Chemistry 351: Inorganic Chemistry (Spring 2014)

Welcome to the rest of the periodic table!

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Class Meetings: LDC 104, MWF Period 5a (MW 1:50–3:00 PM; F 2:20–3:20 PM)

Office Hours: M 10:30–11:30 AM
T 11:00–12:00 PM
F 11:00–12:00 PM
Other times by appointment (or just stop by!)

Summary
Inorganic chemistry is really such a huge area that we should be talking about "inorganic chemistries". It is the study of all compounds that don’t contain carbon as well as many that do! The goal of this course is to guide you through the organizing principles that govern the behavior of inorganic complexes and then examine the way those principles play out in a number of venues (see Outline at the end of this document).

Within this context, I have several specific goals in mind:

- To help you understand the importance and role of symmetry in governing the structure and behavior of molecules (inorganic and organic).
- To give you a framework for using group theory to organize the principles of symmetry and apply them to molecular orbital theory and spectroscopy of complex molecules.
- To introduce you to several diverse types of reactivity exhibited by metal complexes (e.g., photochemical, electrochemical, organometallic, biological) with applications in renewable energy storage, organic synthesis, and biochemistry.
- To help you gain comfort with the whole periodic table (including main group) and the trends that govern structure, bonding, and reactivity across all of the elements.

Prerequisites
Don’t leave behind what you’ve already learned! This is a highly integrative course (after all, inorganic touches on almost every other chemical sub-discipline), and we will regularly address topics that relate to organic, physical, and biochemistry.

Textbooks
Required:
A. Vincent, Molecular Symmetry and Group Theory – “Vincent”

Recommended:
D. Harris & M. Bertolucci, Symmetry and Spectroscopy (only $12 on Amazon!!) – “H&B”
Miessler & Tarr, Inorganic Chemistry (5th ed.) – “M&T”

Additional Resources:
F. A. Cotton, Chemical Applications of Group Theory – “CAGT”
F. A. Cotton, Advanced Inorganic Chemistry
J. F. Hartwig, Organotransition metal chemistry: from bonding to catalysis
Your Responsibilities
We will cover a lot of information in a short time this term (as per usual for Carleton courses), so there will be regular assignments to help you process and apply what we discuss in class.

Homework: There will be weekly (or more often) homework assignments in addition to other scheduled exams and assignments related to the critical review paper (see below). The type of assignment will change from week to week. Unless otherwise announced, these will be posted on Moodle and will be due in my office at 5:00 pm on Friday. The length of the homework assignment will typically be adjusted (at my discretion) on weeks when I require you to turn in other assignments.

Late and Corrected Homework Policy: In general, homework assignments that are turned in late will not receive any credit but will be graded for your benefit. However, you will be given 2 “passes”, which allow you to turn in an assignment by noon on the school day following the assignment due date for full credit. Additionally, you may correct and return any homework assignment within a week of receiving the graded assignment back, and the final grade you receive will be the average of your pre- and post-correction grades.

Periodic Table Quizzes: We are interested in the whole periodic table, so it is critical that you become intimately familiar with it! There will be three mid-term quizzes (worth a total of 5% of your final grade) on the periodic table.

Quiz #1 (transition metals): Monday, April 7th
Quiz #2 (groups 1/2 and main group): Monday, April 14th
Quiz #3 (everything): Monday, April 21st

Examinations: There will be two mid-term exams and a final exam. The first mid-term exam will emphasize symmetry, group theory, vibrational spectroscopy, and molecular-orbital theory; the second mid-term exam will emphasize ligand-field theory and applications of symmetry/group theory to spectroscopy. The first mid-term will be in-class, the second will be a take-home, timed exam. The final exam is not self-scheduled.

Mid-term Exam #1: Friday, April 25 (in class) [20%]
Mid-term Exam #2: May 15–18 (take-home; tentative – scheduled with class) [20%]
Final Exam: Saturday, June 7 at 3:30pm (in LDC 104) [25%]

Short Paper: Because it is impossible for us to cover the full breadth of inorganic chemistry in 10 weeks, we will have a short writing assignment (approx. 2 pages) due toward the end of the term. These will be written on an interesting application of your transition metal (to be assigned at random during the first week of class). This application can be almost anything (biological, solid-state, catalysis, medicinal, etc.), but your metal must be central and you must relate the application to the fundamental concepts we cover during the term. Details will be provided as we get closer to the end of the term.

I encourage you to discuss your topic with me in advance, as I may be able to provide some guidance and I'm very interested to hear what you are researching!

I hope that you will view this short paper as a fun opportunity to apply what you’re learning in class to a new inorganic system, as well as an opportunity to show me how much you know outside the exam or homework format.
**Grading**

Your final grade in this class is determined based on the following rubric. Please come and talk to me at any point during the term (the earlier, the better) if you have questions about your performance in the class or your grades.

