Chemistry 3130 Syllabus

Spring 2015

Course Information	Introduction to Biochemistry (CHEM 3130) 3 credit hours		
Course Meetings	*Section 01* MWF 8:00 - 8:50 am NCF 102 Watt	*Section 02* MWF 11:00 - 11:50 am NCF 102 McIntyre	*Section 03* MWF 10:00 - 10:50 am NCF 175 Watt
Instructors	Dr. Neil McIntyre NCF 301K x 5083 nmcintyr@xula.edu	Dr. Terry Watt NCF 314 x 5271 tjwatt@xula.edu	
Office Hours	M 12:00 pm - 2:00 pm T 12:00 pm - 1:00 pm W 12:00 pm - 2:00 pm R 8:30 am - 9:30 am	T 10:45 am - 11:45 am W 2:00 pm - 5:00 pm R 4:15 pm - 5:15 pm F 9:00 am - 10:00 am	
	You may attend office hours for any instructor and may also request appointments outside of these scheduled times.		
Textbook	*Essential Biochemistry*, 3rd edition. Pratt & Cornely, 2013 (Wiley).		
Course Description	The students' understanding of cellular structure and composition on the molecular level will be developed through a study of the physical and chemical properties of the biomolecules of cells.		
Course Prerequisites	Grade of C or better in CHEM 2220/2240L		
Hour Exam Dates	All exams at 6:00 pm: Mon. Feb. 9, Mon. Mar. 9, Fri. Apr. 10		

Course Objectives

Introduction to Biochemistry will present the chemistry of biological compounds. The goals of this course are: 1) to build your skills in problem solving and analytical reasoning; 2) to enhance your knowledge of cellular structure and composition in preparation for professional school, graduate school, and careers; and 3) to help you learn to work with and communicate about the fundamental principles governing the chemistry of life processes. These principles include the molecular composition and structure of biological macromolecules, thermodynamics and kinetics of enzymatic processes, and how the principles you learned in General Chemistry and Organic Chemistry apply to biological systems. At the end of the semester, you should be able to describe the structure and function of carbohydrates, lipids, amino acids, proteins, and nucleic acids, as well as discuss molecular techniques for working with these compounds. You will be expected to be able to solve a variety of computational problems for biochemical systems. Finally, you will be asked to approximate answers and evaluate solutions when provided limited information about a system, identify underlying assumptions of techniques or data analysis, and to evaluate conclusions about data.

Course Components

Learning Objectives

A list of learning objectives for the semester is included in this syllabus. Learning objectives are designed to help you focus on the material that is most important and that will appear on quizzes and exams; any additional topics will only be used to illustrate points or provide examples. All quiz and exam questions are written to explicitly address one or more of the learning objectives. Not all objectives will be covered on

any particular quiz or exam. Although objectives are divided according to textbook chapters, each chapter builds on information from previous chapters.

Review objectives are drawn primarily from general chemistry and organic chemistry, but also include basic biological and mathematical facts and concepts. It is assumed that a passing grade in the course prerequisites means you are comfortable with them. If that is not the case, you should review the indicated material.

Fundamental objectives are the core facts, equations, definitions, and relatively simple molecular structures that underly a conceptual understanding of biochemistry. Fundamental objectives often require rote memorization, in the same way that learning a language requires the rote memorization of the vocabulary of words that makes up that language. You should learn the fundamental objectives as soon as possible, even *before* the first lecture on the chapter, because it is difficult to understand complex biochemical ideas when you are unfamiliar with these objectives. Questions addressing fundamental objectives emphasize your ability to recall knowledge and identify information. Many fundamental objectives, especially definitions and structures, are important in multiple sections of the course, but are only listed as an objective for the first chapter in which they occur.

Conceptual objectives include qualitative ideas, quantitative approaches, and more complex molecular structures and interactions. Conceptual objectives are not best learned by trying to memorize large quantities of information; instead, you should try to master the principle or approach the objective refers to. Questions addressing conceptual objectives are designed to primarily measure your biochemical skills and have less emphasis on your core knowledge of facts. Examples of conceptual objectives include performing calculations (using equations); interpreting plots to determine values; drawing plots and figures; explaining experimental techniques and when they are applicable; discussing general principles; applying the principles of molecular interactions important for the 3-D structure of large molecules; and applying relevant principles involved with chemical reactions and mechanisms. Solving problems based on conceptual objectives requires knowledge of one or more fundamental objectives. Some conceptual objectives are also inherently cumulative, so some conceptual objectives from later chapters depend on objectives from prior chapters. An important aspect of conceptual objectives is to know when a particular principle is valid; many conceptual objectives focus on different aspects or approaches to a large idea, but not all objectives are relevant or useful for every problem.

Mastery objectives combine multiple conceptual objectives. Mastery objectives focus on more advanced analysis and evaluation of experimental systems, comparisons between different systems, recognizing connections between ideas, and applying your knowledge to new systems. Mastery questions are challenging and will often ask you about a system we have not discussed in class, but solving mastery questions does not require information or concepts other than those in the learning objectives. All mastery objectives are inherently cumulative and may draw on any prior fundamental or conceptual objective. These questions are the most demanding test of your ability to communicate your understanding of the material and ability to apply that knowledge. Mastery questions assume that you have a solid foundation in biochemical knowledge, and therefore points are rarely earned simply for demonstrating that you know a fact; full credit requires a demonstration of both your biochemical skills in a new context and your ability to clearly communicate a complex idea. Long, rambling answers are not clear communication, and in many cases a short but highly directed answer can early full credit; mastery questions can be difficult because they require deep understanding of the material, not because they are necessarily more complicated or involved.

Many learning objectives are cross-referenced to textbook chapters and recommended textbook problems. Material for objectives can also found in the lecture notes. In addition, a list of suggested resources for understanding the course material is provided at the end of the learning objectives. Many of these activities provide visual and/or interactive tools for learning the course concepts that supplement lecture and textbook presentations, particularly those concepts involving 3-D structure, experimental techniques, and working with plots. These activities allow you to work with the material at your own pace.

Lecture and In-class Concept Questions

Regular attendance at lecture classes is strongly recommended. Some course material will only be presented in lecture, and the lecture slides are frequently supplemented by additional verbal and written informational. You will often be asked to work with or think about a concept during lecture. These questions do not count toward your grade and do not require that you turn in an answer, but are designed to emphasize key or confusing points. Active participation in these exercises is an important learning tool, and you can discuss solutions with your classmates. Some lectures are designated "review" in the schedule. Those days will be used to review material prior to exams, based on student questions, if time allows; if there are many questions or other delays in the class days prior to the review, the review may be reduced or eliminated to finish presenting material. Review classes are most beneficial to those who have studied in advance and bring specific questions.

