CHEM 6980/8980:001
Special Topics in Chemistry: Molecular Modeling

The University of Toledo
Department of Chemistry and Biochemistry

Instructor: Dr. Xiche Hu
Office: Wolfe Hall 2277, xhu@utoledo.edu, 530-1513
Office Hours: MW 3:00 to 4:00 PM
Term: Fall 2019
Credit hrs: 4
Lecture/lab: Bowman Oddy 1053, MW 5:30 to 7:20PM
Web site: https://blackboard.utdl.edu/webapps/login/

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 LEARNINNG 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
- Introduction to Computational Chemistry, 2nd Ed., F. Jensen, 2007
- Molecular Modeling Basics, J. Jensen, 2010
- Understanding Molecular Simulation, D. Frenkel & B. Smit, 2002
- Exploring Chemistry with Electronic Structure Methods, J. B. Foresman and A. Frisch (Gaussian Inc.)
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.

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<tr>
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<th>Points</th>
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<tbody>
<tr>
<td>Exam 1</td>
<td>100</td>
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<tr>
<td>Computational Labs</td>
<td>120</td>
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<tr>
<td>Literature Reviews</td>
<td>40</td>
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<tr>
<td>Quizzes</td>
<td>40</td>
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<tr>
<td>Computational project</td>
<td>100</td>
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**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.

**Professional Behavior**
All of us must conduct ourselves in a manner that is conducive to learning for everyone (i.e., professional). When teaching or working with others, we expect them to listen to us. When we ask questions or engage in class discussion, we expect others to listen to us. Others expect the same from us.

The following are examples of responsible professional behavior and irresponsible professional behavior. They are presented as examples and not as complete, exhaustive lists.

**Responsible**
- Attending class
  If a class is missed, for any reason, students are responsible for all material covered and announcements made in their absence. Class interaction is considered if there is a question regarding
lowering or raising the final grade from the numerically calculated final grade. Obviously, not attending class prevents observable, positive class interaction.

- Being on time and remaining for the entire class
- Demonstrating an understanding of assignments by using appropriate psychological concepts to explain or justify comments
- Thoughtful and effortful completion of assignments
- Active, enthusiastic participation in class discussion and activities, including asking thoughtful questions
- Responding to other students’ comments in a reasonable and constructive manner

**Irresponsible**

- Physical absence from class
- Physical presence, but cognitive absence (e.g., surfing the web, text messaging, tweeting, blogging, “off in space,” sleeping, dozing off, etc.)
  
  Unless there is an appropriate reason (e.g., medical issue, someone is traveling) for them to be on, pagers, mobile phones, iPods, etc., are to be turned off. If there is an appropriate reason for them to be on, then they are to be in *vibrate only* mode. PDA’s, electronic tablets, smartphones, and laptops may be used to take notes. They are not to be used for surfing the web, text messaging, tweeting, blogging, etc.
- Arriving late or leaving early
- You may record the class. However, please notify the other students and me that you are recording the class. Everyone has a right to know they are being recorded.
- Non-constructive responses to the comments of others
- Physical, intellectual, and/or emotional bullying

There are differences between an intellectual disagreement and behaviors that denigrate, humiliate, etc. (i.e., bully), the individual(s) with whom one has a disagreement. Such behaviors are usually intentional, persistent, and hostile. They include snide comments (e.g., name calling, insults), “rolling the eyes,” hand gestures, turning the body, “looking down one’s nose” at someone, mimicking/mocking a classmate, ostracizing or attempting to get others to consistently ignore a classmate, etc. These behaviors will not be tolerated, and will negatively affect a final grade, or, in severe cases, result in a student being removed from the class, and possibly the course.

**Statement of Inclusion and Civility**

In concert with the University of Toledo’s values and expectations, the faculty within the Judith Herb College of Education, Health Science and Human Service upholds the tenets pledged by the University to respect and value personal uniqueness and differences. Specifically, we will actively participate in the initiatives of the University to attract and retain diverse faculty, staff, and students; to challenge stereotypes; and to promote sensitivity toward diversity and foster an environment of inclusion in all curricular and extra-curricular activities.

