Instructor: **Tyler Meldrum,** ISC 1060, 221-2561 *tkmeldrum@wm.edu*

Course Meetings: Tuesdays and Thursdays, 12:30–1:50 pm, ISC 1280

Open student help: Wednesdays 9:30–10:30 am in ISC 1060
Appointments are available upon request

Course Description

This course explores principles of physical and analytical chemistry applied directly to biological systems. Topics include structure of nucleic acids and proteins, thermodynamics, quantum mechanics, spectroscopy, and chemical kinetics, and several techniques used in biophysical research. More broadly, I expect students to develop quantitative competency in (bio)physical chemistry, and to learn how physical chemistry and analytical methods apply to biological problems. Note: this course does *not* count towards the chemistry major; however, it does count towards the chemistry and biochemistry minors.

Prerequisites include two years of chemistry (through Organic II and General II) and integral calculus (MATH 112/132). Students who have taken differential calculus (MATH 111/131) and have some exposure to integrals or are currently enrolled in MATH 112/132 are probably sufficiently prepared for this course—they should see the instructor to discuss their math background and, if appropriate, to receive a course override.

Text

Atkins, P. and De Paula, J. *Physical Chemistry for the Life Sciences* (2^{nd} ed.); Oxford University Press, 2011.

(Not a text but related) You will be required to make at least one scientific figure for your final poster (see below). You will need to use some graphical design software to do so (e.g., Adobe Illustration, Affinity Designer, Inkscape). There are both paid and free options available; in addition, the Reeder Media Station (basement of Swem) has workstations equipped with Adobe Illustrator. You should select a program early that you intend to use and look for tutorials for basic usage. You will not need to become an “Illustrator Expert” to complete this course, but early preparation will prevent a rush at the end of the semester.

Course Details

Blackboard: This course makes extensive use of Blackboard. Please check the Blackboard site regularly for announcements, problem sets, exam submission instructions, grades, and other course supplements.

Lecture recordings: Barring major technical problems, I will be recording each lecture and posting it to Blackboard after each class period. Please use those recordings to help you study. Also, consider research that indicates that students who take notes by hand tend to outperform those who take notes on the computer. I suggest you focus on main concepts and their applications during lectures, then you can revisit the videos to catch any details that you may have missed.

Absences: Because of the small size for CHEM 341, things work best when everyone is in attendance. If you miss class, please use the lecture recordings, posted notes, the textbook, and/or assistance from classmates to catch up. If you will need to miss class for an extended period or if your absences will interfere will completing assignments, please contact me directly so we can find an appropriate solution.

If either (1) the instructor or (2) a sufficiently high proportion of the class is unable to attend in person, we will meet remotely via Zoom. This is expected to be only a temporary solution. Any changes will be communicated to the class as soon as possible.

Grading

Exams (40%)

Two untimed, take-home exams will be due on **Friday, March 4** and **Friday, April 15**, both at 11:59 pm. You will have approximately three days to complete these exams and will be allotted one class period for work time. Each exam will be worth 20% of the course grade, for a total of 40%.

Final poster session (25%)

In lieu of a traditional final exam, you will produce a poster on a major topic/question drawn from class, and we will hold a poster session during the final exam period. You will be expected to contribute an ungraded draft poster for peer review (see below), and a final poster by the final exam period. A grading rubric will be developed and approved by the entire class in April; the rubric used in a previous iteration of this class is available on Blackboard for your reference. Your poster and participation in the poster session will count for 25% of your course grade.

Problem sets (20%)

I will assign approximately six problem sets throughout the semester (two for the thermodynamics unit, two for quantum mechanics, one for chemical kinetics, and one for magnetic resonance). These problem sets will address different problem-solving skills and will reflect the exams in terms of content and difficultly. Collectively, these problem sets will account for 20% of the course grade.

Peer review (5%)

Each student will peer review two other students' draft posters, using the grading rubric established in class. You will receive credit for peer review by giving considerate, meaningful feedback to your peers; the content of your reviews will not be evaluated otherwise. Your peer review score will contribute 5% to the course grade.

Participation (10%)

I expect active participation in class. I will assign a participation grade based on active contributions to class discussions and activities; this participation grade will be worth 10% of the course grade.

Important statements that I stand by.

Student Accessibility Services: William & Mary accommodates students with disabilities in accordance with federal laws and university policy. Any student who feels they may need an accommodation based on the impact of a learning, psychiatric, physical, or chronic health diagnosis should contact Student Accessibility Services staff at **757-221-2512** or at **sas@wm.edu** to determine if accommodations are warranted and to obtain an official letter of accommodation. For more information, please see **www.wm.edu/sas**.

Religious Accommodations: I am happy to accommodate holidays of organized religions. Please inform me as soon as possible of such observances that are likely to conflict directly with this class.

Honor Code: As members of the William & Mary community, we pledge on our honor not to lie, cheat, or steal, either in our academic or personal life. We understand that such acts violate the Honor Code and undermine the community of trust, of which we are all stewards.

