Chemistry 303: The Role of Metals in Life – Introduction to Bioinorganic Chemistry

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Office Hours (virtual): Tuesday, 11 am – noon, Thursday, 2 – 3 pm
Class Hours (**in person**): Monday, Wednesday, Friday: 12:00 – 1:00 pm, 1210 CHEM

	Topic	Concepts	Literature [a]
Aug. 31	Brief introduction to biomolecules: amino acids, proteins	Protein structure and folding, dynamics	Introductory textbooks to biochemistry
Sept. 02	Brief introduction to biomolecules (cont.): nucleic acids, DNA and RNA, cofactors		Introductory textbooks to biochemistry
Sept. 04	Functions of metals in cells: metalloproteins: classification according to metals, function (molecular transport, catalysis, electron transfer, signaling), and cofactors		C, Chapter 1; GSVB, Chapter IV
Sept. 09	Functions of metals in cells (cont.): gene transcription, regulation of cell function, etc.		C, Chapter 11 (Ca^{2+}); GSVB, Chapters XIV.1/2
Sept. 11	Introduction to inorganic chemistry: Group Theory: Symmetry elements and operations		MT, Chapter 4
Sept. 14	Group Theory (cont.): point groups, character tables		MT, Chapter 4
Sept. 16	Properties of transition metals: Metal oxidation and spin states, d-orbitals, octahedral complexes, high- and low-spin	Ligand Field Theory	MT, Chapter 9; C, Chapter 2
Sept. 18	Properties of transition metals (cont.): the coordinative bond, simple molecular orbital diagrams	MO Theory	MT, Chapters 5 and 10
Sept. 21	MO Theory of transition metal complexes	Types of metal-ligand bonds	MT, Chapter 10
Sept. 23	MO Theory of transition metal complexes (cont.)		
Sept. 25	Acid-Base Chemistry	Hard and soft acids and bases	MT, Chapter 6
Sept. 28	Iron homeostasis: uptake and transport by transferrin in humans, transfer into cells		C, Chapter 8; GSVB, Chapters V and VIII.1
Sept. 30	Iron Storage: ferritin - nanoparticles in your body! Iron metabolism and bacterial infection: siderophores	Quantum dots, absorption spectroscopy	C, Chapter 7, GSVB, Chapters V and VIII.2
Oct. 02	Iron metabolism and bacterial infection (cont.), thermodynamics and kinetics of ligand binding	Chemical equilibrium, Arrhenius equation	C, Chapter 13; GSVB, Chapter VIII.3; Berg, Biochemistry, Chapter 7, and GSVB, Chapter XI.4
Oct. 05	Understanding the importance of iron: dioxygen transport by red blood cells, hemoglobin, myoglobin	Hydrogen bonds	
Oct. 07	Understanding the importance of iron (cont.)	Cooperativity	C, Chapter 13
Oct. 09	Iron (cont.): other O_2 carriers, diseases related to insufficient/inflated iron uptake: anemia and hemochromatosis	What are genetic diseases?	
Oct. 12	Red blood cells (cont.): sickle cell anemia and malaria: the 'ethnicity' of genetic diseases as a response to the environment		Berg, Biochemistry, Chapter 7
Oct. 14	Inorganic Reaction Mechanisms: Associative and dissociative ligand substitution, associated kinetics	Kinetics	MT, Chapter 12
Oct. 16	The cytochrome P450 enzyme family - nature's blow torch: structure and molecular mechanism		C, Chapter 13; GSVB, Chapter XI.5.1
Oct. 19*	Cytochrome P450 (cont.): drug metabolism, biosynthesis of steroids Iron proteins for electron transfer: iron-sulfur proteins, types of iron-sulfur cluster	What is a cluster?	GSVB, Chapter X.1 C, Chapter 13
Oct. 21	Electron transfer in biology: the respiratory chain	Electron tunneling in proteins	C, Chapter 13; McKee, Biochemistry, Chapter 10 and GSVB, Chapters XI.6 and XI.8
Oct. 23	Powering the cell: cytochrome c oxidase - mechanism and intermediates		

