Molecular Modeling

The University of Toledo
Department of Chemistry and Biochemistry
(CHEM 6730/8730, Section 001)

Instructor:	Xiche Hu	**Offered**:	Fall 2021
Email:	xhu@utoledo.edu	**Course Website**:	Blackboard Learn
Office Hours:	MW 11:00 AM - 12:00 noon	**Class Location**:	Bowman Oddy 2059
Office Location:	Wolfe Hall 2277	**Class Day/Time**:	MW 5:30 to 7:20 PM
Instructor Phone:	(419)530-1513	**Credit Hours**:	4

CATALOG/COURSE DESCRIPTION

Theory and techniques of contemporary molecular modeling, and their application to calculate physical and chemical properties of realistic molecular systems.

Web site **https://blackboard.utdl.edu**

SPECIAL COURSE EXPECTATIONS DURING COVID-19

Maintaining a safe campus during the ongoing COVID-19 pandemic remains a top priority. UToledo continues to follow the guidance of the U.S. Centers for Disease Control and Prevention and Ohio Department of Health to keep our campus safe.

ATTENDANCE

The University of Toledo has a missed class policy. It is important that students and instructors discuss attendance requirements for the course. Before coming to campus each day, students should take their temperature and complete a self-assessment for symptoms of COVID-19, such as cough, chills, fatigue or shortness of breath. Anyone with a temperature at or above 100.0 degrees Fahrenheit or who is experiencing symptoms consistent with COVID-19 should not come to campus and contact their primary care physician or the University Health Center at 419.530.5549. For more information on the symptoms of COVID-19, please go to https://www.cdc.gov/coronavirus/2019-ncov/symptoms-testing/symptoms.html

COVID-19 testing for sick students is available on both Main Campus and Health Science Campus. Call 419.383.4545 for an appointment. Absences due to COVID-19 quarantine or isolation requirements **are** considered excused absences. Students should notify their instructors and follow the protocols summarized in this document on Navigating COVID-Related Course Concerns.

In the event that you have tested positive for COVID-19 or have been diagnosed as a probable case, please review the CDC guidance on self-isolation and symptom monitoring, and report the disclosure to the Division of Student Affairs by emailing StudentAffairs@utoledo.edu or by connecting with their on-call representative at 419.343.9946. Disclosure is voluntary and will only be shared on a need to know basis with staff such as in the Office of Student Advocacy and Support, The Office of Residence Life, and/or the Office of Accessibility and Disability Resources to coordinate supportive measures and meet contact tracing requirements.

FACE COVERINGS

Face coverings are required while on campus, except while eating, alone in an enclosed space, or outdoors

practicing social distancing. Students will not be permitted in class without a face covering. If you have a medical reason preventing you from wearing a face covering due to a health condition deemed high-risk by the CDC, submit an online application to request an accommodation through the Office of Accessibility and Disability Resources. Students will need to provide documentation that verifies their health condition or disability and supports the need for accommodations. Students already affiliated with the Office of Accessibility and Disability Resources who would like to request additional accommodations due to the impact of COVID-19, should contact their accessibility specialist to discuss their specific needs. You may connect with the office by calling 419.530.4981 or sending an email to StudentDisability@utoledo.edu.

VACCINATION

Doctors and other health care professionals agree that the best way to protect ourselves and each other is to get vaccinated. Case data clearly show that vaccines remain highly effective at preventing serious illness from COVID, including the highly contagious delta variant. If you have not yet received your COVID vaccine, the University encourages you do so as soon as possible. No appointment is needed to get the shot at the UTMC Outpatient Pharmacy, University Health Clinic or Main Campus Pharmacy. Once you receive the COVID vaccination, please register on the COVID Vaccine Registry site at: https://utvaccinereg.utoledo.edu/.

SPECIAL NOTES

It's important to note, that based on the unpredictability of the COVID-19 virus, things can change at any time. So please be patient and understanding as we move through the semester. I also ask that you keep me informed of concerns you may have about class, completing course work/assignments timely and/or health concerns related to COVID.

