THEREFORE THE PORTS SHOULD BE CONSTRUCTED OF SOME TYPE OF MATTER WHICH MINIMIZES X-RAY ABSORPTION.  ELEMENTS WITH LOW ATOMIC NUMBER HAVE LOW X-RAY ABSORPTION.  BERYLLIUM IS THE LOWEST ATOMIC NUMBER MATERIAL THAT IS SOLID AND NON-REACTIVE.

4.5    4. When discussing Tantalum, why did the speaker in the video"Global Trends in Mineral Commodity Supplies" say the United States was more at risk of supply shortages in 2015 than during the period 2000-2006? How much of the U.S. supply is imported? (2 points)

> The United States imports 100% of its Tantalum supply. The biggest risk is what is called "governance risk". During the 2000-2006 period, U.S. supplies came mainly from Australia and Brazil, countries with low to moderate ricks of governance instabilities. As demand for Ta increased, the major suppliers were Democratic Republic of Congo and other African nations, with high to very high risk of governance instabilities.

6    5. What units does k, the absorption coefficient, have? Why? (2 points)

> Since the expression for absorption is $I/I_0 = e^{-kt}$, kt must be dimensionless. Since t has units of thickness, k must be the reciprocal of the same unit of thickness.

9    6. In Scanning Electron Microscopy, four different types of detectors are used. Name and describe the use of three of these, including what they detect, and what information can be determined through their use. (3 points)

> Secondary electron (SE) detectors measure electrons ejected from the sample, and produce very high definition images, with a large depth of field. Backscattered electrons (BSE) are electrons from the imaging beam reflected backward. The analysis uses a polished sample, and allows observation of chemical zoning and reaction fronts on a very small scale. X-rays may be detected using the EDS system, which allows a qualitative identification of material in the unknown sample. The sample area is much larger than tin TEM. Cathodoluminescence (CL) detects emissions in the UV, visible, and IR portion of the spectrum, useful for seeing internal zones and domains having different chemical compositions and/or structures with a high spatial resolution.

7  7. Describe two ways in which electrons can generate magnetic forces. (2 points)
Moving electrical currents generate magnetic forces. This includes electrons:
a) Orbiting around a nucleus
b) Spinning around their own axis

1  8. What does 3m mean? (1 point)
3m means three-fold rotation  with 3 parallel mirror planes

**Diagram** - Diagrams may have been altered to remove labels, etc. Answer each question. (1 point each, unless otherwise indicated)

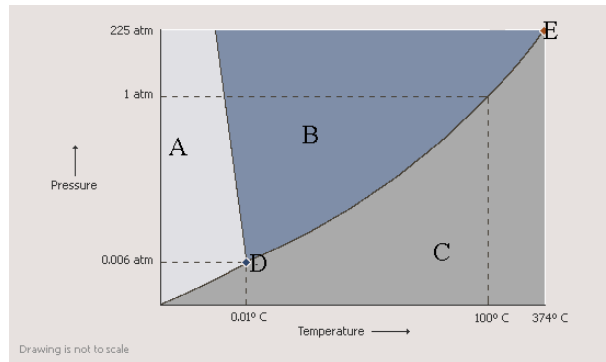1. Each of the following questions pertain to Figure 1.(1 point each)



**Figure 1**

What are the names of the following points?

3  D _Triple point_

3  E _Critical point_

THIS IS THE DIAGRAM FOR WATER!

**Problems** - Do each of the following problems. **Show all work. Label answers, including units, if any. Express answers to the correct number of significant figures. List any formula used, and define all symbols used in the formula**. "Miraculous answers", unsupported by all necessary calculations, will receive little or no credit.

**Given**: $c_{vacuum} = 2.998 \times 10^8$ m/s

9.5    1. If $\lambda = 637$ nm, what if f? (4 points)

$$c = f\lambda \qquad f = c/\lambda$$
$$f = 2.998 \times 10^{17} \ nm/s \ / \ 637 \ nm \ = \ 4.71 \times 10^{14} \ hertz$$

6    2. If light travels from air into melanite, and the angle of incidence is 38.7°, what is $\triangle r$? n for melanite = 1.940. (3 points)

$$\sin\triangle r = (n_i \sin\triangle i)/n_r = (1\sin(38.7°)/1.940) = 0.3223$$
$$\triangle r = 18.8°$$

0    3. What is the retardation, expressed in nm, of a crystal of dolomite of standard thickness, which shows the maximum possible birefringence? (2 points)
     Discussion question 2 had the data for dolomite. Howver, most of you didn't recognize this, so the question was thrown out.