Inclusivity: William & Mary values and actively nurtures an inclusive environment where every individual, regardless of race, religion, gender, ethnic origin, age, socioeconomic status, political preferences, physical abilities, or sexual orientation (a non-exclusive list) is respected and afforded the opportunity to grow and to succeed.

Course Learning Goals (adapted from CU Boulder)

1. *Foster intuition.* Develop an intuition about physical chemistry systems and models. This intuition may include:
    - Areas in which quantum and classical systems diverge.
    - The effects of quantization of energy.
    - Wave nature of matter and energy.
    - Scales of energy and how they affect (bio)molecular behavior.
    - Energetic, entropic, and kinetic influences in (bio)chemical processes.

2. *Form connections between math and chemistry.* Translate a physical description of a physical chemistry problem into the mathematical formalism necessary to solve it. Explain the physical meaning of the mathematical formulation and solution. Develop physicochemical insight through the mathematics of a problem.

3. *Visualize.* Sketch appropriate parameters of a problem (e.g., wave function, probability distribution, energy levels). When presented with a graph of some data, derive appropriate physical parameters of a system. Produce high-quality figures that accurately and clearly convey scientific findings.

4. *Predict, solve, and check problems.* As appropriate for a given problem, articulate expectations for the solution to a problem in advance of finding a complete solution. From these expectations, learn to choose and apply appropriate problem-solving methods. Transfer the methods learned in class and through homework to novel contexts.

    Some specific problem-solving methods to be developed in this course include:
    - *Models.* Consider which physical chemistry models are most helpful when approaching a problem and implement them appropriately.
    - *Approximations.* Recognize when approximations are useful, and to use them effectively.
    - *Symmetry.* Recognize symmetry and be able to take advantage of it to solve a problem.
    - *Coordinate systems.* Recognize when using certain coordinate systems provide clear advantages for particular problems.

    Justify the reasonableness of a solution reached, by using methods such as:
    - Order of magnitude estimates.
    - Dimensional analysis.
    - Validating against limiting or special cases.

5. *Develop intellectual maturity.* Students should accept responsibility for their own learning and be aware of what they do and do not understand about physical chemistry. Students should learn to ask specific questions, and to identify and articulate the parts of a problem that they found difficult so they can take appropriate action. Finally, students should regularly check their understanding against these learning goals and seek appropriate help to fill in gaps.

Tentative course schedule (as of 26 January 2022)

Date	Unit	Topics	Text Sections
R, 1/27	Intro	Course intro, syllabus Main questions (structure, protein folding, energetics, techniques) Fundamentals (biomolecules, interactions, energy)	F.1–F.3 Resource Section 1
T, 2/1	Energy and entropy (thermodynamics)	Work and heat, state and path functions, the first law	F.3, 1.1–1.5
R, 2/3		Enthalpy and calorimetry	1.6–1.11
F, 2/4		*Add/drop deadline* *Deadline to file Minor Declaration form for May or August graduates*	
T, 2/8		Entropy and the second law	2.1–2.2
R, 2/10		Cycles and connecting gases to organisms	—
T, 2/15		Statistical entropy	2.4–2.5
R, 2/17		Gibbs energy, equilibrium	2.6–3.6
T, 2/22		Bioenergetics	p. 151–156
R, 2/24		*Technique: Calorimetry*	see 1.6, supplements
T, 3/1		*Skills: figures*	
R, 3/3		*No class meeting: exam time allotted* *Exam due, Friday, 4 March, 11:59 pm*	—
T, 3/8	Quantum mechanics and spectroscopy	Origins of QM Operators, observables, eigenstuff	9.1–9.2
R, 3/10		Particle in a box	9.4
3/12–3/20		***SPRING BREAK—NO CLASS***	
T, 3/22		Harmonic oscillator and molecular vibrations	9.6
R, 3/24		Vibrational spectroscopy	12.1–12.5
M, 3/28		*Withdraw deadline*	
T, 3/29		Rigid rotor and molecular rotations	9.5
R, 3/31		The hydrogen atom	9.7–9.8
T, 4/5		*Technique: Optical spectroscopy*	12.6–12.8 Case Study 12.2
R, 4/7		*Technique: Fluorescence*	12.9–12.13
T, 4/12		*Skills: peer review* *Finalize rubric*	
R, 4/14		*No class meeting: exam time allotted* *Exam due, Friday, 15 April, 11:59 pm*	—
T, 4/19	Reaction kinetics	Collisions and rate laws	Ch. 6
R, 4/21		Activated complex theory	7.6–7.7
T, 4/26		Michaelis-Menten enzyme kinetics Complex reactions	Ch. 8
R, 4/28	MR	NMR spectroscopy	Ch. 13
T, 5/3		MRI	Supplemental
R, 5/5		*Final peer review, course evaluation*	—
R, 5/12	***FINAL EXAM PERIOD 9:00 am–12:00 pm (poster session)***		