# Chem 208-02: General Chemistry II and Introduction to Inorganic Chemistry

Spring 2019, MW 12:00 – 12:50 pm ISC 1127; F 12:00 pm – 12:50 pm Small 110
Instructor: Professor Deborah C. Bebout; ISC 2039; 221-2558; dcbebo@wm.edu

**Group Help Sessions** Every week Thursday 5:15-6:15 pm & Friday 4:00-5:00 pm in ISC 2018 & Test weeks Monday 8 pm
**Office Hours** Tuesday 2:00-3:00 pm; Wednesday 5:15 – 6:15 pm in ISC 2039
*Weeks of tests: Wednesday night office hours moved to Monday (2/11, 3/18 & 4/8) & no RF Group Help Sessions*

**Virtual Help:**
E-mails are responded to Monday 9 pm – Saturday midnight (NOT SUNDAY)
HW hints on Blackboard (final update after Friday help session)

COURSE CATALOG DESCRIPTION: (3 credits; Prerequisite Chem 103) A continuation of the study of the principles of chemistry begun in Chemistry 103. Topics include acid-base chemistry, thermodynamics, nuclear chemistry, chemical kinetics, descriptive inorganic chemistry, and coordination chemistry.

Recommended for students expecting to major chemistry, life sciences, geology, and physics. Chem 205, 208, 305, 308 and 335 are interchangeable for the purposes of meeting biology, chemistry, geology, neuroscience and physics major degree requirements, chemistry and biochemistry minor degree requirements, as well as admission requirements for medical school.
**********Students are only permitted to take ONE of these courses for credit.**********
There is no coordination between these courses, nor between the two sections of Chem 208. Students enrolled in Chem 208 Section 02 should plan to consult Professor Bebout regarding all issues related to this course. A complementary laboratory course (CHEM 254 or CHEM 256) is offered separately; review degree and post-baccalaureate plans to see if enrollment in the laboratory course is needed.

NOTE: The course sequence Gen Chem I, Orgo I, Orgo II, Gen Chem II is normal for those planning to take two years of college chemistry since Orgo I is only taught in the spring and summer. Although Chem 208 does not have organic chemistry as a prerequisite and may be taken immediately after Gen Chem I for those only planning to take two semesters of college chemistry, students who have completed three semesters of college level chemistry are naturally better prepared for academic success in this class. Furthermore, it is not advisable to take CHEM 208 after earning a grade of C- or lower in CHEM 103 unless individual remediation has been undertaken, especially in the areas of equilibria, redox chemistry, stoichiometry, thermochemistry, electron configuration, chemical bonding and molecular geometry.

## *Course Objectives:*

1. Study the content, principles and methods of chemistry;
2. Develop an appreciation for the relevance of chemistry in our daily lives;
3. Improve analytical and problem solving skills.

## *Course related electronic resources:* See Blackboard Course Information for more details.

1. https://openstax.org/details/books/chemistry-atoms-first: Required free virtual textbook & student resources
   *This text was required for most sections of CHEM 103 in Fall 2018; the text is similar to OpenStax, Chemistry used previously.*
2. https://blackboard.wm.edu: CHEM 208-02 Syllabus, various course documents, lecture capture and extra credit lecture quizzes
3. https://www.saplinglearning.com/ibiscms/login/: College of William & Mary - CHEM 208 - Spring19 - BEBOUT
   Students are required to register for Sapling, an interactive homework and instruction service, with their W&M ID # and pay the associated $42 fee (free trial period through Jan 29) to access weekly homeworks and associated instructional services.
4. https://www.polleverywhere.com: The Poll Everywhere student response system may be used for interactive lecture elements and attendance (informative, not punitive).

## *Student Course Responsibilities & Course Policies:*

Time commitment: Excelling in college level course work typically requires on average three to four hours per credit per week. Since this is a three credit course, in addition to almost three hours spent in class each week you should expect to spend six to nine hours on average reading the textbook, doing homework and otherwise preparing for this class on a weekly basis.