Textbook Reading Assignments

The course material covers approximately half of the textbook (see the schedule). You are responsible for all the material in the learning objectives, whether or not a particular topic is covered in lecture, including all of the sample calculations and special topic boxes that students frequently skip. The assigned reading includes some topics that are purely illustrative and will not be emphasized; use the learning objectives as a guide. *You should read each complete chapter prior to the first day of lecture covering the chapter, and then re-read the each section after it is covered in lecture.* Make your reading an active process and keep track of those concepts that are confusing so that you will be able to pay especially close attention as those concepts are covered in class. Either the paper or electronic version of the textbook is acceptable. The 2nd edition (2011) of the textbook is acceptable, but see the document on Blackboard for information on how to match references in the 3rd edition to the 2nd edition. Use of a different textbook is possible but strongly discouraged. If you use a different textbook, it is your responsibility to work out how chapters, content, figures, and end of chapter questions correspond to the material in the official textbook.

Recommended Textbook Questions

Selected practice textbook questions are provided in the learning objectives, listed after the objective that each question corresponds to. Although these questions are not graded, they are a good mechanism to immediately test and practice your understanding of the material. Working with other students on these questions is strongly encouraged. The textbook has solutions to all odd numbered questions, and the selected even solutions are posted to Blackboard. *All quizzes and exams will have at least one question similar or identical to a textbook question.* These questions are the best way to regularly test your ability to express ideas about the course in your own words, something you are expected to do on quizzes and exams. Keep in mind that the online exercises (see below) do not test your ability to communicate ideas or draw structures, so the textbook questions should be an integral part of your regular studying. You should not be intimidated by the number of questions, as you can be selective about which ones you complete based on your current understanding of the material and the concepts you may be struggling with.

Online Exercises

There will be 46 online exercise sets posted through the quiz interface in Blackboard (under Content, in a folder), three to five sets of exercises per chapter. Each exercise consists of five questions randomly selected from a pool of questions, so each time you practice an exercise you will see a different combination of questions. *Only your highest score is recorded.* Questions sets are divided to focus on: (a) definitions; (b) other fundamental objectives; (c) qualitative conceptual objectives; (d) conceptual objectives emphasizing quantitative approaches and experimental techniques; and (e) mastery objectives and advanced applications. Question sets of types (a), (b), and (c) will be available for all chapters; types (d) and (e) will only be available for selected chapters. The questions are in a variety of formats, including multiple choice, multiple answer, fill-in-the-blank, and calculation. Online exercises are designed to support your learning in the class and enable easy repetition to test your growing knowledge, but should not be your only method of practice because they are not a good measure of your ability to communicate complex explanations or analysis (see Recommend Textbook Questions). *Students who work on online exercises regularly and*

consistently throughout the semester tend to achieve significantly higher quiz scores, and students consistently report that the online exercises are useful in exposing areas of poor understanding, highlighting essential information, and thinking critically about the material. It is highly recommended to spend 2-4 hours per week, every week, working on these exercises. You are encouraged to work with other students, consult course materials, keep a written record of questions and answers (Blackboard will not), and work through questions on paper. Students who habitually skip "hard" questions and only answer "easy" ones tend to earn below-average grades, whereas students who often repeat the online exercise sets, even after answering a set of five questions correctly, tend to finish the semester with a substantially higher final grade. Students who do well in this course tend to make average at least 5 attempts per online exercise question set, with at least one attempt after earning 5 points.

Hour Exams

There will be several 1-hour exams during the semester. *All exams are given in the evening outside of class, as indicated on the course schedule, so that all course sections may take the exam at the same time. Put these dates on your calendar at the beginning of the semester and plan accordingly; if you have a legitimate conflict (as determined by your instructor), you must bring it to the attention of your instructor at least 3 weekdays prior to the exam so that you can be scheduled to take the exam early. Adjust your work schedules for the semester now so that you are available during exam times.* Exams are closed to all materials. All exams follow a specific, regular format: (i) 15 multiple choice questions covering fundamental objectives (30%); (ii) 5 multiple choice questions covering conceptual objectives (10%); (iii) 2 short answer questions covering fundamental objectives (10%); (iv) 4 short answer questions covering conceptual objectives (40%); and (v) a single, multi-part mastery question (10%). Some exam questions will give you multiple options, from which you must choose a topic or question part to answer instead of answering all parts of the question. Exams in this course are most likely somewhat longer and more challenging than you are used to, so it is important to be prepared. In addition to testing your biochemical knowledge, exams will measure your ability to communicate your understanding and relate it to a larger context. Regular practice is essential to perform well on the exams (see Online Exercises and Recommended Textbook Questions).

In-class Quizzes

A 15-20 minute quiz will be given every week unless otherwise indicated on the schedule (see the schedule for your section). Quizzes may be given at the beginning, middle, or end of class without advance warning. Quizzes may include material from the previous two weeks of class (the previous 6 MWF or 4 TR lectures), including assigned reading and everything presented in lecture. Most quizzes will have the format of mini-exams: (i) 7 multiple choice, with 5-6 questions covering fundamental objectives and 1-2 questions covering conceptual objectives (47%); (ii) 1 short answer question covering fundamental objectives (10%); (iii) 2 short answer questions covering conceptual objectives (33%); (iv) one mastery question (10%); and (v) a bonus multiple choice question that asks about information in this syllabus (3%). Quiz bonus questions increase your total quiz score directly and are not counted as a separate pool.

Final Exam

The final exam will be structured similarly to the hour exams, but twice as long and cumulative over the entire semester: questions covering any learning objective from any chapter could appear. As with in-class exams, you will be required to answer all multiple choice questions on the final exam (30 fundamental and 10 conceptual). Also like the in-class exams, there will be a variety of short answer questions that you will need to answer: 4 fundamental, 8 conceptual, and 2 mastery. However, there will be two more short answer questions in each section than you are required to answer (*i.e.*, 6 fundamental, 10 conceptual, and 4 mastery), allowing you to choose those questions you feel you can best answer. Both multiple choice and short answer questions will be evenly distributed across the material from the entire semester. If you wish to review your final exam, you can schedule a meeting after the semester ends.

Course Grading

The Blackboard gradebook will be updated periodically so that you can confirm that your grade record is correct; please bring discrepancies to your instructor's attention. Scores of zero for failure to take a quiz or exam will become your drop scores; make-ups will not be provided.

Online exercises. Only your highest score on each exercise will be recorded, for a maximum of 5 points on each of the 46 exercises.

Quizzes. There will be thirteen quizzes during the semester, each worth 30 points. Your *three* lowest scores during the semester will be dropped from your final (not midterm) grade.

In-class exams. There will be three in-class exams this semester, each worth 100 points. The *one* lowest exam score will be dropped from your final (not midterm) grade.

Final exam. The final exam is worth 300 points.

