Chemistry 104: Inorganic Chemistry, Harvey Mudd College, Spring 2020

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MWF 10 a.m., SHAN 2407
Course homepage: `sakai`
Text: *Principles of Inorganic Chemistry*, Pfennig, Wiley
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What is inorganic chemistry?

Inorganic chemistry interfaces and overlaps with the other areas of chemistry. Inorganic chemists synthesize molecules of academic and commercial interest, measure properties such as magnetism and unpaired electron spin with sophisticated instruments, study metal ion uptake in living cells, and prepare new materials like photovoltaics. Inorganic chemistry is a diverse field, and we will only be able to touch on some of the chemistry of the 118 elements that currently reside in the periodic table. The major subdisciplines of inorganic chemistry are coordination chemistry, organometallics, bioinorganic chemistry, and solid-state/materials chemistry. Inorganic chemists study the s-, p-, d- and f-block elements, reaction rates, determine reaction mechanism, and prepare new compounds. In this course, you will get a broad overview of some areas, and a more detailed study of others.

By the end of the course you will be able to…[†]

- explain the history and breadth of inorganic chemistry using the inorganic Nobel Prizes
- select and use an appropriate theory or model to describe the structure, bonding, reactivity, and physical properties of inorganic compounds
- construct qualitatively correct MO diagrams for centrosymmetric molecules
- describe MOs as $\sigma/\pi/\delta$, bonding, non-bonding or antibonding, and be able to draw them
- carry out high level quantum calculations on inorganic compounds
- describe the correspondence between qualitative and quantitative MO diagrams
- explain bonding and magnetism in transition metal complexes using MO arguments
- draw mechanisms for common inorganic/organometallic reactions
- explain why and how transition metals are used in biological systems
- describe the chemical reaction catalyzed by a metalloenzyme
- interpret spectroscopic methods (UV-Vis, Xray, NMR and IR) for inorganic compounds
- describe how the common crystalline and ionic solids are derived from simple lattices
- describe the composition of more complex solids
- explain the trends in the chemistry of the representative elements

…*if* you have the prerequisite knowledge and skills I plan to build on in the course.[‡]

[†] not all topics are taught every year; topics we won't get to this year are greyed out
[‡] this information is on today's handout

Homework will be assigned in class approximately *daily* and is due in hardcopy form at the start of the next class meeting, though they will not always be collected. I will also provide suggested practice problems for your own review. Answers to all problems will be posted on Sakai. It is in your best interest to *understand* the homework problems and their solutions.

Examination schedule. The following schedule has been coordinated with Chem 114.
Quizzes: There will be seven take-home quizzes handed out on Jan 29, Feb 7, Feb 17, Feb 26, March 25, April 6 and April 15. The quizzes will be due at the beginning of the following class period. Quizzes will mostly be problems with some short answer or multiple choice and will cover the prior 4-6 class periods. I will drop your two lowest quiz scores.
Midterms: There will be two take-home exams. The first will be handed out Friday, March 6, is due Friday, March 13 (or before you leave for spring break). The second will be handed out Friday April 24, is due Wednesday April 29. Midterm exams will be a mixture of multiple choice and problems.
Final: A cumulative in-class final exam will be given on Monday, May 11 at 9 AM. Senior finals will be arranged individually on May 7-8. The final exam will be an ACS standard exam.

A note on due dates: During the first week of the course you will have the opportunity as a class to negotiate changes to the schedule of due dates for assignments and exams. Please use this "flex week" to plan your semester and take into account your other courses with large assignments. Extensions will not be given past the first week on any assignments without medical or other serious and unavoidable conditions. Seniors may ask for extensions to accommodate graduate school visits.

Honor code policy
All students enrolled in this course are bound by the HMC Honor Code. More information on the HMC Honor Code can be found in the HMC Student Handbook. I encourage you to collaborate with other students on homework assignments (e.g., working the problem on a whiteboard together and then copying down the solution). You may not reference step-by-step solution instructions in published solution manuals. You may reference the assignments and tests of this course from previous semesters, although the direct copying of solutions from previous assignments and tests is forbidden.

Course Grade

Midterms	15%+15%	Quizzes	5%+5%+5%+5%+5% (2 dropped)		
Homework	10%	in class work	20%	Final exam	15%

A	**B**	**C**	**D**	**F**
100-85%	84-75%	74-65%	64-55%	<55%

Other factors I consider in your final grade:

- All work turned in for a grade in this course is subject to a *substantial penalty* if turned in late. Stay on top of your assignments and get them turned in on time.
- Do excellent work on homework and exams. Instead of simply answering questions, annotate your mathematical or logical reasoning with sentences and diagrams.

Teaching philosophy
I teach through a combination of lecture and small group in-class problem solving activities. I expect you to fully engage in both learning modes. Participate in class by asking or responding to questions, and contributing in an active and generous way to the in-class activities. Ask questions *early* and *often* to make sure you understand how to solve the problems in the course. My office hours are under-utilized, but the students who take advantage of them tend to do well in my class.

Attendance is important, as we do a lot of group problem solving. Unavoidable absences due to illness or travel for athletic events or graduate school visits are of course excused, but notify me *in advance*. Missing class may reduce your in-class work grade. If you miss class, it is your responsibility to check with your classmates in order to find out what happened in class. The answer to the question "did I miss anything?" is here:
http://canpoetry.library.utoronto.ca/wayman/poem5.htm

Accommodations policy: It is the policy of The Claremont Colleges to accommodate students with temporary or permanent disabilities. Any student with a documented disability who requires reasonable accommodations should contact the HMC Office of Disability Resources (ability@hmc.edu). You will find information about disability resources on the college website: https://www.hmc.edu/ability. Students from the other Claremont Colleges should contact their home college's disability officer.

