Syllabus

Inorganic Chemistry

Modern society has made great strides in developing new technologies in communications, medicine, and entertainment that are dynamically shaping our daily lives. The challenge is to maintain the advancements while ensuring sustainable technologies. This is not a trivial undertaking. It will require the holistic, intelligent application of several technologies, including renewable energy, energy-efficiency, a ubiquitous telecommunications infrastructure, high-density information storage, inexpensive sensors, and personalized medicine. How do these technologies work, and how do we improve them? What resources do they require? Are they ultimately sustainable? If not, can we ultimately transform them into sustainable technologies?

These questions ultimately come down to *materials* that possess desirable physical properties. Research in materials chemistry drives at three goals: (a) manipulating the chemical and physical structure of materials to control their properties; (b) understanding how a material's properties depend on its structure; and (c) assembling materials — with the right properties — into heterogeneous systems that perform specific functions.

In this course, we will explore a variety of materials, with a focus on the physical properties that make these materials useful in functional systems, such as solar cells, electronic devices, fuel cells, batteries, and sensors. In the process, we will practice building models, metaphorical and mathematical, to guide us in the design, use, and analysis of materials.

Course information

Instructor

John Payton
Department of Chemistry
Office: Tomsich 212
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Class meetings

Hayes 215
Tuesday & Thursday, 8:10 – 9:30 am
Credit: 0.5 units

Contact information

Office hours: *Tue.: 9:30–11:00 am & 3:00–5:00 pm; Thurs.: 9:30–11:00 am*

Office hours are an open time to discuss any questions you have, clarify something on a reading or assignment, or even just to chat. You can drop in; however, make an appointment if you need to reserve a specific time slot.

Appointment: If you need to meet outside of office hours, use your Kenyon gmail calendar to check my calendar. Find a mutually available time, create an event on your calendar, and send me an invitation. If the time is okay, I will accept it.

Learning Objectives & Outcomes

This course is built around two main objectives. The first is to master a basic set of principles essential to understanding and recognize inorganic compounds, and to some important ideas in chemistry. As examples, we will focus on coordination compounds, solid-state materials, and electronic materials.

The second objective is to practice and develop scientific communication skills, which include the ability to investigate and evaluate scientific ideas. Through the research project, you will have the opportunity to study specific topics in inorganic chemistry research and explore creative ways to express scientific ideas.

Upon successful completion of the course, students will…

- developed skills to create, evaluate, record, and report scientific ideas and data,
- understand important ideas in inorganic chemistry,
- recognize how electronic structure effects periodic trends,
- be able to identify different types of crystal structures,
- know basic coordination chemistry, and
- have a working knowledge of chemical bonding by molecular orbital theory.

Course structure

Study guides

The study guide for each topic will contain a list of learning objectives, study questions, notes, and puzzles.

Discussion

Class meetings will typically involve structured group discussion around different topics. At the beginning of each week, discussion will center on essential concepts from study guides and quizzes. Your group's task will be to identify the concepts or applications you would like the entire class to discuss. Toward the end of each week, discussions will center on project planning.

Class Research Project

Your project is an opportunity to explore in more detail how the scientific method is practically applied to solve unanswered problems. The project is true original research; nobody currently has the answer to the questions we will ask. We will employ computational methods to perform the work, and access to the required software and hardware will be provided. Details of background, methodology, and validation will be discussed throughout the course. The goal is to enhance your communication and creation of novel scientific ideas in a precise, accurate, and interesting way.

Class participation includes team discussion and work on the project, both in and out of class, and creation of a final product that can be shared publicly. You should consult with the instructor (and other professors) for advice on understanding, defining, or presenting your topic.

Assessment & Grading

Participation (20% of final grade)

The participation points will be assessed by conveying clear evidence of engagement in your studies for the course. For an inclusive classroom, public or private engagement will be fully considered. The public engagement will include attending and participating in classroom discussion. Private engagement may be demonstrated by making non-trivial updates to your "Journal" file in your course Google Docs and by utilizing my office hours. Answering the in-class polling software (kahoot.com) will also be considered evidence of engagement.

Project (20% of final grade)

Research projects have both the potential for success and failure, as we are designing experiments to test a hypothesis. **The assessment of your work will be based on your ability to interpret, collect, record, and communicate the data,** not on the success of proving the hypothesis. If the project does fail, you need to explain how the hypothesis is flawed and how you would rewrite it based on the collected data.

You will have a digital "Notebook" file in your course Google Docs to record all plans, results, and calculations you collect for this project. Classroom discussions about project aims, hypothesis, literature references, and proposed experiments should be in this digital notebook. The digital notebook does not need to look pretty but does require all your records are clearly stated and very detailed. Someone else should be able to reproduce your work if you are keeping good records. As the final part, you will have a formal written report that will tentatively take the format of the ASC journal Organometallics.