Attendance: Class attendance is expected for all scheduled meetings and required on scheduled exam dates. Poll Everywhere questions may be integrated into class meetings for informal attendance and real-time instructor feedback. Students are responsible for everything that is covered during class including demonstrations and other visual aids. Students missing class for any reason are expected to get notes from a peer in the class and check Blackboard for any important announcements that they might have missed.

Classroom Behavior: Students attending lecture are expected to be attentive and refrain from activities that would distract other students in the class. Please refrain from eating, cell phone and laptop use not directly related to this class during class.

Lecture Quizzes (Extra Credit; Maximum 24 points): To provide practice with multiple choice type problems, Lecture Quizzes (5-20 questions) will be posted on Blackboard before each lecture. Each Lecture Quizzes is due before the next lecture (no cost extension to noon January 28 before the end of add/drop). Lecture quizzes may be taken up to five times – highest score will be recorded. Students may work together on reading quizzes with the understanding that content mastery is an individual responsibility.

Homework Assignments (weekly; 10 points each): Working problems is important for reinforcing the chemical principles emphasized in the lecture and text. There will be twelve Sapling homework assignments, each worth 10 pts maximum. Your overall homework score will be based on the ten highest scores; any additional homework submissions will count as extra credit. Answers to homework assignments must be submitted via Sapling before 11:59 pm every Sunday (for Spring Break due **Monday, March 11th @ 11:59 am**). There is no homework due weeks with mid-terms scheduled on Wednesday. **NO CREDIT FOR LATE HOMEWORK**. Each student must have personal access to Sapling to submit homework responses. Each homework assignment will consist of 10 problems posted at least one week in advance. You can keep trying to answer each question until you get it right without penalty for incorrect answers. You can view solutions when you complete or give up on any question. There is no penalty for incorrect answers. Assignments are set up so they can be started, saved and resumed later numerous times. Students may work together on homework with the understanding that content mastery is an individual responsibility. *In other words: EVERY POINT MATTERS There are a total of 120 homework points available, 20 of which are extra credit, almost enough to bump your grade on level.*

Practice Problems: Answers for all odd numbered end-of-chapter problems are found in the back of the text and detailed solutions to these problems are found in the *Student Solutions Guide* available from OpenStax. Doing all the odd end of chapter problems for practice is highly recommended.

Review Sessions: Review sessions will be held at 8 pm in ISC 1127 two days before each midterm (Mondays February 11th, March 18th and April 8th). A review session for the final will be announced before the last day of class (probably Noon, Saturday May 4, but room accessibility may require alternative scheduling). Review session attendance is optional but strongly encouraged.

***Grading Policies***

Point totals required for specific grades will be calculated based on proportion of points earned from:

100 pts Sapling Homework: Top ten homework scores. Maximum 10 each (*Two extra HW available for extra credit*).
200 pts Each of three mid-terms (Excused absence from a midterm will result in reweighted final)
300 pts Final (50% material after 3rd mid-term + 50% cumulative = 62.5% material after 3rd mid-term + 37.5% earlier material)
*Up to 44 points are available in extra credit (Two Sapling homeworks with lowest grades and Blackboard Reading quizzes for each lecture) for adjustment of point totals after determination of grade breaks.*

Mid-Terms: All mid-terms will be closed-book, closed-note, independent exercises. **NO MAKE-UP MID-TERM EXAMS WILL BE GIVEN.** For excused absences, the remaining exams and final will be weighted more heavily (25% and 40%, respectively) to account for the missed exam. If you know that you will have a conflict with a scheduled exam due to a College function such as varsity sports, choir, etc., please notify me **in advance** of your absence. Detailed documentation for *severe* illness must be obtained from the Health Center or other medical professional. Documentation for deaths in the family and other extraordinary circumstances must be obtained from the Dean of Students. Unexcused absences for scheduled mid-terms, including early departures or late returns from weekends/spring break, fraternity/sorority functions, family reunions, etc. will result in a grade of zero for the missed exam. *While it is mathematically possible to pass this class with an unexcused exam absence, the one person who tried was unsuccessful.*