COURSE OVERVIEW

In this course, students will learn both theory and techniques of molecular modeling and computational chemistry, and their application to calculate physical and chemical properties of realistic molecular systems.

STUDENTS LEARBNING OUTCOMES

The objective is to provide students with an understanding of the methods, capabilities, and limitations of molecular simulation. This should enable students to: (1) make a sound judgment regarding the quality of molecular simulation studies reported in the literature; (2) decide whether molecular simulation is suited for application to their research, and if so, to know how to begin developing a simulation program applicable to their problems; (3) understand the workings and limitations of commercial molecular simulation software. Further, it is expected that completion of this course will lead student to a deeper understanding of the molecular basis of physical behavior.

To accomplish these goals, experiments have been designed that will:

- illustrate the use of computational chemistry and molecular modeling as applied to modern problems in organic, biochemical, physical, analytical and inorganic chemistry
- allow students to gain technical proficiency with state-of-the-art computational chemistry software (Spartan, WebMo/Gaussian, Chem3D, VMD, AutoDock).
- allow students to choose an independent project in which they will apply the techniques learned in the course to computationally simulate a system of interest. The topic may be related to an ongoing research project, or based on a journal article or a textbook example, or something you always wanted to know.

REQUIRED TEXTS AND ANCILLARY MATERIALS

Reference Books

- Essentials of Computational Chemistry, 2nd Ed., C. Cramer, 2004
- Molecular Modeling – Principles and Applications, 2nd Ed., A. R. Leach, 2001

- Introduction to Computational Chemistry, 2nd Ed., F. Jensen, 2007
- Molecular Modeling Basics, J. Jensen, 2010
- Computer Simulation of Liquids, M. P. Allen & D. J. Tildesley, 1987
- Understanding Molecular Simulation, D. Frenkel & B. Smit, 2002
- Exploring Chemistry with Electronic Structure Methods, J. B. Foresman and A. Frisch (Gaussian Inc.)
- A Handbook of Computational Chemistry: A Practical Guide to Chemical Structure and Energy Calculations, Tim Clark, 1985

COURSE STRUCTURE AND GRADING

The course will consist of lectures and hands-on computational labs. There will be one midterm, multiple quizzes, multiple computational lab assignments, two reviews of papers from the scientific literature and a major computational project.

Exam 1	**100**
Computational Labs	**120**
Literature Reviews	**40**
Quizzes	**40**
Computational project	**100**

Literature Review Projects

To gain an in-depth understanding of molecular modeling techniques, students will be required to study selected papers from current computational chemistry and molecular simulation literature that are closely related to course material. Each student will select two computational papers: one for in class oral presentation, and another for written review in the form of a report to be at the end of the semester. The report should focus on how various modeling techniques are employed to analyze the structures, energetics, dynamics, and interactions in the molecular system of interest, as well as an in-depth discussion of capabilities and limitations of the employed methods. Suitable topics for course projects and guidelines for writing the report will be made available.

Computational Project

Propose and carry out an independent molecular modeling project. The topic may be related to an ongoing research project, or based on a journal article or a textbook example, or something you always wanted to know.

- **Proposal** Make a 5 min presentation of the proposal and obtain feedback from the class and the instructor. One page proposal should be distributed to the class before the presentation. In the proposal, highlight the objective, identify the chemical system(s) to be studied, list the type of calculations you are planning and the expected results.
- **Oral presentation** Make a 15 min presentation during the last week of the class and answer questions about the project. The oral presentation will be evaluated for contents, preparations and presentation skills.
- **Written report** Submit a written report of your project in a standard format including the following sections: introduction, calculations or computational details, results, discussion, conclusion and references. The calculations will be evaluated for appropriateness and correctness. So your report should contain enough data (in the form of figures and tables) to justify the correctness of the procedures and to support the conclusions reached. The report will be evaluated for organization, clarity of contents, and effectiveness of discussion.