Course component	**Midterm Points Possible**	**Final Points Possible**
Online exercises	120: 24 exercises	230: 46 exercises
In-class quizzes	210: 7 quizzes	300: 10 of 13 quizzes
In-class exams	100: 1 exam	200: 2 of 3 exams
Final exam		300
Total possible points	430	1030

Grade	**Midterm Point Range**	**Final Point Range**
A	387 or greater	900 or greater
B	344 - 386	800 - 899
C	301 - 343	700 - 799
D	258 - 300	600 - 699
F	< 258	< 600

Course Strategies (How to Succeed in CHEM 3130)

You will need to devote a considerable amount of time and effort to mastering biochemical principles and learning to solve quantitative exercises, and you will not learn everything you are expected to know in lecture. Many students find that forming a study group to work through exercises is an excellent way to master biochemistry, provided all students *work*. A recommended study strategy for this course, which has been confirmed by many students from prior semesters to be extremely effective and to greatly increase the chance of earning a high grade, is:

1. read each chapter of the textbook before the first lecture covering that chapter, using the learning objectives to focus on key points;
2. learn the definitions given in the Fundamental Learning Objectives before the first lecture on the chapter, and complete the “a” set of online exercises for the chapter;
3. attend class, take your own notes (do not just follow along with a printout of slides), and actively participate during class through Concept Questions and asking your own questions;
4. after each lecture, re-read the section of the textbook that was covered in lecture;
5. practice with textbook questions and the additional online exercise sets for the chapter;
6. when you encounter exercises that you cannot solve, refer to the text, your notes, your fellow students, or a course instructor;
7. each week, explore the material in greater depth using the recommended online resources;
8. and regularly review areas that you are struggling with, as determined by feedback on quizzes and exams, difficulties with in-class exercises, or particular learning objectives.

Chemistry knowledge also often builds upon itself, and biochemistry is no exception. You should regularly review material you studied earlier in the course to most effectively learn new material (and occasionally material from course prerequisites). The most successful students learn the material as part of integrated framework of all their chemistry knowledge, not as a series of isolated facts; however, this

approach requires significantly more time than simply attempting to memorize bits of information. *You should expect to spend at least 2 hours studying outside of class for each hour in class; the amount of time you spend working on questions and efficient, effective practice is the most important correlation with the final grade earned in this course.* However, "efficient, effective practice" is key: hours cramming and randomly guessing on online exercises are neither effective nor efficient. The most effective and efficient study is usually done in small (1-2 hour) increments several times a week. The most best study involves a mixture of activities at each session, including reading, review, and practice with questions. Ask your fellow students or instructor when you have difficulty with a particular concept or question, and then go back and try similar questions to ensure that you now understand it. You will struggle with some of the material in this course; scientific research supports the idea that students are learning the most when they are struggling but also generally answering questions correctly. Unfortunately, a side effect is that most students also lack confidence in their abilities during this stage. You should expect many "ah-ha", "I get it", or "this suddenly feels easy" moments after practicing material and then applying it to a new question; these are important indications you are learning effectively. With this sort of regular practice, many students find that they do not need extensive review sessions or cramming prior to exams. Overall, fundamental objectives are worth about 40% of the final grade, conceptual objectives about 50%, and mastery objectives about 10%; plan your study efforts accordingly.

To successfully answer quiz and exam questions, it is important to both carefully read each question and to explicitly provide the information that is asked for. There may be an adjustment period as you become used to the format of questions, but picking up graded work and learning from your mistakes will help greatly. Make sure you answer all parts of each question and in the format requested; however, it is not necessary nor efficient to restate questions as part of your answer. For multiple choice questions, most students find that they should not change a selected answer unless they sure that the first answer is wrong *and* that another answer is correct; first instincts are very often correct, and it may seem easy to argue another answer "might" be better.

As you are studying for each quiz and exam, use the provided learning objectives to focus on the aspects of the course material that will be tested in each section of the exam. All in-class quizzes and exams will only explicitly test recent material, but the inherently cumulative nature of the course material means that older material frequently appears as part of a question or as necessary knowledge to completely answer a question addressing new material. Answer keys will not be posted, because many questions have multiple solutions and it is essential that *you* work through solutions. Correct answers to incorrect multiple choice questions will be indicated on your paper. Incorrect short answer questions will have written feedback to explain what you got wrong, but may not cover the complete answer or indicate acceptable alternative answers. It is very important that you collect your graded quizzes and exams promptly so that you can correct misconceptions and errors, because you will often see a similar question again later. Looking at copies of exams and quizzes from previous semesters of this course is not an effective study method; you must engage with the material directly. Also remember that internet sources often contain inaccurate, misleading, or inappropriately simplified presentations of material, and so these sources should not be consulted indiscriminately.

A poor score on any quiz or exam should not be interpreted to mean that this course is exceedingly difficult, as many students consistently improve on their scores throughout the course. Similarly, a very high score should not be interpreted to mean the course is or will remain easy, as you will still need to master a large amount of new material to finish the course with a high grade. You should expect that your average score on quizzes and exams will be lower than in most other courses you have taken, because there are no points just for showing up or recalling information from prior classes; these lower scores do not necessarily mean you will end with a poor final grade. Most students complete the course with a letter grade higher than expected from a simple average of quiz and exam scores, once drop scores and other contributions to the grade are factored in.

Due to the inherently cumulative nature of this course, falling behind in material can rapidly build up to a seemingly insurmountable problem in catching up. It is essential that you regularly attend lecture, keep up with the assignments, and pick up your graded assignments to learn from mistakes you may have made to

avoid repeating them. Should you find yourself falling behind, very confused about the material, or unable to fully participate in class due to major non-academic issues (such as illness or interview travel), make an appointment to speak to your instructor as soon as possible; do not wait until additional weeks have passed.

Course Policies

Attendance. Swipe your ID in the card readers when entering the classroom. If you forget your ID or arrive more than 10 minutes after class has begun, your attendance will not be recorded.

Quizzes and exams. If you arrive late to a quiz or exam and no student has left the room, you will be allowed to start but will not be provided any extra time. There are no make-up quizzes available for any reason (including arriving late, medical school interviews, and illness); because several quiz scores can be dropped, one or two zero scores for quizzes rarely has any significant impact on final grades. If you will miss an exam (not a quiz) for a legitimate academic reason and you inform your instructor at least three days beforehand, you may be allowed to take an exam version *early*; no exams will be given after the regularly scheduled time. Your instructor will not provide blank copies of missed quizzes or exams. *Any use of a cell phone during a quiz or exam is academic misconduct (see below).* Bags and notes must be placed away from your desk during exams, and no papers may be visible (including cover sheets on binders) during quizzes. If you finish a quiz early and are waiting for other students to finish, do not take out any course materials.

Online exercises due date. All online exercises are due at 11 am on quiet day. At that time, your highest score for each exercise will be recorded. For midsemester grades, your highest scores on the first 24 exercises as of the morning midsemester grades are due will be used; however, those scores can still be improved upon before the final grade calculation. After 11 am on quiet day, the exercises will remain available for practice, but no additional points can be earned.

Collecting your graded work. Every attempt will be made to return your graded work as quickly as possible and before the next quiz/exam. You may collect your graded work outside your instructor's office. If you do not want your work available in a common area and wish to pick it up directly from your instructor during office hours, notify your instructor by email.

Electronic devices. Turn *off* cell phones for the duration of the class period. If there is a situation that requires that you be able to answer your cell phone during a class, please inform your instructor before the class. If you use your phone during class (including text messaging), you may be asked to leave. Discuss use of laptops/tablets with your instructor, as these are usually not effective note-taking devices for this course. Also be aware that smart phones and tablets may have reduced Blackboard functionality.

