Chemistry 508: Advanced Bioinorganic Chemistry

Professor: Nicolai Lehnert; 2807 Chem
Office Hours: appointment only, email: lehnertn@umich.edu, phone: 615-3673
Class Hours: Monday, Wednesday, Friday: noon – 1 pm, **2642 CHEM** (note new location)

No.	Topic	Remarks	Literature [a]
Jan 07	Introduction and topic distribution. Review: Ligand Field Theory 01	Class discussion	Inorganic textbook, CHEM 507
Jan 09	Review: Ligand Field Theory 02	Class discussion	
Jan 12	Review: Ligand Field Theory 03	Class discussion	
Jan 14	Review: MO Theory 01	Class discussion	
Jan 16	Review: MO Theory 02	Class discussion	
Jan 19	Martin Luther King Day: no classes		
Jan 21	Electronic Absorption Spectroscopy	Class discussion	**Textbook: Que, chapter 1**
Jan 23	Molecular Vibrations	Class discussion	**Textbook: Que, chapter 2**
Jan 26	Aldehyde Decarbonylase 01	**Guest lecture**: Prof. Neil Marsh	Guest lectures take place in **1624 CHEM**
Jan 28	Aldehyde Decarbonylase 02		
Jan 30	Metal Homeostasis:	**Guest lecture**: Prof. Jim Penner-Hahn	
Feb 02	Electron Paramagnetic Resonance Spectroscopy	Class discussion	**Textbook: Que, chapter 3**
Feb 04	Mononuclear non-heme iron enzymes 01: Rieske dioxygenases (**Casey**)	Soil decontamination	**Karlsson, *Science* 2003, 1039**; Ferraro, *BBRC* 2005, 175; **Feng, *Chem. Commun.* 2009, 50**; Barry, *ACS Cat.* 2013, 2362
Feb 06	Mononuclear non-heme iron enzymes 02: α-ketoglutarate dependent dioxygenases (**Nicolai**)	Mossbauer Spectroscopy	**Price, *JACS* 2003, 13008**; Price, *Biochemistry* 2003, 7497; **Proshlyakov, *JACS* 2004, 1022**; Solomon, *Acc. Chem. Res.* 2013, 2725
Feb 09	Dinuclear non-heme iron enzymes 03: Methane monooxygenase (**Jim**)	Non-heme Fe(IV)=O complexes	**Shu, *Science* 1997, 515**; Que, *Acc. Chem. Res.* 2007, 493; **Xue, *Nat. Chem.* 2010, 586**; Friedle, *Chem. Soc. Rev.* 2010, 2768
Feb 11	Cytochrome P450s: mechanism and intermediates (**Andrew**)	Thermodynamics of H-atom abstraction (Warren, *Chem. Rev.* 2010, 6961)	**Riddle, *Science* 2010, 933**; Yosca, *Science* 2013, 825; **McQuarters, *Angew. Chem.* 2014, 4750**; Shaik, *Chem. Rev.* 2010, 949
Feb 13	Cytochrome P450s: applications in biocatalysis (**Hang**)		Julsing, *Curr. Op. Chem. Biol.* 2008, 177; Podust, *NPR* 2012, 1251; **Coelho, *Science* 2013, 307**; Hansen, *JACS* 2013, 11232; **Negretti, *JACS* 2014, 4901**
Feb 16	Catalases and peroxidases (for general information on these enzymes, see reviews: Nicholls, *Adv. Inorg. Chem.* 2001, 51; Veitch, *Adv. Inorg. Chem.* 2001, 107) (**Jessica**)	Compounds I/II with different axial ligation: properties and reactivity	**Berglund, *Nature* 2002, 463**; Watanabe, *Acc. Chem. Res.* 2007, 554; **Zeng, *JACS* 2008, 1816**; de Visser, *Chem. Eur. J.* 2009, 5577; Matsuo, *Chem. Asian J.* 2011, 2491
Feb 18	Cytochrome *c* oxidase (**Ana**)	Protein design 01	**Michel, *PNAS* 1998, 12819**; **Yoshikawa, *Science* 1998, 1723**; Collman, *Science* 2007, 1565; **Ueno, *Angew. Chem.* 2010, 3868**; Miner, *Angew. Chem.* 2012, 5589
Feb 20	Activated bleomycin: an anticancer drug (**Chris**)	Metal-based drugs	Burger, *Chem. Rev.* 1998, 1153; **Decker, *JACS* 2006, 4719**; Liu, PNAS 2010, 22419; Solomon, *Acc. Chem. Res.* 2013, 2725