Final Exam: The final exam for Chem 208 02 is scheduled for Monday, May 6th from 9:00 am – Noon. Since I do not teach Section 01 of this course, plan on taking the exam at the scheduled time unless you meet the limited criteria for rescheduling a final (three consecutive examination periods on consecutive days or a conflict between scheduled examinations). The Office of the Dean of Students handles deferral requests from students unable to take their examinations at the time scheduled on account of documented illness or other extenuating circumstances (such as a death or other family emergency, conflict with a religious holiday, or participation in activities by a student representing the College). Final examinations that are deferred will be scheduled for the beginning of the Fall 2019 semester.

**Class Climate, Culture and the Honor System**

The College of William and May has an Honor System detailing the academic responsibilities of all students. Students may work with other students on reading quizzes and homework, but are required to submit their own answers. Exams will be closed book, closed note and independent. Non-emergency use of a cell phone or other unapproved resources during an exam is grounds for Honor Council proceedings, an F on the exam or an F in the class at the discretion of Prof. Bebout.

Students with disabilities will be accommodated in accordance with federal laws and university policy. Any student who feels he/she/they may need an accommodation based on the impact of a learning, psychiatric, or chronic health diagnosis should contact Student Accessibility Services staff at 757-221-2509 or at sas@wm.edu to determine if accommodations are warranted and to obtain an official letter of accommodation. For more information, please see www.wm.edu/sas. If you anticipate requiring specific accommodation based on documented disabilities, please let me know *no later than January 25* (by response to question 11 on the course survey, an e-mail or personal contact) so I can make adjustments to minimize their impact on your performance in this class.