Quizzes (20% of final grade)

There will be an unnamed number of quizzes throughout the semester. The quizzes are not necessarily announced. The good news is that only the **four best scores will be counted** towards your total quiz grade. The quizzes will be directly based on the study guide posted online.

Midterms (20% of final grade)

There will be two midterm exams during the semester. Each exam will cover the topics discussed in class. You will be only allowed a non-programmable calculator and 3″ × 5″ note card for all exams. Practice questions will be posted online. Set aside time in your schedule to practice in a quiet place, and do it under exam conditions: with a calculator and 3″ × 5″ note card, and without the textbook or music. As you have limited time for exams, you should practice answering questions smoothly and rapidly.

Midterm Grade Forgiveness: As exams may not necessarily demonstrate your complete abilities, a single midterm grade maybe substituted for a 10~15 page report in the field of inorganic chemistry, pending instructors approval. You may apply for this option by writing a one-page letter to the instructor, which clearly justifies how the report will assist you in achieving the course objectives. Applications will be accepted after the first midterm and until two weeks before the final. You may only apply to replace one midterm exam. An application can be denied if you do not clearly state how you will benefit from this opportunity beyond a possible grade increase.

Final Examination (20% of final grade)

The final examination will be about 2 hours and comprehensive. Because of limited time, it is impossible to include every concept or skill encountered in class. For this reason, the exam will *sample* topics, so you should expect that *any* topic could appear. 10–20% of each exam will include novel problems that test not just your knowledge and skills, but mental agility as well.

The Registrar will set the date and time of the final exam. It is your responsibility to check the Registrar's schedule before you make travel plans. *The College explicitly requires instructors to give the final exam at the time scheduled by the Registrar.*

Grading

Your final grade is determined by a point's base system of 1000 earnable total points. The grade will follow a standard scale of ±A > 90% (900 pts.), ±B > 80% (800 pts.), ±C > 70% (700 pts.), and ±D > 60% (600 pts.) with the plus/minus being with 2% of the respective grade cutoff. Grades will not be curve. The points you earned are your achievements. However, the adjustments to the grade scale can made at the end of the course, if appropriate and justified.

The grade for this course is based upon the following components:

Quizzes: 4 @ 50 points each	200 points
Class Project	200 points
Participation	200 points
Midterm Examination 1	100 points
Midterm Examination 2	100 points
Final Examination	200 points
Total Points	1000 points

Resources

You should own or have access to a general chemistry textbook for reference. In addition, you should also own or have access to textbooks on inorganic chemistry and on solid-state materials. Some of the texts below are on reserve at the library.

General textbooks on inorganic chemistry

For the purposes of this class, a general inorganic textbook should address the structure of coordination complexes, the role of symmetry, the nature of ionic bonding, and trends within the periodic table. Recommended options include:

- Chemisty LibreText Online: chem.libretexts.org
  - Inorganic Text: https://chem.libretexts.org/Textbook_Maps/Inorganic_Chemistry/Book%3A_Inorganic_Chemistry_(Wikibook)
- Rodgers, *Descriptive inorganic, coordination, and solid state chemistry*, 2/e or later
- House, *Inorganic chemistry*, any edition
- Housecroft and Sharpe, *Inorganic chemistry*, 3/e or later
- Miessler and Tarr, *Inorganic chemistry*, 2/e or later

General textbooks on solid-state materials

For the purposes of this class, a textbook on solid-state materials should address the structure of crystal lattices, visual representations of periodic structures, electronic structure of solids, the role of defect structures on properties, and electron-hole chemistry. Recommended options include:

- Smart and Moore, *Solid State Chemistry: An Introduction*, 3/e or later
- Tilley, *Understanding Solids: The Science of Materials*, any edition

Advanced Textbooks

If you want to explore a particular topic in greater depth, you can find more detailed, advanced treatments in the following textbooks.

- Douglas *et al*, *Concepts and Models of Inorganic Chemistry*
- Harris *et al*, *Symmetry and Spectroscopy*
- Spessard and Miessler, *Organometallic chemistry*
- Kasap, *Principles of Electronic Materials and Devices*
- West, *Solid state chemistry and its applications*
- Kettle, *Symmetry and structure: readable group theory for chemists*
- Shackelford, *Introduction to materials science for engineers*

Tools/Toys

Model Kit

Because symmetry is such a prevalent consideration in inorganic chemistry, you should have some way to construct physical models of molecules. The simplest kit consists of a bag of gumdrops, plastic straws, and a pair of scissors. To make larger and more robust structures, use uncoated Styrofoam "crafting" balls and wooden dowels or skewers.