	Topic	Concepts	Literature
Feb 23	Mononuclear copper oxygenases		Prigge, *Science*, 1997, 1300; **Chen, *PNAS* 2004, 13105**; Yoshizawa, *Inorg. Chem.* 2006, 3034; Wuertele, *Angew. Chem.* 2006, 3867; **Chufan, *JACS* 2010, 15565**
Feb 25	Multinuclear copper oxidases	Magnetic circular dichroism spectroscopy	Hakulinen, *NSB* 2002, 601; **Taylor, *PNAS* 2005, 15459**; Yoon, *JACS* 2007, 13127; Solomon, *Dalton Trans.*, 2008, 3921; **Heppner, *JACS* 2013, 12212**
Feb 27	EXAM 01		
Mar 09	Superoxide Dismutases	Neurodegenerative diseases	Strange, *JMB* 2003, 877; Elam, *NSB* 2003, 461; **Miller, *Cur. Op. Chem. Biol.* 2004, 162**; **Jackson, *Acc. Chem. Res.* 2004, 461**; Rakhit, *BBA* 2006, 1025
Mar 11	Electron Transfer 01: blue copper	Protein design 02	**Solomon, *Inorg. Chem.* 2006, 8012**; **Marshall, *Nature* 2009, 113**; Lancaster, *Nat. Chem.* 2009, 711; Lancaster, *Struct. Bond.* 2012, 199
Mar 13	Electron Transfer 02: iron-sulfur cluster (**Katie**)	Catalytic 4Fe4S cluster	Fukuyama, JMB 2002, 1155; Bertini, PRM 2003, 272; **Koay, *Biodiversity* 2008, 1571**; **Gerlach, EJIC 2013, 5253**; Wang, *Angew. Chem.* 2014, 4294
Mar 16	Electron Transfer 03: Cytochrome *c*	Apoptosis	Bowman, *NPR* 2008, 1118; **Liptak, *JACS* 2010, 9753**; Bradley, *JACS* 2011, 19676; **Balakrishnan, *JACS* 2012, 19061**
Mar 18	Carbon Monoxide: heme metabolism and signaling (general overview of heme gas sensors: Aono, *Dalton Trans.* 2008, 3137)	Heme-based gas sensors	Roberts_*JIB* 2005, 280; **Clark, *PNAS* 2006, 891**; **Matsui, *Inorg. Chem.* 2010, 3602**; Ibrahim, *JIB* 2007, 1776
Mar 20	Nitrogen Cycle 01: assimilation, denitrification, nitrogen fixation (**Nicolai**)		**Richardson, *Curr. Op. Chem. Biol.* 1999, 207**; Moura, *Curr. Op. Chem. Biol.* 2001, 168; Cabello, *MB* 2004, 3527; **Jetten, *EM* 2008, 2903**; Maia, *Chem. Rev.* 2014, 5273, Chapter 2.1
Mar 23	Nitrogen Cycle: 02: nitrogen fixation by nitrogenase	Biological and synthetic nitrogen fixation	**Yandulov, *Science* 2003, 76**; Studt, *Angew. Chem.* 2005, 5639; **Spatzal, *Science* 2011, 940**; Anderson, *Nature* 2013, 84; **Scott, *JACS* 2014, 15942**
Mar 25	Nitrogen Cycle 03: the assimilatory pathway, assimilatory sulfite and nitrite reductase (overview: Crane, *Curr. Op. Chem. Biol.* 1996, 744)	The marriage of hemes and 4Fe4S clusters	**Zhou, *Inorg. Chem.* 1996, 2767**; Crane, *Biochemistry* 1997, 12101 & 12120; Parey, *Biochemistry* 2010, 8912; **Smith, *Biochemistry* 2012, 9857**
Mar 27	Nitrogen Cycle 04: denitrification, nitric oxide reductases in bacteria		**Hino, *Science*, 2010, 1666**; **Speelman, *Acc. Chem. Res.* 2014, 1106**; Matsumura, *JACS* 2014, 2420; Berto, *Inorg. Chem.* 2014, 6394
Mar 30	Nitric Oxide 01: NO production by NOS	Cyt. P450 mechanistic variations	Woodward, *JACS* 2009, 297; **Gusarov, *Science* 2009, 1380**; Sudhamsu, *Cell* 2009, 212; **Lehnert, *PorphyrinHB*, 2011, Chapter II.A.1**; Smith, *Biochemistry* 2012, 1028

