CHEMISTRY 7500
Angular Momentum Theory and Applications in Chemistry and Physics
Fall B 2019

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Office hours: I’m generally available in my office. Come by when you wish, and I’ll help out, as long as this privilege isn’t taken to excess. If you’re coming from some distance, call or email first to make sure I’ll be available.

Meeting times: MWF 11:00 am – 12:05 pm, in CSC 25

Drop/Withdrawal Dates: The last day to drop classes is Friday, October 18; the last day to withdraw from this class is Friday, November 8. Please check the academic calendar for more information pertaining to dropping and withdrawing from a course. Withdrawing from a course and other matters of registration are the student’s responsibility.

Prerequisites: A substantial background in quantum mechanics is required.

Course Description: This course provides the student with an understanding of the methods used to deal with the different forms of angular momentum in quantum mechanics. Students will learn how angular momenta are coupled through Clebsch-Gordan coefficients and 3-j symbols, and will learn how Wigner rotation matrices are used to express angular momentum wavefunctions in different coordinate systems. These topics are illustrated by their application to a number of different topics that are of interest to physical chemists and physicists. A substantial background in quantum mechanics is required. Credits: 2.

Text: Angular Momentum: Understanding Spatial Aspects in Chemistry and Physics, by Richard N. Zare.

This little book is a gem, providing all the details you need to know about angular momentum in a much more readable format than its predecessors. You can study this book for a long time, and still find new things that you can learn. If you buy any text to supplement my lectures, this should be it.

Angular momentum is the basis for selection rules in spectroscopy, and the angular momentum operators are intimately related to rotations and rotational transformations of coordinate systems. This text provides a concise description of the theory of angular momentum and rotation operators, and their use in chemistry and physics. It is strongly recommended for those interested in pursuing theory, spectroscopy (both gas-phase and condensed-phase spectroscopy, including NMR), and chemical dynamics.

Recommended Texts:
1. Spectra of Atoms and Molecules, by P. F. Bernath (a copy has been requested to be placed on reserve in Marriott Library)
   A good introduction to spectroscopy, which everyone who took Chemistry 7020 or 7030 should already have. This will be used as a background text, but will not be frequently referenced in the course.
2. Molecular Symmetry and Group Theory, by Alan Vincent (a copy has been requested to be placed on reserve in Marriott Library)
   For those of you who do not fully remember your group theory, this is an excellent little book to help you re-learn the mechanics of how to use point group theory. It does not cover the underlying mathematical theory at all. An excellent textbook on the application of group theory to chemistry is by F. A. Cotton, Chemical Applications of Group Theory (a copy has been requested to be placed on reserve in Marriott Library). This does cover some of the underlying mathematical foundations of group theory.
3. Hélène Lefebvre-Brion and Robert W. Field, *The Spectra and Dynamics of Diatomic Molecules*, (Elsevier Academic Press, Amsterdam, 2004). (a copy has been requested to be placed on reserve in Marriott Library)

Lecture Notes: I will also make copies of my lecture notes available, and these will probably be the most useful reference material.

Objectives: Students will learn to use angular momentum raising and lowering operators, to use Clebsch-Gordan coefficients and 3-j symbols to couple angular momenta, to understand and employ the Wigner rotation matrices to solve problems of physical and chemical interest. They will develop a deeper understanding of group theory, particularly the spherical point group. Applications will include the Jahn-Teller effect, the interaction of radiation with matter, the Hamiltonian of a diatomic molecule, spin-orbit interaction in molecules, multiphoton processes, and the quantum theory of radiation.

Outcomes: The desired educational outcomes include:
- Developing an understanding of the various types of angular momenta and how to perform calculations using the angular momentum operators.
- Developing an understanding of how to approach a research-level quantum mechanical problem involving angular momentum or group theory and work through the issues to arrive at a solution.
- Developing further scientific independence, suitable for research.

Topics: Angular Momentum Operators and Eigenfunctions (Spherical Harmonics)
Coupling of Two Angular Momenta (Clebsch-Gordan coefficients and 3-j symbols)
Point group theory for finite groups and for the sphere. Wigner rotation matrices.
Interaction of radiation with matter; electric dipole transitions; magnetic dipole transitions
The Hamiltonian of a diatomic molecule: Hund’s coupling cases; spin-orbit interaction
Electronic spectroscopy of diatomic molecules
Irreducible spherical tensors and the Wigner-Eckardt theorem
Multiphoton Processes
The Quantum Theory of Radiation

Grading: Grading will be on the basis of assigned problem sets, which will be extensive, nearly research-level in scope. There will be no exams in this course. Students who do all of the homework problems successfully can expect to receive an “A” in the course.

Teaching and Learning Methods: Lecture is used to communicate the essentials of the topic in an organized manner that clearly introduces topics and builds on those topics in a logical, step-by-step manner. Detailed lecture notes provide a written summary of what is presented in lecture, with detailed derivations. Homework assignments work through complex problems in a step-by-step manner to illustrate how working scientists approach theoretical computations in atomic and molecular physics.