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Oct. 26	Heavy metal poisoning: historical overview; Lead: source, uptake and toxicity of lead, the 'sociology' of heavy metal poisoning. Mercury: source and toxicity, the Minamata disease, Hunter-Russell syndrome		C, Chapter 23; GSVB, Chapters XIV.2.3.2 and VIII.4; Reading: 'Getting the Lead out'
Oct. 28	Photosynthesis: light harvesting by plants, production of biomass from CO_2 and oxidation of water		McKee, Biochemistry, Chapter 10
Oct. 30	Photosynthesis (cont.): mechanisms of energy transfer and charge separation	Electron transfer and charge separation, life time of excited states	C, Chapter 10; McKee, Biochemistry, Chapter 10
Nov. 02	Oxygen evolving complex (OEC): synthetic models for hydrogen fuel cells		C, Chapter 16; GSVB, Chapter X.4
Nov. 04	Nitric oxide as a signaling molecule: nitric oxide production in biology		GSVB, Chapter XIV.4
Nov. 06	Nitric oxide as a signaling molecule: nitric oxide sensing		GSVB, Chapter XIV.4
Nov. 09	Copper: homeostasis and storage, Menkes' and Wilson's disease		C, Chapter 14; GSVB, Chapters VIII.5, VIII.6 and X.1
Nov. 11	Important copper proteins: blue copper proteins, Marcus theory for electron transfer	Entatic state	
Nov. 13	Important copper proteins (cont.): monooxygenases, Cu-Zn superoxide dismutase	Oxidative stress in cells	
Nov. 16	Zinc: hydrolytic zinc enzymes, carbonic anhydrase	Polarization of bound water: activation of ligands	C, Chapter 12; GSVB, Chapters IX.1.3 and IX.2.4; Reading: 'All I could do was stand in the Woods'
Nov. 18	Zinc (cont.): β-lactamases as bacterial defenses against penicillin antibiotics		C, Chapter 12
Nov. 20	Bioorganometallic chemistry - metal-carbon bonds in proteins: cobalamins	Organometallic chemistry	C, Chapter 15; GSVB, Chapter XIII.2
Nov. 30	Bioorganometallic chemistry (cont.): Acetyl-CoA synthase, nickel-dependent methane generation Biological catalysis as role model for industrial processes: (a) the hydrogen economy (solar energy, hydrogen generation, fuel cells)	Fuel cells and electrochemistry	C, Chapter 15; GSVB., Chapter XII.1
Dec. 02	Hydrogenases (cont.): biological production of hydrogen, synthetic models	CO as a vibrational probe	C, Chapter 15
Dec. 04	Biological catalysis as role model for industrial processes: (b) oxidation of methane by methane monooxygenase	Non-heme iron enzymes	C, Chapter 13; GSVB, Chapter XI.5.1
Dec. 07	Biological catalysis as role model for industrial processes: (c) biodegradation of aromatics (benzene, toluene, etc.) for soil decontamination: Rieske-type dioxygenases	Biotechnology	C, Chapter 13; GSVB, Chapter XI.5.2

[a] MT = Miessler & Tarr, "Inorganic Chemistry"; C = Crichton, "Biological Inorganic Chemistry"; GSVB = Gray, Stiefel, Valentine & Bertini, "Biological Inorganic Chemistry: Structure and Reactivity"

Format and note about COVID-19 safety measures:

CHEM 303 is a hybrid course. Lectures will be held in person in lecture hall 1210 CHEM. In all LS&A classrooms all students are expected to adhere to the required safety measures and guidelines of the State of Michigan and the University of Michigan, including sanitizing their work areas, maintaining 6 feet or more of personal distance, wearing a face covering that covers the mouth and nose in all public spaces, and not coming to class when ill or in quarantine. This course will also limit group gatherings while being thoughtful about classroom activities and exercises that require collaboration. Most importantly: **a mask is required at all times when attending lecture.**

Any student who is not able and willing to comply with campus safety measures for this hybrid course should take advantage of the asynchronous learning opportunities:

(a) All lectures will be life streamed and also recorded as they are held, and then made available through Canvas later, so they can be watched synchronously and/or asynchronously;
(b) All powerpoint slides used during lecture will be made available through Canvas;
(c) All Discussion sections are held virtually/online;
(d) Homework sets will be done at home and turned in electronically (to the GSI);
(e) The course paper is written at home, and turned in electronically.

Students who do not adhere to these safety measures while in a face-to-face class setting, and do not have an approved exception or accommodation, will be asked to leave the class room and can ultimately be disenrolled from the class.