**Anticipated Course Calendar subject to change by acts of Nature and other unanticipated events:**

| Date | Topic | Assigned readings,♪ Studying‡ & Required Homework† |
|---|---|---|
| Jan 16 & 18 | L1 & L2: Acids, Bases & pH Scale | Read 14.1, 2, 3 (742-745), 5; 15.2 |
| Jan 20 | HW #1 "due" @ 11:59 pm (No cost extension until 11:59 pm Jan 27 after add/drop ends) | Review problems from General Chemistry I |
| Jan 21 | Martin Luther King Day – No Classes<br>OPTIONAL GENERAL CHEMISTRY I REVIEW<br>Equilibria, Significant Figures & Selected Other Topics | Suggested reading 13.1-4 |
| Jan 23 & 25 | L3 & L4: Acid/Base equilibria; Polyprotic acids & Linked equilibria | Read 14.3;15.3 |
| Jan 27 | HW #2 due @ 11:59 pm | Introductory Aqueous Equilibrium concepts |
| Jan 28-Feb 1 | L5-L7: Salts, Common Ions & Buffers | Read 14.4, 6; 15.1 |
| Feb 3 | HW #3 due @ 11:59 pm | Core Aqueous Equilibrium concepts |
| Feb 4-8 | L8-L10: Titrations & Solubility | Read 14.7; 15.1, 2, 3 |
| Feb 10 | HW #4 due @ 11:59 pm | Advanced Aqueous Equilibrium concepts |
| Feb 11 | L 11: Enthalpy & Entropy<br>*5:15 pm Monday test week office hour*<br>*8:00 pm Q & A Review Session ISC 1127* | Review 9.3, 9.4(497-501); 12.1,2 |
| **Feb 13** | **Mid-term I: Chapters 14 & 15**<br>*Test week, no homework due, No WRF office hours* | |
| Feb 15 | L12: Laws of Thermodynamics; Free Energy (ΔG) | Read 12.3,4; 679-680; 13.4(706-712) |
| Feb 18-22 | L13-15: ΔG under Non-standard State Conditions; Redox & Electrical Energy from Chemical Energy; | 16.1-16.3 |
| Feb 24 | HW #5 due @ 11:59 pm | Thermochemistry |
| Feb 25-Mar 1 | L16-18: Nernst, Batteries, Corrosion & Electrolysis | 16.4-16.6 |
| **Mar 2-10** | **Spring Break:** MC HW #6 "due" @ 11:59 pm Mar 10 with no-cost extension to noon Mar 11 | Advanced Thermochemistry & Electrochemistry |
| Mar 11-15 | L19-21: Electrolysis (cont.) & Biochemical redox rxns<br>*Midnight March 15 last day to withdraw* | 16.7 |
| Mar 17 | HW #7 due @ 11:59 pm | Advanced Electrochemistry |
| Mar 18 | L22: VESPR & Hybridization<br>*5:15 pm Monday test week office hour*<br>*8:00 pm Q & A Review Session ISC 1127* | 4.6, 5.1-3; If needed, review 3.3-5; 4.1,2-5 |
| **Mar 20** | **Mid-term II: Chapters 16 & 17**<br>*Test week, no homework due, no WRF office hours* | |
| Mar 22 | L23: Hybridization & Molecular Orbital Theory | 5.4-5.6 |
| Mar 25-29 | L24-26: MO Theory & Transition Metals | 19.1,2 |
| Mar 31 | HW #8 due @ 11:59 pm | Hybridization, MO Theory & Transition Metals |
| Apr 1-5 | L27-29: Coordination Compounds & Metal Spectroscopy | 19.2-19.3 |
| Apr 7 | HW #9 due @ 11:59 pm | Coordination Compounds |
| Apr 8 | L30: Nuclear chemistry<br>*5:15 pm Monday test week office hour*<br>*8:00 pm Q & A Review Session ISC 1127* | 20.1-2 |
| **Apr 10** | **Mid-term III: MO, Chapters 20 & 21**<br>*Test week, no homework due, no WRF office hours* | |
| Apr 12 | L31: More nuclear chemistry | 20.3-4 |
| Apr 14 | *Test week, no homework due… Start HW #12* | |
| Apr 15 | L32-34: Biological nuclear chemistry; TBD | 20.4-5; TBD |
| Apr 21 | HW #10 due @ 11:59 pm | Nuclear Chem & TBD |
| Apr 22-26 | L35-37: TBD | TBD |
| Apr 28 | HW #11 due @ 8:59 pm | TBD |
| May 4 | MC HW #12 (Extra credit) due @ 11:59 am (tentative)<br>*Noon Review Session (tentative)* | Review problems from the semester |
| **May 6** | **Monday – Comprehensive Final – 9:00 am – noon** | |

♪ Lecture quizzes are posted on Blackboard ‡Answers for odd numbered textbook problems are in the back of the textbook and complete solutions are in the Student Solution Guide.

**Overview of Critical General Chemistry I and Math Knowledge**

Symbols & Abbreviations

∴ Therefore

| | | | | |
|---|---|---|---|---|
| Rxn = reaction | E = Energy | T = Temperature | K = equilibrium constant | eq = equation |
| Soln = solution | H = Enthalpy | t = time | k = rate constant | ρ = density |

Arrows: $\longrightarrow$ used if reaction goes to completion; $\rightleftharpoons$ used for equilibria; $\leftrightarrow$ used for resonance

[A] = Molar concentration of A (moles A/liter solut)

${}^{A}_{Z}X$ = Atomic symbol where A = Mass Number = # protons + # neutrons, Z = Atomic number = # protons, X = element symbol