Attendance: The class meets 3 days a week. Your job is to attend and participate with your full attention;
my job is to make it worth your while to attend.

Cell Phones: As a courtesy to me and your fellow classmates, please turn off cell phones during class.
ADA Statement: The Americans with Disabilities Act. The University of Utah seeks to provide equal access to its programs, services, and activities for people with disabilities. If you will need accommodations in this class, reasonable prior notice needs to be given to the Center for Disability Services, 162 Olpin Union Building, (801) 581-5020. CDS will work with you and the instructor to make arrangements for accommodations. All written information in this course can be made available in an alternative format with prior notification to the Center for Disability Services.

Addressing Sexual Misconduct: Title IX makes it clear that violence and harassment based on sex and gender (which includes sexual orientation and gender identity/(expression) is a civil rights offense subject to the same kinds of accountability and the same kinds of support applied to offenses against other protected categories such as race, national origin, color, religion, age, status as a person with a disability, veteran’s status or genetic information. If you or someone you know has been harassed or assaulted, you are encouraged to report it to the Title IX Coordinator in the Office of Equal Opportunity and Affirmative Action, 135 Park Building, 801-581-8365, or the Office of the Dean of Students, 270 Union Building, 801-581-7066. For support and confidential consultation, contact the Center for Student Wellness, SSB 328, 801-581-7776. To report to the police, contact the Department of Public Safety, 801-585-2677(COPS).

Campus Safety: The University of Utah values the safety of all campus community members. To report suspicious activity, call campus police at 801-585-COPS (801-585-2677). You will receive important emergency alerts and safety messages regarding campus safety via text message. For more information regarding safety and to view available training resources, including helpful videos, visit http://safeu.utah.edu/

Academic Honesty: Collaborating with fellow members of this course is strongly encouraged and will be an essential tool in your progress. All assignments should, however, be completed by you. Furthermore, any form of cheating on exams will not be tolerated. Neither will copying another’s work on homework assignments without evidence of your own work. Please refer to the University of Utah student code for more information: http://www.regulations.utah.edu/academics/6-400.html

Student Names & Personal Pronouns: Class rosters are provided to the instructor with the student’s legal name as well as “Preferred first name” (if previously entered by you in the Student Profile section of your CIS account, which can be managed at any time). While CIS refers to this as merely a preference, I will honor you by referring to you with the name and pronoun that feels best for you in class or on assignments. Please advise me of any name or pronoun changes so I can help create a learning environment in which you, your name, and your pronoun are respected. If you need any assistance or support, please reach out to the LGBT Resource Center: https://lgbt.utah.edu/campus/faculty_resources.php

Diversity/Inclusivity: It is my intent that students from all diverse backgrounds and perspectives be well served by this course, that students’ learning needs be addressed both in and out of class, and that the diversity that students bring to this class be viewed as a resource, strength and benefit. It is my intent to present materials and activities that are respectful of diversity: gender, sexuality, disability, age, socioeconomic status, ethnicity, race, and culture. Your suggestions are encouraged and appreciated. Please let me know ways to improve the effectiveness of the course for you personally or for other students or student groups. In addition, if any of our class meetings conflict with your religious events, please let me know so that we can make arrangements for you.
**Undocumented Student Support:** Immigration is a complex phenomenon with broad impact - those who are directly affected by it, as well as those who are indirectly affected by their relationships with family members, friends, and loved ones. If your immigration status presents obstacles to engaging in specific activities or fulfilling specific course criteria, confidential arrangements may be requested from the Dream Center. Arrangements with the Dream Center will not jeopardize your student status, your financial aid, or any other part of your residence. The Dream Center offers a wide range of resources to support undocumented students (with and without DACA) as well as students from mixed-status families. To learn more, please contact the Dream Center at 801-213-3697 or visit https://dream.utah.edu/

**Wellness Statement:** Personal concerns such as stress, anxiety, relationship difficulties, depression, cross-cultural differences, etc., can interfere with a student’s ability to succeed and thrive at the University of Utah. For helpful resources contact the Center for Student Wellness at www.wellness.utah.edu or 801-581-7776.

**Veterans:** If you are a student veteran, the U of Utah has a Veterans Support Center located in Room 161 in the Olpin Union Building. Hours: M-F 8-5pm. Please visit their website for more information about what support they offer, a list of ongoing events and links to outside resources: http://veteranscenter.utah.edu/. Please also let me know if you need any additional support in this class for any reason.

**Learners of English as a Second Language:** If you are an English language learner, please be aware of several resources on campus that will support you with your language and writing development. These resources include: the Writing Center (http://writingcenter.utah.edu/); the Writing Program (http://writing-program.utah.edu/); the English Language Institute (http://continue.utah.edu/eli/). Please let me know if there is any additional support you would like to discuss for this class.

Note: This syllabus is meant to serve as an outline and guide for our course. Please note that I may modify it with reasonable notice to you. I may also modify the Course Schedule to accommodate the needs of our class. Any changes will be announced in class and posted on Canvas under Announcements.