UNIVERSITY POLICIES

Institutional Classroom Attendance Policy
Please be aware that the university has implemented an attendance policy, which requires faculty to verify student participation in every class a student is registered at the start of each new semester/course. For this course, if you have not attended/participated in class (completed any course activities or assignments) within the first 14 days, I am required by federal law to report you as not attended. Unfortunately, not attending/participating in class impacts your eligibility to receive financial aid, so it is VERY important that you attend class and complete course work in these first two weeks. Please contact me as soon as possible to discuss options and/or possible accommodations if you have any difficulty completing assignments within the first two weeks.

Policy Statement on Non-Discrimination on the Basis of Disability (ADA)
The University is an equal opportunity educational institution. Please read The University's Policy Statement on Nondiscrimination on the Basis of Disability Americans with Disability Act Compliance. Students can find this policy along with other university policies listed by audience on the University Policy webpage (http://www.utoledo.edu/policies/audience.html/#students).

Academic Accommodations
The University of Toledo embraces the inclusion of students with disabilities. We are committed to ensuring equal opportunity and seamless access for full participation in all courses. For students who have an Accommodations Memo from the Office of Accessibility and Disability Resources, I invite you to correspond with me as soon as possible so that we can communicate confidentially about implementing accommodations in this course.
For students who have not established accommodations with the Office of Accessibility and Disability Resources and are experiencing disability access barriers or are interested in a referral to health care resources for a potential disability, please connect with the office by calling 419.530.4981 or sending an email to StudentDisability@utoledo.edu.

ACADEMIC AND SUPPORT SERVICES
Please follow this link to view a comprehensive list of Student Academic and Support Services (http://www.utoledo.edu/studentaffairs/departments.html) available to you as a student.

SAFETY AND HEALTH SERVICES FOR UT STUDENTS
Please use the following link to view a comprehensive list Campus Health and Safety Services available to you as a student.

INCLUSIVE CLASSROOM STATEMENT
In this class, we will work together to develop a learning community that is inclusive and respectful. Our diversity may be reflected by differences in race, culture, age, religion, sexual orientation, gender identity/expression, socioeconomic background, and a myriad of other social identities and life experiences. We will encourage and appreciate expressions of different ideas, opinions, and beliefs so that conversations and interactions that could potentially be divisive turn, instead, into opportunities for intellectual and personal development.

Course Outline (tentative)

Theory	• Introduction to molecular modeling: potential energy surface
	• Molecular Mechanics ➢ Nature and development of force fields ➢ Techniques for searching conformation space; identification of minima ➢ The global minimum problem
	• Semi-Empirical Molecular Orbital Methods ➢ The AM1 and PM3 Hamiltonians ➢ Identification of minima and transition states - vibrational spectra
	• Ab Initio Molecular Orbital Methods and Density Functional Methods ➢ Choice of Basis Sets and Functionals ➢ Hartree-Fock SCF theory ➢ Electron Correlation ➢ The GAUSSIAN and Spartan programs ➢ Performance and cost issues ➢ Applications
	• Biomolecular Modeling ➢ Generalities of Protein and Nucleic Acid Structure ➢ PDB databank ➢ Molecular Mechanics Force Fields ➢ Molecular Dynamics ➢ Docking: AutoDock Program ➢ Homology Modeling
Lab (tentative)	Introduction to computational graphics visualization with VMD, PDB
	Introduction to Webmo/Gaussian and Spartan
	Basis set
	Geometry Optimization
	Model Chemistry: Energetics of Molecules
	Vibrational Frequency and IR Spectra
	Thermochemistry: Energetics of Chemical Reactions
	Energetics of Ligand-Protein Binding
	Introduction to Molecular Dynamics Simulation
	Molecular Dynamics Simulation
	Computing the pKa of Alcohols, Amines and Carboxylic Acids
	Homology Modeling
	Docking Indinavir to HIV Protease with AutoDock
	Virtual screening with Autodock