	Topic	Concepts	Literature
Apr 01	Nitric Oxide 02: NO-based signaling by soluble guanylate cyclase	The trans effect of NO	Dierks, *JACS* 1997, 7316; **Cary, *TRENDS*, 2006, 231**; Lehnert, *Inorg. Chem.* 2010, 7197; **Herzik, *PNAS* 2014, E4156**; Campbell, *PNAS* 2014, 2960
Apr 03	Nitric Oxide 03: NO and iron-sulfur sites (DNICs)	Alternative NO sensors	**Ye, *JACS* 2010, 3646**; Tinberg, *JACS* 2010, 18168; Lo, *Chem. Eur. J.* 2012, 2565; **Victor, *Inorg. Chem.* 2014, 5311**; Fitzpatrick, *JACS* 2014, 7229
Apr 06	**Students' choice.** Cytochrome P450s: the role of the second coordination sphere (**Andrew**)	Resonance Raman Spectroscopy	Yoshioka, *JACS* 2002, 14571; Dey, *JACS* 2005, 12046; **Galinato, *Biochemistry* 2011, 1053**; **Mak, *Angew. Chem.* 2012, 10403**; Yang, *Biochemistry* 2014, 5080
Apr 08	**Students' choice.** Nitrogen Cycle 05: denitrification, copper nitrite reductase (**Casey**)	Low-temperature crystal structures versus room temperature reactions	**Tocheva, *Science* 2004, 867**; Kujime, *Angew. Chem.* 2006, 1089; Fujisawa, *JACS* 2008, 1205; **Ghosh, *JACS* 2009, 277**; Merkle, *Dalton Trans.* 2012, 3355
Apr 10	**Students Choice.** Nitric Oxide 04: flavodiiron proteins, mechanism of NO resistance in pathogens (**Jim**)		**Kurtz, *Dalton* 2007, 4115**; **Hayashi, *JACS* 2012, 6878**; **Zeng, *JACS* 2013, 4902**; Speelman, *Angew. Chem.* 2013, 12283; Caranto, *JACS* 2014, 7981
Apr 13	Students' choice		
Apr 15	Students' choice		
Apr 17	Students' choice		
Apr 20	Students' choice		

Please note: **Papers printed in bold will be read by every student in preparation for class**. This is necessary in order to have an in-depth discussion about the topic in class. The other references are for the student presenting the topic. These provide some more background and also highlight other interesting aspects of the topic that could potentially be used for the presentation.

Prerequisites for undergraduate students: CHEM 302 or CHEM 303

Course Requirements: Your grade will be based on the oral presentations in class and participation in the discussions in class, and two exams.

Oral class presentation	50% of final grade
Participation in class	20 % of final grade
Midterm Exam (see below)	10% of final grade
Final Exam (see below)	20% of final grade

Extra Credit: students who are extraordinarily active in the discussions in class, who are well prepared, and who bring good questions to class will receive up to 10 % extra credit for participation.

Exams: Midterm Exam: Feb. 27, held during class time (50 minutes)
Final Exam: TBA, held in Finals Week (2 hours)

PLEASE NOTE: If you will not be able to attend any exam ***for any reason,*** you must notify Professor Lehnert ***before*** the exam takes place. You will *not* be able to take a make-up exam unless this policy is followed.

Oral presentations in class:

The oral class presentations will be given on the topics listed above in the syllabus. Topics will be divided up in the first week of class. Each student will present a topic about every 2 - 3 weeks. In return, there are no graded homework assignments, and there are no quizzes in class. Besides the oral presentations, students are required to prepare for class by reading the material listed in the syllabus in bold print. The other references provide a broader basis for the topic, so the presenting student has sufficient material to choose from for his/her presentation.

The presentations are 25 minutes long and will be given in class. These presentations will form the basis to discuss a given topic. Presentations need to be given using powerpoint or an equivalent program. The grade given for the oral presentations will be based on the scientific quality of the presentation (level of depth and understanding at which the topic is presented), the clarity of the presentations, and the ability of the presenting student to answer questions. This is the core of the class, and constitutes 70% of the final grade (presentations and participation in discussions) with the possibility to earn another 10% of extra credit for students who are particularly active in discussions.

Textbook:

1. **Gray, Stiefel, Valentine & Bertini, editors, "Biological Inorganic Chemistry: Structure and Reactivity", University Science Books, 2006**

Other resources:

2. Spectroscopy: Que (editor), "Physical Methods in Bioinorganic Chemistry", University Science Books, 2000 (available in the SLC)
3. Inorganic Chemistry textbooks, for example:
    a. Shriver & Atkins, "Inorganic Chemistry", 5th edition, Oxford University Press, 2010
    b. Miessler & Tarr, "Inorganic Chemistry", 5th edition, Prentice Hall, 2013 (available in the SLC)
4. Biochemistry textbooks, for example:
    a. Berg, Stryer & Tymoczko, "Biochemistry", W. H. Freeman, 2006
    b. Garrett & Grisham, "Biochemistry", Brooks Cole, 2008
    c. Mathews, van Holde & Ahern, "Biochemistry", Prentice Hall, 1999
    d. McKee & McKee, "Biochemistry: The Molecular Basis of Life", Oxford University Press, 2008
    e. Nelson & Cox, "Lehninger Principles of Biochemistry", W. H. Freeman, 2008
    f. Voet, Voet & Pratt, "Fundamentals of Biochemistry", John Wiley, 2008

Course Reserve: references are available in CTOOLS

Note about Grievance:

Departmental policy indicates the first step in inquiring about the accuracy of a final grade should be directed to the lead instructor of the course. This initial inquiry should take place within the first fifteen University business days of the first full term following the term in which the disputed grade was issued. If, after this inquiry, the student is not satisfied with the instructor's response, the student may choose to initiate a formal grade grievance. To initiate a formal grade grievance, the student should contact the Associate Chair of Undergraduate Studies (ACUS) of the home department of the course in question before the end of the fifth week of classes in the first full term following the term in which the disputed grade was issued.