Among commercial kits, the two most popular are HGS polyhedral kits and Orbit modeling kits. When looking for a kit, make sure it includes pieces able to represent trigonal, tetrahedral, trigonal bipyramidal, and octahedral geometries. ZomeTool kits, which are used for geometrical modeling, can be useful for crystal structures.

Calculator

Your calculator should be capable of exp, ln, 10^x, log, x^y, sin, and $\sin^{-1}$ functions (devices with internet, voice, or texting functions are prohibited on exams). A calculator will often be necessary for examinations.

Molecular visualization and editing software

You should own or have access to software for visualizing molecular and electronic structures. The software should be able to read a Gaussian or GAMESS output file, allow you to rotate imported structures, and append molecular orbital isosurfaces. Recommended options are GaussView, Avogadro, and MacMolPlt. (Despite its name, MacMolPlt is cross-platform.) Each can also serve as a molecular *editor*, allowing you to construct molecular structures in three dimensions, and provides a user interface to build input files for Gaussian or GAMESS jobs.

Computational chemistry software

You should own or have access to software for self-consistent-field calculations, such as energy minimization, geometry optimization, and vibrational analysis. We will mainly use Hartree-Fock methods, but density-functional and semi-empirical methods might be useful, too. Recommended options are Gaussian or GamessQ.

Background

Chemistry

This course assumes that you have taken the equivalent of one year of college-level introductory chemistry.

Mathematics

You should be comfortable with standard algebraic procedures (*e.g.*, solving for unknowns, simplifying expressions, canceling factors). You should know algebraic properties of exponents, logarithms, and powers, and be able to enter operations (including exponentiation and logarithm) on a calculator and spreadsheet.

Physics

You should be familiar with basic physical concepts (like force, energy, temperature, and waves) and unit conversions for energy. These topics are normally covered in a typical physics or advanced physical science course in high school.

Additional subjects

Students in this course tend to have widely varying backgrounds. Depending on your experiences, please expect to fill in fellow students on concepts in organic and physical chemistry, mathematics, physics, biology, and art. Conversely, be ready to learn some concepts from fellow students.

Spatial and artistic representations. A compulsive sketching habit, and obsession with perspective, is helpful in any advanced chemistry course. When creating visual representations, you should understand layers, surfaces, and transparency.

Mathematics. Knowledge of derivatives, integrals, series expansions, vectors, matrices, and geometrical relationships will be useful for several topics.

Physics. We will use concepts of electrical circuits to understand the behavior of semiconductor materials and their application to electronic devices.

Statistical analysis. In several situations you will have access to standard data or experimental results, and one way to understand these situations is to model the data and apply statistical procedures to them.

Tentative Schedule

Week	Topic	Events	Class Project
O	Course Overview	1st Day	Project Aims
1	Periodic trends		
2	Ionic bonding		
3	Covalent bonding		
4			
5	Symmetry and Spectroscopy	Exam 1 on Thur.	
6	Computational Chemistry		Methods
7			Proposals
8	Crystal structure		
9			
10	Solid-state chemistry	Exam 2 on Thur.	
11			
Break			
12	Coordination chemistry		
13			
14	Project Discussions		Discussion
Finals		*scheduled by Registrar*	Final Report

Policies

Attendance. Attendance at all class meetings is expected. Excessive, unexplained absences will result in dismissal from the course. Only the Dean of Students (not the instructor) can excuse an absence. If you must miss a class meeting, or will be late, please notify the instructor by email, or ask a friend to tell the instructor.

Etiquette. Upon arriving in class, please greet the instructor and the students sitting near you. Silence any devices you have. Maintain a respectful presence in class, and avoid disrupting or distracting fellow classmates from class activity once class begins. If circumstances require you to leave the classroom throughout the period, please seat yourself near the door so that you can exit unobtrusively. Please inform the instructor when leaving the classroom and indicate where you are going.

Classroom Space. We will move around during class, so please keep unnecessary items off the tables. Place bags and food at the back or front of the classroom; bring a notebook, pencil/pen, and computer/calculator to your seat.

Computers and tablets. If you have a computer or tablet, and don't mind sharing it, please bring it to class. You can use it to look up information as needed to facilitate discussion, record notes during group discussion, and sketch out structures or carry out calculations.

Discussion. In discussion your fellow students may not know all of the terms or notation you are using, or understand an assumption you are making, so expect occasional confusion and be ready to "back up" and explain. Conversely, be ready to gently interrupt and ask someone to explain something if you don't follow their logic, or at least use body language to indicate confusion.