Significant Figures

*Rounding:* Carry all the digits available through calculations to avoid round off error. If $\geq 5$, round up; if $< 5$ round down.
*Addition & Subtraction:* Modify the result to have the same number of *decimal places* as the number with the *fewest decimal places*.
*Multiplication & Division:* Modify the result to have the same number of *significant figures* as the number with the *fewest sig. figs.*
*Combined calculations:* Apply above rules in the same order as their respective operations in performing calculation.
*Logarithms:* Number of decimal places in the log is equal to the number of significant figures in the original number.
*Approximations:* $100 - x \cong 100$ when $x << 100$

Nomenclature

*General:* Cations first by element name(oxidation state) then simple anions Xide; Compounds are **neutral**
*Number prefixes:* 1-10 = mono- (rarely used), di-, tri-, tetra-, penta-, hexa-, hepta-, octa-, nona-, deca-
*Oxyanions:* if two O max $XO_n$ = Xite, $XO_{n+1}$ = Xate; if four O max XO = hypoXite; $XO_2$ = Xite; $XO_3$ = Xate; $XO_4$ = perXate

Important types of solution reactions

*Acid-base reactions:* typically involve a transfer of $H^+$ ions (more generally electron pair donor/acceptor chemistry)
*Precipitation reactions:* formation of a solid occurs
*Oxidation-reduction reactions:* involve electron transfer [organic: reduction (oxidation) gain H (O) OR lose O (H), not both!]

Bonding

*Ionic bond:* electrons are transferred to form ions
*Covalent bond:* equal sharing of electrons
*Polar covalent bond:* unequal electron sharing
*Electronegativity:* Relative ability of atom to attract shared $e^-$; polarity of bond depends on relative electronegativity of bonded atoms
*VESPR Model:* Valence shell Electron Pair Repulsion model = minimization of electron pair repulsion dictates geometry

Thermodynamics

*First law of thermodynamics:* Energy is conserved.
*State functions:* Functions which are path independent and only depend on endpoints (eg. energy, enthalpy)
*Standard state:* 1 M concentrations, 1 atm, 25 °C
*Exothermic:* Energy as heat flows out of system; opposite of endothermic

$\Delta H^\circ_{rxn} = \Sigma n_p \Delta H^\circ_f(\text{products}) - \Sigma n_r \Delta H^\circ_f(\text{reactants})$ (elements omitted since $\Delta H^\circ_f(\text{element}) = 0$)

Kinetics

*Differential Rate Law:* $\text{Rate} = -\frac{\Delta[A]}{\Delta t} = k[A]^n$ where A = reactant; k = rate constant; n = order of rxn (NOT coefficient in balanced eq)

*Integrated Rate Law:* For a reaction of type $aA \rightarrow$ products for which Rate = $k[A]^n$

n = 0: $[A] = -kt + [A]_0$ n = 1: $\ln[A] = -kt + \ln[A]_0$ n = 2: $[A]^{-1} = kt + [A]_0^{-1}$

These equations have the form y = mx + b, the value of k can be determined from the slope of the plot of appropriate [A] vs t plot

*Arrhenius equation:* $k = Ae^{-E_a/RT}$

Equilibria

K = Equilibrium Constant = [product]/[reactants] = $[C]^c[D]^d/[A]^a[B]^b$ for the reaction $aA + bB \rightleftharpoons cC + dD$
= $k_f / k_r$ = rate of forward reaction / rate of reverse reaction

Q = Reaction Quotient; If Q > K, rxn will shift toward reactants, if Q < K rxn will shift toward products

Standard practices for K and Q: Molar concentrations used for all solutes; partial pressures in atmospheres used for all gases; both K and Q are "unitless" themselves but must be calculated using numbers with the right units

Equilibria are temperature, concentration, and pressure (volume) dependent

*Le Châtelier's Principle*: when a stress is placed on a system at equilibrium, the system shifts in the direction that relieves the stress

*Dynamic State*: At equilibrium, reactants and products are interconverted continually; Forward rate = Reverse rate

*Mass Balance:* Products come from reactants in a stoichiometry dependent manner; Facilitated calculations based on change