Class courtesy. You may discuss in-class questions with the other students; however, please do not shout out answers until asked. Other than these discussions and questions directed toward your instructor, please keep talking and other distracting behaviors to a minimum out of respect for the other students. As needed, raise your hand and ask for more time to take notes or to clarify an issue.

Regrade requests. You may request a re-evaluation of any assignment up to one week after the first opportunity to collect the graded assignment or quiet day at 11 am, whichever comes first. Requests for anything other than errors in totaling points must be made in writing on an attached sheet; verbal regrade requests are not accepted. Requests must explicitly state what problem is at issue and why your answer is correct. Explaining what else you knew that you did not write in your original answer, that "someone else got credit for the same answer", and other similar responses will not result in additional points.

Lecture slides. You will be provided electronic copies of the lecture slides, available through the course Blackboard site (under Content, in a folder). The slides for a particular chapter will be posted before covering the material in that chapter.

Instructor communication. As needed, you are strongly encouraged to attend office hours, talk to your instructor after class, or set up an appointment. Your instructor will answer email questions, although some questions may be difficult to answer in email. Replies to email may take 24 hours, so plan accordingly. Phone conversations about course material are inefficient and will generally be avoided; phone messages

will not be responded to. Your instructor will occasionally communicate with the entire class via Blackboard announcements and email, so check your xula.edu email at least once a day.

Calculators. This course frequently involves calculations, so bring a non-programmable calculator capable of logs (including natural logs and antilogs), exponents, and scientific notation to class each day. (Calculators that round off very small values instead of switching to scientific notation will cause you to have calculation errors.) On quizzes and exams, cell phones and multimedia devices may not used as calculators, any sharing of calculators must be explicitly approved by your instructor, and you should not assume that your instructor will have a spare calculator.

Evacuation. If classes are canceled due to a hurricane evacuation, assignments and course materials will be posted to Blackboard. Please log on to the Blackboard site as soon as possible after the evacuation.

Health or disability concerns. If you have special needs, please make an appointment to speak to your instructor to discuss any appropriate accommodations.

Academic Misconduct

The CAS Academic Integrity Policy will be followed in this course. According to the policy, academic misconduct includes, but is not limited to, the following:

1. Using unauthorized materials in completion of an exam, quiz, or assignment.
2. Assisting or gaining assistance from an unauthorized source during an exam, quiz, or assignment.
3. Providing assistance to another student in a manner not authorized by the instructor.
4. Obtaining an examination or assignment in an unauthorized manner.
5. Using material from a source without giving proper citation.
6. Fabricating or altering data.
7. Submitting work to one class that is substantially similar to work submitted for another class without prior approval from the instructors involved.
8. Submitting written work that is not completely one's own or allowing others to submit one's work.
9. Destroying or altering the work of another student.
10. Committing any other violation of academic integrity as described in this syllabus.

Specific examples of academic misconduct include:

- the use of a cell phone during an exam or quiz for any reason (even as a calculator);
- talking during an exam or quiz;
- using anything other than explicitly authorized materials on a quiz or exam;
- attempting to read from another student's quiz or exam;
- copying class assignments, including sharing files to analyze or present data;
- using data that you did not collect in a report without proper attribution;
- working with others on any assignments (in or out of class) when not authorized.

You are responsible for arriving on time for all quizzes or exams, as you will not be permitted to begin after any other student has left the room. You are responsible for all written materials on, under, and near your seat during quizzes and exams, so it is in your best interest to ensure that the desk surface is clear of writing and that no extraneous papers are within your line of sight (both when you begin and finish). Cell phones should always be off and inside a bag during a quiz or exam; your instructor will not give you the benefit of the doubt if a cell phone is used or visible. The CAS policy makes no distinction between the person receiving unauthorized assistance (copying an assignment) and the person providing the assistance (allowing work to be copied); both actions are academic misconduct.

All cases of academic misconduct will be reported to the CAS Dean's Office per Xavier's Academic Integrity Policy. Any case of academic misconduct on assignments will result in a grade of zero for the assignment and may result in a grade of F for the entire course. Premeditated academic misconduct during an exam (for example, using a cell phone to text or preparing a "cheat sheet") will result in the student being asked to leave immediately and in a failing grade for the course. A grade of zero assigned for academic misconduct may not be counted as a drop score.

Course Schedule

#	Date		Lecture Topic	Reading	Quiz
1	Mon	Jan 12	Biomolecules, origin of life	Syllabus, 1-1, 1-2, 1-4	
2	Wed	Jan 14	Thermodynamics	1-3	#1
3	Fri	Jan 16	Gibbs free energy, chemical equilibrium	1-3, 12-3 (pp. 323-328)	
	Mon	Jan 19	*No class: Labor Day*		
4	Wed	Jan 21	Chemical equilibrium	12-3 (pp. 323-328)	#2
5	Fri	Jan 23	Coupled reactions	12-3 (pp. 323-328)	
6	Mon	Jan 26	Water processes, acids and bases	2-1, 2-2, 2-3	
7	Wed	Jan 28	Acid-base equilibria	2-3	#3
8	Fri	Jan 30	Buffers	2-4	
9	Mon	Feb 2	Nucleic acids, DNA structure, transcription, translation	3-1, 3-2, 3-3	
10	Wed	Feb 4	Manipulating DNA	3-4	#4
11	Fri	Feb 6	Review		
	Fri	**Feb 6**	**Exam #1 at 6:00 pm: Chapters 1, 2, 3**		
12	Mon	Feb 9	Amino acids	4-1	
13	Wed	Feb 11	Amino acid properties, p*I*	4-1, 4-5 (p. 112, top)	#5
14	Fri	Feb 13	Primary & secondary structure	4-1, 4-2	
	Mon	Feb 16	*No class: Mardi Gras break*		
	Wed	Feb 18	*No class: Mardi Gras break*		
15	Fri	Feb 20	Tertiary & quaternary structure	4-3, 4-4	
16	Mon	Feb 23	Protein folding	4-3	
17	Wed	Feb 25	Protein structure determination and modifications	4-3, 4-5, 22-4 (pp. 608-609)	#6
18	Fri	Feb 27	Myoglobin, ligand binding	5-1	
19	Mon	Mar 2	Hemoglobin	5-1	
20	Wed	Mar 4	Hemoglobin regulation, hemoglobin variants	5-1	#7
21	Fri	Mar 6	Fibrous proteins, motor proteins	5-2, 5-3	
22	Mon	Mar 9	Review		
	Mon	**Mar 9**	**Exam #2 at 6:00 pm: Chapters 4, 5**		
23	Wed	Mar 11	Enzymes, cofactors	6-1, 6-2	#8
24	Fri	Mar 13	Transition state stabilization, enzyme kinetics	7-1, 7-2	
25	Mon	Mar 16	Michaelis-Menten kinetics	7-2	
26	Wed	Mar 18	Enzyme inhibition: competitive	7-2, 7-3	#9
27	Fri	Mar 20	Enzyme inhibition: uncompetitive, mixed	7-3	
28	Mon	Mar 23	Enzyme classes, enzyme mechanisms	6-1, 6-2	
29	Wed	Mar 25	Serine proteases	6-3	#10
30	Fri	Mar 27	Enzyme mechanisms	6-2, 6-3, 6-4	
	Mon	Mar 30	*No class: spring break*		
	Wed	Apr 1	*No class: spring break*		
	Fri	Apr 3	*No class: spring break*		
31	Mon	Apr 6	Enzyme regulation	6-4, 7-3	
32	Wed	Apr 8	Polysaccharides, glycoproteins	11-1, 11-2, 11-3	#11
33	Fri	Apr 10	Review		
	Fri	**Apr 10**	**Exam #3 at 6:00 pm: Chapters 6, 7**		
34	Mon	Apr 13	Self-recognition, antibodies	11-3	
35	Wed	Apr 15	Lipids, membranes	8-1, 8-2, 8-3	#12
36	Fri	Apr 17	Membrane proteins, potential, transport	8-4, 9-1, 9-2	
37	Mon	Apr 20	Transport proteins, membrane fusion	9-2, 9-3, 9-4	
38	Wed	Apr 22	Signal transduction	10-1, 10-2, 10-3	#13
39	Fri	Apr 24	Cellular signaling	10-3, 10-4	
40	Mon	Apr 27	Review		
	Mon	**Apr 27**	**Graduating senior final exam at 6:00 pm**		
	Mon	**May 4**	**Final exam at 4:00 pm**		