- $\Delta = t(N - n) = 0.030 \ mm \ (1.681 - 1.500) = 0.030 \ (0.181) =$ $5.40 \times 10^{-3}$ mm $= 5400 \ nm$

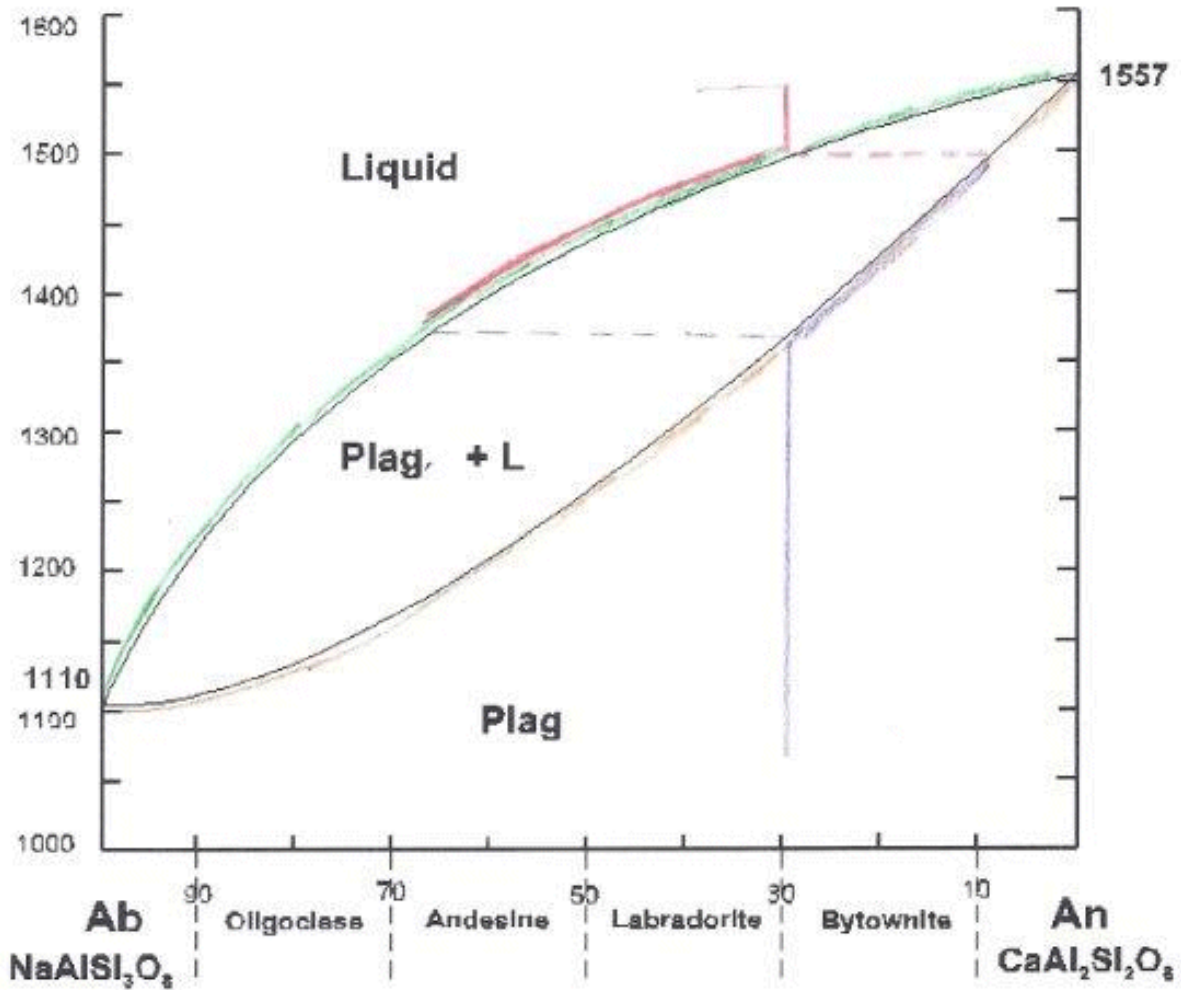4. Use figure 2 to answer the questions 1-8 (one point each)



**Figure 2**

1    1. Show the liquidus line in green.

1    2. Show the solidus line in brown.

Starting at 1550°C and $Ab_{30}$

1    3. Plot the path followed by the liquid in red as it cools until it disappears.

2    4. Plot the path followed by the solid in blue until it reaches a temperature of 1050°C.

14

2      5. What is the composition of the first solid? _____$Ab_{8.5}$_____

2      6. What is the composition of the final liquid? __$Ab_{67}$_____

8      7-8. At 1400°C, what percentage of the material is solid? ___85% solid_____
         (Show calculations below) LEVER RULE

         LF = 7   SF =40 LF + SF = 47

         % Solid = SF/(LF + SF) x 100 = 40/47 x 100 = 85%

## HAVE A GREAT VACATION AND A
## VERY HAPPY AND SAFE NEW YEAR!

# Previous Years Results -Final Examination

**Term, Year, Mean %**

Fall, 2019  67.7
Fall, 2018  67.5
Fall, 2017  71.6
Fall, 2016 73.6
Fall, 2015 77.5
Fall, 2014 82.2
Fall, 2013 79.1
Fall, 2012 73.4
Fall, 2011 76.1
Fall, 2010  70.0
Fall, 2009 68.8
Spring, 2009 75.6
Fall, 2007 73.9
Fall, 2006 73.7
Fall, 2005 69.0
Spring, 2004 89.7
Fall, 2002 73.2
Spring, 2001 69.7
Spring, 2000 87.2
Fall, 1998 66.8
Fall, 1997 76.8
Fall, 1996 71.5
Fall, 1995 76.1
Fall, 1994 69.6
Fall, 1993 79.6
Fall, 1992 73.2
Fall, 1991 73.8