Hence, all students enrolled in this course will be expected to:

- Promote a collaborative and supportive educational environment in a diverse community
- Treat every individual with kindness, consideration, dignity, and respect regardless of:
Gender,
Race/ethnicity,
Religion,
Sexual orientation,
Impairment(s)/Disability(ies),
Social economic status,
Political views, and
Other element(s) of diversity

Anti-Bullying Policy

Every University of Toledo student deserves to enjoy our school equally, and feel safe, secure and accepted. It is my goal to promote an inclusive, accepting environment in this course. Consequently, any form of bullying will not be tolerated. Bullying is defined as intentionally persistent, hostile behavior that is aimed at harming another individual. Bullying can take many forms including verbal (e.g., name-calling, insults), physical (e.g., pushing, shoving), and relational (e.g., eye rolling when a classmate enters the room, mimicking a classmate, ostracizing or attempting to get others to consistently ignore a classmate). Bullying can also be cyber in nature; specifically, repetitively rude text messages or comments on Facebook statuses or photos.

Please be it known that any form of bullying will not be tolerated. If you experience bullying, or are a witness to a bullying incident in this classroom or anywhere on campus, please feel free to approach me and I will take appropriate action. If you are uncomfortable reporting it to me, please visit The University of Toledo’s Anti-Bullying Task Force link at www.utoledo.edu/tlc/bully and complete The Anonymous Reporting Tool.

Academic Accommodations/Accessibility

“The University of Toledo abides by the Americans with Disabilities Act (equal and timely access) and Section 504 of the Rehabilitation Act of 1973 (non-discrimination on the basis of disability). If you have a disability and are in need of academic accommodations but have not yet registered with the Office of Accessibility (OA) (Rocket Hall 1820; 419.530.4981; officeofaccessibility@utoledo.edu) please contact the office as soon as possible for more information and/or to initiate the process for accessing academic accommodations. I also encourage students with disabilities receiving accommodations through OA to discuss these with me, after class or during my office hours, so that I may be better informed on how to assist you during the semester” (Faculty resources, 2012, “Academic accommodations,” para. 4).

Absence Policy

The University supports basic protections and reasonable accommodations for students who miss class with excused absences. Students are expected to attend every class meeting of courses in which they are registered. Only in specific, unavoidable situations does the University excuse absences from class: (1) personal emergencies, including, but not limited to, illness of the student or of a dependent of the student [as defined by the Policy on Family and Medical Leave], or death in the family; (2) religious observances that prevent the student from attending class; (3) participation in University-sponsored activities, approved by the appropriate University authority, such as intercollegiate athletic competitions, activities approved by academic units, including artistic performances, R.O.T.C. functions, academic field trips, and special events connected with coursework; (4) government-required activities, such as military assignments, jury duty, or court appearances; and (5) any other absence that the professor approves. Students are responsible for all material covered in classes they miss, even when their absences are excused as defined above. Students must make arrangements with instructors to complete missed assignments, labs, examinations or other course requirements. In turn, instructors are not to penalize students with excused absences.
Cell Phone Policy

The University of Toledo notifies its students of all emergencies via the UT Alert System. In the event of an on campus emergency, students are notified via text message. As a result, it is my policy to allow cell phones in my class. Please put your phone on vibrate upon entering the classroom and make every attempt to leave your phone untouched unless there is an emergency. If you must take a call, I ask that you exit the room to do so.

Winter Weather Policy/Class Suspension Procedures

In the rare event the University delays or suspends classes or campus events for any reason, the University will announce this information through several sources:

- UT Alert text message and email: Sign up for UT Alert
- Web: utoledo.edu and myut.utoledo.edu
- Phone: 419.530.SNOW (7669)
- Social media: UT on Facebook and Twitter
- Local media

  In the rare event that I must cancel class, I will send an e-mail to your Rocket e-mail account as soon as possible.
### Course Outline (tentative)

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