- **Homework:** 20%
- **Quizzes:** 5%
- **Midterm #1 (in-class):** 20%
- **Midterm #2 (take-home):** 20%
- **Final Exam:** 25%
- **Short Paper:** 10%

**Grading Scheme**

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**Academic Honesty and Collaborative Work**

Intellectual integrity is paramount in the learning process and is central to the process of self-discovery that is at the core of a liberal-arts education. I will assume that, to the extent that other resources are not referenced, all of your graded assignments represent your own work. You can find some good general resources about academic honesty on the Carleton site: [http://apps.carleton.edu/campus/doc/honesty/](http://apps.carleton.edu/campus/doc/honesty/).

I recognize that in a course like this one, where problem solving is a key component, collaborative work is incredibly beneficial and so it can be difficult to definitively assign the origin of certain ideas to specific people or resources. I encourage collaboration on homework problems, and my policy for collaborative work on homework assignments is simple and two-fold:

1) When writing your final solution to any homework problem, you should solve the problem from beginning to end on your own without direct input from others. This will help to ensure that you understand your answers.

2) If you receive a key piece of input or advice from another student that provides an important step or key argument in your solution, please acknowledge that student’s input on the assignment. *Your grade will not be penalized in any way for this sort of acknowledgment,* but it should be helpful to you in assessing your personal strengths and weaknesses in the subject.

I will assume that all group presentations are fully collaborative and thus no acknowledgment of other members within a group is necessary, but the same policies described above apply to significant input from those not in your group.

If you are unsure about any issue related to academic integrity, please ask me.
**Academic Accommodations**
If you need accommodations based on a documented learning disability or other special need, please make me aware of this at the beginning of the term so I can take appropriate measures to facilitate your learning experience.

**Questions? Concerns?**
I will be regularly asking for your feedback about the structure and content of this course during the term, but I also encourage you to come directly to me with any questions or concerns. I want for us all to be on the same page as much as possible, and I promise you will not be penalized for questions or complaints, though I can’t promise I’ll always acquiesce to your suggestions.
Topics
The following outline provides a tentative list of the topics for this term. It is not written in stone… in fact, it probably has way more information than we can realistically cover and we're likely to move some topics around, but it will give us some guidelines. Note that the suggested readings are simply guidelines to help you know where to look for additional guidance. They are not “assigned” readings in the traditional sense.

1) Symmetry, Group Theory, and Molecular Orbital Theory
   • Symmetry operations and the symmetry of chemical compounds
   • Group theory and point groups
   • Molecular orbitals and the utility of symmetry in MO theory
   • Molecular-orbital description of metal–element and metal–metal multiple bonds
   • Suggested Reading: M&T ch. 3–5; Vincent Programmes 1–6; H&B ch. 1; CAGT ch. 1–6, 8

2) Spectroscopy of Inorganic Complexes: Taking Group Theory to the Next Level
   • Crystal-field and ligand-field theory
   • Selection rules for spectroscopic transitions (spin, electronic, and nuclear restrictions)
   • Case Studies: UV-vis, IR, and Raman spectroscopies
   • Where does the energy go? Decay of excited states by emission (fluorescence/phosphorescence), energy transfer (Förster and Dexter), and radiationless decay → introducing Jablonski diagrams
   • Suggested Reading: M&T ch. 10–11; Vincent Programmes 7,8; H&B ch. 3–5; CAGT ch. 9,10

3) Inorganic Reaction Mechanisms
   • Ligand substitution: Kinetics of associative and dissociative processes; trans influence/effect; chelate effect
   • Electrochemistry of metal complexes
   • Electron transfer: Inner- and outer-sphere processes
   • Marcus theory of electron transfer
   • The interface of photochemistry and electrochemistry: photoinduced electron transfer
   • Inorganic catalysis: Small-molecule activation and multielectron redox processes
   • Suggested Reading: M&T ch. 12; Handouts on Marcus theory and photoinduced ET

4) Introduction to Organometallic Chemistry
   • Bonding in organometallic complexes and the 18-electron “rule” – relation to MO theory
   • Organometallic reaction mechanisms
   • Organometallic catalysis: kinetics and thermodynamics
   • Case study: Cativa process for acetic acid synthesis
   • Suggested Reading: M&T ch. 13–14; Hartwig pp. 1–26, 539–548

5) A Bit of Descriptive Inorganic Chemistry
   • Looking WAY back (or don't forget gen chem!): Periodic trends and Slater's rules
   • Hard/Soft Acid/Base (HSAB) theory
   • Battle of the Century! Main Group vs. Transition Metals (… are they really so different?)
   • Case study: Descriptive chemistry of Group 14 (aka Group IVA)
   • Small-molecule activation by main group complexes: Frustrated Lewis Pairs
   • Suggested Reading: M&T ch. 6, 8; Handouts on FLPs

6) Bioinorganic Chemistry
   • Overview of metals in biological systems
   • Physical methods used for the characterization of bioinorganic systems
   • Oxygen carriers: Hemoglobin, hemerythrin, and hemocyanin
   • Oxygen-atom transfer by Cytochrome-P450
   • Suggested Reading: Handouts from Lippard and Berg ch. 11.1–2