Prerequisites: the same as for CHEM 302 (CHEM 210/211, 215/216)

Course Requirements: Your grade will be based on the homework and the exams.

Two Exams (online/virtual)	40% of final grade
Final Exam (online/virtual)	20% of final grade
Homework	10% of final grade
Paper	30% of final grade

Exams: Exam 01: Tuesday, Oct. 06, 7 – 9 pm, location: online (Canvas), timed.
Exam 02: Tuesday, Nov. 17, 7 – 9 pm, location: online (Canvas), timed.
Final Exam: Tuesday, Dec. 15, 10.30 am – 12.30 pm, location: online (Canvas), timed.

PLEASE NOTE:
All exams are open notes, but no outside help is allowed. The College promotes the assumption of personal responsibility and integrity, and prohibits all forms of academic dishonesty and misconduct. All cases of academic misconduct will be referred to the LSA Office of the Assistant Dean for Undergraduate Education. Being found responsible for academic misconduct will usually result in a grade sanction, in addition to any sanction from the college. For more information, including examples of behaviors that are considered academic misconduct and potential sanctions, please see lsa.umich.edu/lsa/academics/academic-integrity.html

If you will not be able to attend any exam at the specified time ***for any reason*****,** you must notify Professor Lehnert ***before*** the exam takes place, and we can make accommodations. You will *not* be able to take the exam at a different time unless this policy is followed.

Paper:

The paper can be written by a single student or in groups of 2 students. The topics for the papers will be distributed in the beginning of the class (per separate handout), towards the middle of September. Each topic is represented by a small selection of research publications (usually 3 – 4) of a participating faculty from the University of Michigan. Hence, *the paper will be written on a topic that is currently actively researched on campus*. The style of the paper is a focused review. The topics that we hand out are very broad, and students are encouraged to focus their paper on a certain aspect of the topic, like enzyme structure & function, model systems, or medicinal aspects (depending on the topic).

You will first read the publications, and then meet with the corresponding faculty to have questions answered about the papers (technical aspects, general significance, etc.), and discuss the content of the publications in detail. This is also a good opportunity to obtain more general background knowledge about the topic of your paper.

The paper is expected to be at least 8 pages long (single student) or 12 pages long (groups of 2 students) **plus** citations (citations are not included in these page requirements), 12pt Times New Roman, 1.5pt line spacing, 1'' page margins. Make sure to include figures to illustrate protein structures, reaction mechanisms, important data, other complicated aspects, etc. You can take figures from the original sources, and then indicate the source in the figure caption.

We will also provide an online workshop on how to write a scientific paper. Details will be disseminated during class.

IMPORTANT DATES:

Sept. 28: topic selection forms due (please hand in one per group)
Oct. 02: topics will be distributed (assigned) to the different groups
Oct. 23: outline of the paper due
Nov. 30: paper due (and faculty signature)

PLEASE NOTE: meeting (virtual) with the corresponding faculty is mandatory. Please make sure to have either met with the faculty or at least have emailed the faculty to set up a meeting *by Oct. 23*.

Papers turned in late without prior authorization will be rejected, resulting in 0 points. Remember that the paper determines 30% of your final grade, so the paper is very important!

Discussions:

Besides office hours with Prof. Lehnert, the GSI for the class, Lizzie Manickas, will offer online/virtual Discussion Sessions every week. Here, challenging concepts will be discussed (using problem sets) in more detail, for example: group theory, ligand field theory, MO theory, inorganic reaction mechanisms, electrochemistry, and NMR spectroscopy. There will also be review sessions in Discussions prior to every exam. **In addition, 8 graded homework sets will be distributed over the course of the class.** The homework sets account for 10% of your final grade. If you fail to turn in a homework set at the due date there will be **no** opportunity for a make-up set.

Textbooks:

Required: Crichton, "Biological Inorganic Chemistry", 2nd edition, Elsevier, 2012

Recommended: Miessler & Tarr, "Inorganic Chemistry", 5th/6th edition, Prentice Hall, 2013 (also available in the SLC)

Other resources:

1. Gray, Stiefel, Valentine & Bertini, "Biological Inorganic Chemistry: Structure and Reactivity", University Science Books, 2006 (available in the SLC)

2. Biochemistry textbook, optional:
    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: Handouts and Readings, Powerpoints used during class, homework sets, etc. are available via **Canvas** (**please check frequently!!**).

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.