Learning Objectives

Cross-references to textbook chapters are indicated by chapter and sub-chapter in parentheses separated by a dash: (12-3). Most, but not all, of the cross-referenced objectives are also covered in the lecture slides. Objectives that do not have a chapter cross-reference are covered only in the lecture slides.

Recommended textbook problems are indicated by the chapter and problem number separated by a period in square brackets: [8.18]. (See the document on Blackboard for corresponding 2nd edition problems if needed.) Note that some recommended problems come from different chapters than the reading. Not all objectives have corresponding textbook questions; some are only covered in online exercises and concept questions. A combination of textbook problems, concept questions, and online exercises is necessary to thoroughly learn the course material. Textbook questions are especially important for practice drawing structures and writing short answer responses, which you will be expected to do on exams.

Review Material from General & Organic Chemistry

Chapter 1 and later

Basic algebra, such as rearranging equations, solving for unknowns, and the quadratic equation.

Dimensional analysis, units, and unit prefixes.

Significant digits. (Hint: use 3 in this class.)

Nomenclature of simple organic molecules and functional groups, especially amides and carbonyls [1.1, 1.2].

Nomenclature of simple inorganic functional groups, especially aqueous ions such as phosphate.

The concept of equilibrium, equilibrium constants, and Le Chatlier's principle.

Chapter 2 and later

Definition of an acid and base, weak and strong acids and bases.

Intermolecular forces, especially covalent bonds, hydrogen bonding, dipole interactions, and electrostatic interactions [2.2, 2.3].

Chapter 6 and later

Determine the oxidation state of atoms in organic compounds [1.39, 1.40, 1.41].

How to draw organic reaction mechanisms using curved arrow notation.

Simple chemical kinetics, including the definition of reaction rate and rate equations [7.12, 7.13, 7.14].

Chapter 1 (and Chapter 12-3): Biochemical Principles

Fundamental Objectives

Define and correctly use the following terms:

- amino acid (1-2)
- carbohydrate (1-2)
- catalysis (1-3)
- complement (1-4)
- coupled reaction (1-3)
- endergonic (1-3)
- endothermic
- enthalpy, H, ΔH (1-3)
- entropy, S, ΔS (1-3)
- enzyme (1-3)
- equilibrium (12-3)
- evolution (1-4)
- exergonic (1-3)
- exothermic
- Gibbs free energy, G, ΔG (1-3)
- heat
- *in vitro* (1-3)
- *in vivo* (1-3)
- irreversible
- lipids (1-2)
- microstate
- monomer (1-2)
- natural selection (1-4)
- non-spontaneous (1-3)
- nucleic acid (1-2)
- nucleotide (1-2)
- polymer (1-2)
- polysaccharide (1-2)
- protein (1-2)
- reaction quotient, Q
- replication (1-4)
- residue (1-2)
- reversible
- saccharide (1-2)
- small molecule
- spontaneous (1-3)
- standard conditions, standard state (12-3)
- system
- work

Know the following equations:

Δ = final state - initial state = after state - before state = products - reactants (1-3)

$\Delta G = \Delta H - T\Delta S$ (1-3) $\quad \Delta G° = -RT \ln K$ (12-3) $\quad \Delta G_{rxn} = -RT \ln \left(\frac{K}{Q}\right)$ $\quad K = e^{\frac{-\Delta G°}{RT}}$ (12-3)

$\Delta G_{rxn} = \Delta G° + RT \ln Q$

Identify examples of amino acids, carbohydrates, lipids, monomers, nucleic acids, nucleotides, polymers, polysaccharides, proteins, residues, saccharides (1-2) [1.4].

Know what positive and negative values mean with respect to the direction of energy transfer, heat, microstates, work, spontaneous behavior, and equilibrium (1-3).

Know how to write equilibrium constant expressions and reaction quotients for any given reaction (12-3).

Know the physical and biochemical standard state conditions (12-3).

Conceptual Objectives

Describe polymers, their relationship to monomers, and the chemistry of their formation (1-2) [1.3].

Describe the molecular features of saccharides, nucleotides, amino acids, and lipids (1-2)[1.5, 1.7, 1.9, 1.10, 1.11, 1.12, 1.13, 1.15, 1.16].

Explain the general functions of proteins, nucleic acids, and polysaccharides in cells (1-2) [1.20].

Use basic thermodynamic concepts (microstates, path independence, etc.) to explain chemical behavior, *e.g.,* bond formation releases energy, polymer formation [1.23, 1.24, 1.25, 1.34, 1.35].

Calculate ΔG, $\Delta G°$, and $\Delta G°'$ using appropriate equations when provided with relevant values, such as ΔH and ΔS or the equilibrium constant (1-3, 12-3) [1.29, 1.30, 1.33, 12.36].

Calculate the equilibrium constant for a reaction using an appropriate equation when provided with relevant values, such as $\Delta G°$ or concentrations of products and reactants (12-3) [12.41, 12.44a].

Determine the direction of a reaction or sign of ΔG when given any combination of information regarding ΔG_{rxn}, $\Delta G°$, $\Delta G°'$, K, ΔH, ΔS, T, Q, and/or concentrations of products and reactants (1-3, 12-3) [12.35, 12.42].

Use the reaction quotient and K or $\Delta G°$ to calculate ΔG_{rxn} for a reaction (12-3) [12.39, 12.40, 12.43, 12.44b].

Discuss the purpose of thermodynamic standard state and when it is appropriate to use (12-3).

Explain how reaction coupling affects chemical spontaneity (12-3) [1.37, 1.38].