Course schedule: Below is the preliminary course schedule and a list of topics (Unit I) for you to review on your own; I will assume you know this information. Unit II is on crystal field theory and magnetism. This module is first in order to support the experiments in Chem 110 and to provide justification for more advanced bonding theories. Unit III will be devoted to the development of a sophisticated description of chemical bonding for main group and coordination compounds using group theory and molecular orbital theory. Physical methods (focusing on interpretation of spectra) will be incorporated throughout the course where appropriate. Unit IV will explore organometallic chemistry, and Unit V will explore bioinorganic chemistry. Detailed reading assignments and homework will be handed out weekly. Most reading assignments are from Pfennig, but the reading for units IV and V will be handed out in class.

Unit I: Atomic structure and simple bonding theory, ***Review on your own!***

Quantum Theory (skim)	Ch. 3
Atomic Structure (skim)	Ch. 4 (not 4.5)
Simple bonding theory	Ch. 6, 7.1

Unit II: CFT and magnetism, ~9 days, Ch. 8, 9, 15, 16

Unit III: Structure and bonding in main group/coordination complexes, ~11 days, Ch. 10, 16

Unit IV: Coordination and Organometallic chemistry, ~10 days, Ch 15, 17, handouts

Unit V: Bioinorganic chemistry, ~8 days, handouts

Nobel prizes in chemistry that are inorganic or pertain to inorganic chemistry

From: http://almaz.com/nobel/chemistry/chemistry.html or http://nobelprize.org/nobel_prizes/chemistry/

2010 The prize is being awarded jointly to RICHARD F. HECK, EI-ICHI NEGISHI, and AKIRA SUZUKI for palladium-catalyzed cross couplings in organic synthesis.

2005 The prize is being awarded jointly to YVES CHAUVIN, ROBERT H. GRUBBS, and RICHARD R. SCHROCK, for the development of the metathesis method in organic synthesis.

2001 The prize is being awarded with one half jointly to: WILLIAM S. KNOWLES, and RYOJI NOYORI, for their work on chirally catalyzed hydrogenation reactions and the other half to: K. BARRY SHARPLESS for his work on chirally catalyzed oxidation reactions.

1996 The prize was awarded jointly to: ROBERT F. CURL, Jr. , SIR HAROLD W. KROTO , and RICHARD E. SMALLEY for their discovery of fullerenes.

1995 The prize was awarded jointly to: PAUL CRUTZEN , MARIO MOLINA , and F. SHERWOOD ROWLAND for their work in atmospheric chemistry, particularly concerning the formation and decomposition of ozone.

1992 RUDOLPH A. MARCUS for his contributions to the theory of electron transfer reactions in chemical systems.

1985 The prize was awarded jointly to: HERBERT A. HAUPTMAN and JEROME KARLE for their outstanding achievements in the development of direct methods for the determination of crystal structures.

1983 HENRY TAUBE for his work on the mechanisms of electron transfer reactions, especially in metal complexes.

1981 The prize was awarded jointly to: KENICHI FUKUI and ROALD HOFFMANN for their theories, developed independently, concerning the course of chemical reactions.

1979 The prize was divided equally between: HERBERT C. BROWN and GEORG WITTIG for their development of the use of boron- and phosphorus-containing compounds, respectively, into important reagents in organic synthesis.

1976 WILLIAM N. LIPSCOMB for his studies on the structure of boranes illuminating problems of chemical bonding.

1973 The prize was divided equally between: ERNST OTTO FISCHER and SIR GEOFFREY WILKINSON for their pioneering work, performed independently, on the chemistry of the organometallic, so called sandwich compounds.

1963 The prize was divided equally between: KARL ZIEGLER and GIULIO NATTA for their discoveries in the field of the chemistry and technology of high polymers.

1944 OTTO HAHN for his discovery of the fission of heavy nuclei.

1935 The prize was awarded jointly to: FRÉDÉRIC JOLIOT and IRÈNE JOLIOT-CURIE in recognition of their synthesis of new radioactive elements.

1931 The prize was awarded jointly to: CARL BOSCH and FRIEDRICH BERGIUS in recognition of their contributions to the invention and development of chemical high pressure methods.

1922 FRANCIS WILLIAM ASTON for his discovery, by means of his mass spectrograph, of isotopes, in a large number of non-radioactive elements, and for his enunciation of the whole-number rule.

1921 FREDERICK SODDY , for his contributions to our knowledge of the chemistry of radioactive substances, and his investigations into the origin and nature of isotopes.

1918 FRITZ HABER for the synthesis of ammonia from its elements.

1913 ALFRED WERNER in recognition of his work on the linkage of atoms in molecules by which he has thrown new light on earlier investigations and opened up new fields of research especially in inorganic chemistry.

1912 The prize was divided equally between: VICTOR GRIGNARD for the discovery of the so-called Grignard reagent, which in recent years has greatly advanced the progress of organic chemistry and PAUL SABATIER for his method of hydrogenating organic compounds in the presence of finely disintegrated metals whereby the progress of organic chemistry has been greatly advanced in recent years.

1911 MARIE CURIE, née Marie Sklodowska, in recognition of her services to the advancement of chemistry by the discovery of the elements radium and polonium, by the isolation of radium and the study of the nature and compounds of this remarkable element.

1906 HENRI MOISSAN in recognition of the great services rendered by him in his investigation and isolation of the element fluorine, and for the adoption in the service of science of the electric furnace called after him.

1904 SIR WILLIAM RAMSAY in recognition of his services in the discovery of the inert gaseous elements in air, and his determination of their place in the periodic system.

1903 SVANTE AUGUST ARRHENIUS in recognition of the extraordinary services he has rendered to the advancement of chemistry by his electrolytic theory of dissociation