Academic honesty. Please read the College's statement on Academic Honesty in the *Course of Study*, pages 26–29. Pay special attention to the definition of plagiarism and to the examples of activities that violate the standards of academic honesty. I expect you to avoid plagiarism and cheating and to avoid even the mere appearance of possible plagiarism or cheating in all of your work.

Excused absence. There are no excused absences.

Unexcused absence. There are no unexcused absences.

Discretionary absence. All absences are considered discretionary. This means that you are responsible for judging the necessity to miss class.

Extenuating circumstances. In special cases, such as an extended or serious illness that confines you to your bed (the "Dorm List"), long-term emotional distress due to bereavement, MagiKarp evolution, or other emergency situation, please inform the Dean of Students, who will notify me of your absence (while keeping the reason confidential). Afterward, consult with me and the Dean of Academic Advising to make special arrangements for completing your course work.

Late work. A late assignment is the first step in a vicious cycle of late work. If you find yourself running out of time, you may request an extension with a penalty of 20 percentage points per 24 hours after the deadline. Consult with the instructor first — never assume that late work will be accepted. If your absence is excused, consult with the instructor at least two weeks in advance to determine when you will turn in the assignment. In most cases, it will be earlier than the deadline, not later. If your absence is unplanned and excused (for illness or emergency), the Dean of Students will determine the length of the extension.

Disability services and accommodations. If you have a learning disability or other disability that impacts your ability to learn, or think that you might have one, please schedule an appointment with Disability Services *as soon as possible*. Only the Coordinator of Disability Services is authorized to review your documentation and to recommend an accommodation. All discussions with the Coordinator are confidential. The Coordinator will work with you to design an accommodation tailored to your exact situation. If your accommodation requires special testing conditions (*e.g.*, extra time, separate venue, extra breaks, assistive devices, assistive services), then you must inform me *at least two weeks in advance*. It is your responsibility arrange these conditions with the Office of Disability Services.

If your accommodation requires special testing conditions (*e.g.*, extra time, separate venue, extra breaks, assistive devices, assistive services), then you must inform me *at least two weeks in advance*. You must also plan any necessary arrangements, such as reserving a scribe, assistive device, or separate room and proctor.

Changes to syllabus. The policies articulated in this Syllabus are subject to change in response to unusual situations. You will be notified of any changes at least 48 hours before they go into effect.

Academic honesty

Please note the College's principles and policies regarding academic honesty:

> Kenyon College is, at the core, an intellectual community of scholars — students and faculty — engaged in the free and open exchange of ideas. Critical to this lively exchange and deep engagement with ideas is the academic integrity of our work, both inside and outside the classroom.
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> At Kenyon we expect all students, at all times, to submit work that represents these standards of academic integrity. It is the responsibility of each student to learn and practice the proper ways of documenting and acknowledging those whose ideas and words you have drawn upon (see *Academic Honesty and Questions of Plagiarism in the Course Catalog*). Ignorance and carelessness are not excuses for academic dishonesty. If you are uncertain about the expectations for academic honesty in a class, please ask your instructor for clarification.

Academic accommodations

Please note the College's principles and policies regarding academic accommodations:

> Students who anticipate they may need accommodations in this course because of the impact of a learning, physical, or psychological disability are encouraged to meet with their instructor privately — early in the semester — to discuss their concerns. In addition, students must contact Erin Salva, Director of Student Accessibility and Support Services (740-427-5453 or salvae@kenyon.edu), as soon as possible, to verify their eligibility for reasonable academic accommodations. Early contact will help to avoid unnecessary inconvenience and delays.
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> Only the Director of Student Accessibility and Support Services is authorized to review your documentation and to recommend an accommodation. Discussions with the Director are not shared with the instructor. The Director will work with you to design an accommodation tailored to your exact situation. If your accommodation requires special conditions or services provided by the instructor, then you must inform the instructor *at least two weeks before the service is needed.*

Compliance with Title IX of the Education Amendments Act

Please note the College's principles and policies regarding sexual misconduct:

> Kenyon College seeks to provide an environment that is free of gender bias, discrimination, and harassment. If you have been the victim of sexual harassment/misconduct/assault, interpersonal violence, or stalking we encourage you to report this. Faculty members are required by federal law to notify the College's Title IX Coordinator of any relevant information you provide. For further information, please refer to Kenyon College's Title IX and VAWA Policy:
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> http://www.kenyon.edu/directories/offices-services/title-ix/policy/

NB: Although instructors are expected to keep Journal entries in confidence, they are still bound to comply with mandatory reporting requirements.