Mastery Objectives

Discuss the development of life from chemical precursors, including the roles of polymers, chemical functional groups, natural selection, self-replication, and ongoing evolution (1-4) [1.45, 1.46].

Use thermodynamic principles and appropriate calculations to rationalize chemical behavior, particularly with respect to reaction coupling with ATP, how reaction conditions determine the direction of a reaction, and the formation of biologically relevant molecules (1-3, 1-4, 12-3) [1.27, 1.28].

Chapter 2: Water Chemistry

Fundamental Objectives

Define and correctly use the following terms:

- acid (2-3)
- aggregate
- amphiphilic, amphipathic (2-2)
- base (2-3)
- bind
- buffer (2-4)
- conjugate (2-3)
- diffusion (2-2)
- hydrogen bond (2-1)
- hydrophilic (2-2)
- hydrophobic (2-2)
- hydrophobic effect (2-2)
- micelle (2-2)
- monoprotic (2-3)
- neutral (2-3)
- non-polar (2-1)
- osmosis
- pH (2-3)
- pK_a, pK (2-3)
- polar (2-1)
- polyprotic (2-3)
- proton jumping (2-3)
- solute (2-1)
- solvated, hydrated (2-1)
- vesicle (2-2)

Know the following equations:

$K_w = [H^+][OH^-] = 10^{-14}$ (2-3)

p = -log (2-3)

$$K_a = \frac{[H^+][A^-]}{[HA]} \quad (2\text{-}3)$$

$$pH = pK_a + \log \frac{[A^-]}{[HA]} \quad (2\text{-}3)$$

Identify and describe the molecular interactions of water with solutes, including hydrogen bonding (2-1, 2-2, 2-3).

Know the difference between and identify strong acids/bases and weak acids/bases (2-3).

Recognize the relative strengths of acids or bases from the functional group structure, K_a, or pK_a (2-3) [2.50].

Identify conjugate acid/base pairs and know how to determine a conjugate acid/base (2-3) [2.45, 2.46, 2.47, 2.48a].

Write the molecular formulas and draw the structures of carbonic acid and phosphoric acid.

Conceptual Objectives

Use basic principles of thermodynamics to explain the behavior of water in biological systems, water autoionization, and the behavior of solutes in water including diffusion and osmosis (2-1, 2-2, 2-3) [2.10, 2.11, 2.16, 2.22, 2.25, 2.34, 2.37].

Calculate the $[H^+]$ and/or $[OH^-]$ in a solution when provided appropriate information (2-3) [2.33, 2.39].

Calculate the pH, pK_a, or base:acid ratio of a buffer (2-3) [2.35, 2.36, 2.41, 2.60].

Calculate the decimal fraction, percentage, and absolute concentration of the acid and base forms of an ionizable substance in a buffer (2-3).

Identify the dominant species or charge state of a molecule when given pH and pK_a (2-3) [2.52, 2.56].

Identify a good buffer system for particular conditions and explain why a buffer would be effective, how buffers maintain pH, the role of buffering capacity, and the effect of adding proton donors, proton acceptors, or other components that change $[H^+]$ to a buffer (2-4) [2.53ab, 2.54ab, 2.57].

Mastery Objectives

Explain the basic thermodynamic principles underlying water chemistry and be able to apply appropriate calculations, including the dominant ionization state of a molecule, the equilibrium constant for a weak acid, blood buffering, and other types of aqueous chemistry in buffered solutions (2-2, 2-3, 2-4) [2.26, 2.29, 2.66].

Chapter 3: Nucleic Acids

Fundamental Objectives

Define and correctly use the following terms:

- 3' end (3-1)
- 5' end (3-1)
- anneal (3-1)
- antiparallel (3-1)
- backbone (3-1)
- base pair, bp (3-1)
- coding strand, sense strand (3-2)
- codon (3-2)
- denature (3-1)
- deoxyribonucleic acid, DNA (3-1)
- double helix, duplex (3-1)
- expression (3-2)
- gene (3-1)
- homologous (3-3)
- kilobase, kb (3-1)
- ligase (3-4)
- major groove (3-1)
- melting temperature (3-1)
- minor groove (3-1)
- mRNA (3-2)
- mutation (3-2)
- noncoding strand, antisense strand (3-2)
- nucleoside (3-1)
- oligonucleotide (3-1)
- phosphodiester bond (3-1)
- plasmid (3-4)
- polymerase (3-1)
- polymerase chain reaction, PCR (3-4)
- polynucleotide (3-1)
- primer (3-4)
- purine (3-1)
- pyrimidine (3-1)
- recombinant DNA, rDNA (3-4)
- renature (3-1)
- replication (3-2)
- restriction endonuclease, restriction enzyme (3-4)
- ribonucleic acid, RNA (3-1)
- rRNA (3-2)
- single nucleotide polymorphism, SNP (3-3)
- stacking interactions (3-1)
- transcribe (3-2)
- translate (3-2)
- tRNA (3-2)

Draw the structures of adenine, cytosine, guanine, thymine, and uracil (3-1) [3.9].

Write the full name, three-letter abbreviation, and one-letter abbreviation for the five standard nucleic acid bases when given any one of the three forms of the name or the structure (3-1).

Conceptual Objectives

Draw the structures of the standard nucleotides, including the appropriate sugar, the sugar-nucleic acid base bonding, and the location and number of phosphates (3-1) [3.11].

Draw the phosphodiester linkage between two nucleotides (3-1) [3.11].

Draw Watson-Crick basepairing between nucleic acid bases (3-1) [3.17].

Use Chargaff's rules to determine the composition of a genome (3-1) [3.14, 3.15, 3.16].

Write the complement of DNA and RNA sequences (3-1) [3.31].

Describe the molecular interactions within DNA and RNA that influence their 3-D structures, including the duplex structure of B-DNA, differences between typical DNA and RNA structures, and the denaturation and renaturation of nucleic acids (3-1) [3.13].

Describe the roles of nucleic acids and the information flow from gene to protein (3-1, 3-2) [3.29, 3.40].

Use a codon table to translate DNA sequences (you do not need to memorize the codon table) and be able to identify when mutations, including SNPs, will change the sequence of a protein (3-2) [3.39, 3.41].

Mastery Objectives

Explain how the basic principles of thermodynamics and molecular interactions determine DNA and RNA structure, behavior, melting temperature, and function (3-1, 3-2) [3.20, 3.22b].

Discuss the process of manipulating DNA sequences and creating recombinant DNA, including the roles of different types of enzymes and of selection, and the applications of rDNA technology, such as transgenic organisms, genetic engineering, and gene therapy (3-4) [3.61].

Chapter 4 (and Chapter 22-4): Protein Structure

Fundamental Objectives

Define and correctly use the following terms: [4.23, 4.24]

α-helix (4-2)
β-sheet (4-2)
C-terminus (4-1)
Cα (4-1)
dimer (4-4)
disulfide bond (4-1)
domain (4-3)
fibrous (4-3)
globular (4-3)
hetero- (4-4)
homo- (4-4)
intrinsically unstructured protein (4-3)
ion pair, salt bridge (4-3)
irregular secondary structure (4-2)
isoelectric point, p*I* (4-5)
loop (4-2)
microenvironment (4-1)
molecular chaperone (4-3)
molten globule
N-terminus (4-1)
native structure (4-3)
NMR spectroscopy (4-5)
peptide bond (4-1)
primary structure (4-1)
post-translational modification
protease (4-5)
protein breathing
quaternary structure (4-1)
random coil
secondary structure (4-1)
subunit (4-4)
tertiary structure (4-1)
tetramer (4-4)
torsion angles, dihedral angles, phi, psi
trimer (4-4)
X-ray crystallography (4-5)
zwitterion

Know the following equation:

$pI = \frac{1}{2}(pK_1 + pK_2)$ (4-5)

Draw the dominant structure for all 20 standard amino acids at pH 7 (4-1).

Write the full name, three-letter abbreviation, and one-letter abbreviation for the 20 standard amino acids when given any one of the three forms of the name or the structure (4-1).

Know the approximate pK_a values for all ionizable groups of the standard 20 amino acids (4-1).

Conceptual Objectives

Draw the structure of peptide bonds and polypeptides (4-1) [4.14, 4.15, 4.16, 4.17].

Determine, draw, or calculate ionization states of standard amino acids at any pH (4-1) [2.49, 4.7, 4.11, 4.12, 4.13].

Recognize, describe, and explain the relevance of amino acid properties, including chirality, polar, non-polar, charged, bulky, aromatic, and sulfur-containing (4-1) [4.1, 4.3, 4.4, 4.10].

Explain which amino acids can act as proton donors or acceptors at physiological pH (4-1).

Calculate the average charge of an amino acid or peptide in a buffered solution.

Describe the structures of α-helices and β-sheets, including residues per turn or parallel vs. antiparallel orientation, location of hydrogen bonding, and side chain orientation (4-2) [4.28, 4.31].

Describe the role of irregular secondary structures and differences from regular structures (4-2).

Explain how torsion angles influence secondary and tertiary structure, interpret Ramachandran diagrams, and explain why Gly and Pro are less common in regular secondary structure [4.29, 4.30].

Recognize and draw chemical modifications to the standard 20 amino acids (4-3) [4.15, 4.17].

Explain the roles of molecular chaperones, the hydrophobic effect, hydrogen bonding, electrostatics, disulfide bonds, metal ions/ligands, and van der Waals interactions in determining the 3-D positions of amino acids in proteins, secondary structure, tertiary structure, quaternary structures, and the folding and denaturing of proteins (4-3, 4-4, 22-4) [4.34, 4.37, 4.40, 4.41, 4.42, 4.43, 4.47].

Calculate the p*I* of amino acids or peptides when provided with pK_a values (4-5) [4.51, 4.52, 4.53, 4.54].

Describe major techniques used to obtain protein sequences and structures (4-5) [4.65, 4.69].

Mastery Objectives

Predict the effects of microenvironment on the pK_a of amino acid side chains in proteins (4-1).

Explain why certain amino acids are more or less frequently observed at particular positions in secondary structures and predict effects of changes to 3-D structure as a result of mutations and post-translational modifications [4.9, 4.35, 4.36, 4.38, 4.45, 4.46, 4.49].

Describe protein folding in terms of the relationship to thermodynamic principles, protein breathing, and folding pathways, including drawing and interpreting folding energy diagrams (4-3) [4.44].

Chapter 5: Protein Function

Fundamental Objectives

Define and correctly use the following terms:

actin (5-2)	cooperative (5-1)	ligand (5-1)	saturated (5-1)
alignment	deoxyhemoglobin (5-1)	microfilament (5-2)	thick filament (5-3)
allosteric (5-1)	dynein	microtubule (5-2)	thin filament (5-3)
bisphosphoglycerate, BPG (5-1)	fractional saturation, *Y* (5-1)	myoglobin (5-1)	triple helix (5-2)
	heme (5-1)	myosin (5-3)	tubulin (5-2)
Bohr effect (5-1)	hemoglobin (5-1)	oxyhemoglobin (5-1)	variable residue (5-1)
coiled coil (5-2)	intermediate filament (5-2)	p_{50}	variant
collagen (5-2)	invariant residue (5-1)	pO_2 (5-1)	
conservative substitution (5-1)	keratin (5-2)	processive (5-3)	
	kinesin (5-3)	prosthetic group (5-1)	

Know the following equations:

$$K_D = \frac{[\text{Protein}][\text{Ligand}]}{[\text{Protein}-\text{Ligand Complex}]} \quad (5\text{-}1) \qquad Y = \frac{[X]}{K_D + [X]} \quad (5\text{-}1) \qquad Y = \frac{(pO_2)^n}{(p_{50})^n + (pO_2)^n}$$

Identify the relationships between binding affinity, K_D, and p_{50} (5-1) [5.6].

Describe the practical meaning and significance of p_{50}, n, K_D, and Y (5-1).

Identify what information can be obtained from protein sequence and structure alignments(5-1).

Conceptual Objectives

Calculate or estimate the K_D for a reaction when provided relevant information (5-1).

Calculate or estimate the decimal fractional saturation or percentage of protein bound to ligand using equations for single ligand and cooperative systems (5-1) [5.13, 5.14, 5.15, 5.16].

Draw and interpret binding curves for single ligand and cooperative systems (5-1) [5.27].

Discuss and predict molecular interactions between any combination of amino acid residues in myoglobin or hemoglobin, heme, iron, and oxygen, when provided relevant facts [5.9, 5.21, 5.23].

Explain effects of BPG, pH, and other p_{50} changes on hemoglobin binding to O_2 (5-1) [5.17, 5.19].

Discuss how allostery can affect binding of ligands and the relationship to the quaternary structure of proteins, cooperativity, and binding affinity (5-1).

Explain and interpret protein sequence alignments, such as identifying functionally important and/or conserved residues, and the relationship to the evolution of proteins (5-1) [5.11, 5.12].

Explain how the structures of keratin and collagen relate to function and repetitive elements (5-2) [5.49, 5.53b].

Describe the function of filaments, and how the structures of filaments are assembled from monomeric units of keratin, actin, and tubulin (5-2) [5.35, 5.39, 5.40, 5.53a].

Describe structure-function relationships in motor proteins (5-3) [5.71, 5.72, 5.78].

Explain the functional relationships between structural proteins and motor proteins (5-2, 5-3).

Mastery Objectives

Explain why structure is more conserved than sequence, how this can be demonstrated, and how this concept manifests itself in natural variation in a protein sequence (5-1).

Make predictions about the role of particular amino acids or what effect specific mutations might have on the structure, function, and/or ligand binding of a protein, such as hemoglobin, when given specific structural, functional, or experimental information [5.7, 5.8, 5.28, 5.31, 5.32].

Describe how the repetitive sequence of fibrous proteins is important for the observed structure of those proteins, how their sequence and structure differs from globular proteins, and how changes to specific molecular interactions, such as with drugs, affect their function (5-2, 5-3) [5.33, 5.41, 5.42, 5.43, 5.44].

Chapter 6: Enzyme Mechanisms

Fundamental Objectives

Define and correctly use the following terms:

- acid-base catalysis (6-2)
- activation energy, free energy of activation, $\Delta G^{\ddagger}$ (6-2)
- active site (6-1)
- activity
- apo
- catalytic triad (6-2)
- chymotrypsin (6-2)
- coenzyme (6-2)
- cofactor (6-2)
- convergent evolution (6-4)
- cosubstrate (6-2)
- covalent catalysis (6-2)
- elastase (6-4)
- holo
- induced fit (6-3)
- intermediate (6-2)
- irreversible step
- isozyme (6-1)
- oxyanion hole (6-3)
- proximity and orientation effects (6-3)
- rate
- rate enhancement (6-1)
- reaction coordinate diagram (6-2)
- reversible step
- serine protease (6-2)
- specificity (6-1)
- specificity pocket (6-4)
- substrate (6-1)
- transition state (6-2)
- trypsin (6-4)
- zymogen (6-4)

Know the following equations:

$$\Delta\Delta G^{\ddagger} = \Delta G^{\ddagger}_{\text{catalyzed}} - \Delta G^{\ddagger}_{\text{uncatalyzed}}$$

$$\text{rate enhancement} = e^{\frac{-\Delta\Delta G^{\ddagger}}{RT}} = \frac{\text{rate}_{\text{catalyzed}}}{\text{rate}_{\text{uncatalyzed}}}$$

Know the six enzyme classes and the reactions catalyzed by enzymes in each class (6-1) [5.56, 6.9, 6.10, 6.11, 6.12, 6.13].

Identify the substrate and the product in an enzyme-catalyzed reaction if given any combination of $\Delta G°$, $\Delta G°'$, ΔG_{rxn}, a reaction scheme, and/or a reaction mechanism (6-1).

Conceptual Objectives

Explain the relationships between reaction rate, rate enhancement, and activation energy (6-1, 6-2) [6.6].

Discuss the roles of cofactors in enzymatic reactions (6-2).

Interpret $\Delta G^{\ddagger}$ and explain the thermodynamics of enzyme catalysis (6-2) [6.23].

Calculate $\Delta\Delta G^{\ddagger}$, rate enhancement, and reaction rate when provided appropriate information [6.3, 6.19].

Identify and fill in missing details for enzyme mechanisms when provided specific information, and explain the role of specific residues in those mechanisms (6-2) [6.2, 6.24, 6.25, 6.26, 6.34a, 6.44].

Draw the complete serine protease mechanism using curved arrow notation, explain the function of all key residues involved, and describe the overall process occuring during the mechanism (6-2) [6.8, 6.60].

Explain the relationships between the 3-D structure of an enzyme, catalysis, the active site, molecular interactions with substrates and products, specific enzyme features such as a specificity pocket or oxyanion hole, and the enzyme function (6-1, 6-2, 6-3, 6-4) [5.64, 6.1, 6.20, 6.52, 6.61a].

Discuss the effect of pH and temperature on catalysis, including the use of molecular arguments to identify which residues are likely causing the effect.

Mastery Objectives

Relate reaction mechanisms to the underlying thermodynamics, including drawing a reaction coordinate diagram to represent a mechanism, choosing an appropriate mechanism to match a reaction coordinate diagram, and explaining reversible and irreversible steps using thermodynamic principles (6-2, 6-3) [6.21].

Make predictions about what effect specific mutations or post-translational modifications might have on the mechanism of an enzyme when provided information about a particular reaction and enzyme, and explain why the effects would occur [6.34b, 6.59, 6.61bc].

Evaluate whether or not a propose enzyme mechanism is consistent with provided data, such as pH effects, required metal ions, and the presence of intermediates.

Chapter 7: Enzyme Kinetics

Fundamental Objectives

Define and correctly use the following terms:

- catalytic constant, turnover number, k_{cat} (7-2)
- catalytic efficiency, k_{cat}/K_M (7-2)
- competitive inhibition (7-3)
- diffusion-controlled limit (7-2)
- enzyme-inhibitor complex, EI (7-3)
- enzyme-substrate complex, ES (7-1)
- enzyme-substrate-inhibitor complex, ESI (7-3)
- feedback inhibition (7-3)
- inhibition constant, K_I, K_I' (7-3)
- inhibitor (7-3)
- initial velocity, v_0 (7-2)
- irreversible inhibitor (7-3)
- maximum velocity, V_{max} (7-2)
- Michaelis constant, K_M (7-2)
- mixed inhibitor, noncompetitive inhibition (7-3)
- negative effector (7-3)
- positive effector (7-3)
- product inhibition (7-3)
- rate constant, k (7-2)
- reaction velocity, v (7-1)
- reversible inhibitor (7-3)
- steady state (7-2)
- suicide substrate (7-3)
- transition state analog (7-3)
- uncompetitive inhibition (7-3)

Know the following equations:

$$v_0 = \frac{V_{max}[S]}{K_M + [S]} = \frac{\Delta[P]}{\Delta t} \quad (7\text{-}2) \qquad v_0 = k_2[ES] \quad (7\text{-}2) \qquad V_{max} = k_2[E]_T \quad (7\text{-}2) \qquad k_{cat} = \frac{V_{max}}{[E]_T} \quad (7\text{-}2)$$

$$\alpha = 1 + \frac{[I]}{K_I} \quad (7\text{-}3) \qquad \alpha' = 1 + \frac{[I]}{K_I'} \qquad K_M^{app} = \frac{\alpha}{\alpha'} K_M \qquad V_{max}^{app} = \frac{1}{\alpha'} V_{max}$$

Write the enzyme reaction scheme that corresponds to Michaelis-Menten kinetics (7-2).

State the steady state assumption in Michaelis-Menten kinetics (7-2).

For each type of inhibition, identify the inhibitor-enzyme complex and effects on apparent K_M and V_{max} (7-3).

Conceptual Objectives

Calculate K_M, V_{max}, v_0, and k_{cat} (7-2) [7.22, 7.23, 7.24, 7.27, 7.28, 7.36].

Interpret the relevance and physical meaning of K_M, V_{max}, v_0, and k_{cat} (7-2) [7.19, 7.20, 7.29, 7.33, 7.34].

Explain the steady state assumption in Michaelis-Menten kinetics and whether or not Michaelis-Menten kinetics is appropriate to use for a particular reaction (7-2) [7.37a].

Calculate or estimate k_{cat}/K_M, explain why it is a measure of catalytic efficiency, and discuss why diffusion limits efficiency (7-2) [7.35].

Calculate α, α', K_I, K_I', v_0, and apparent K_M and V_{max} values for a reaction when an inhibitor is present (7-3).

Sketch Michaelis-Menten and Lineweaver-Burk plots when given appropriate information (7-2, 7-3).

Interpret Michaelis-Menten and Lineweaver-Burk plots when provided to you, including using the plots to estimate v_0, V_{max}, and K_M, and determine the type of inhibition (7-2, 7-3) [7.25, 7.26, 7.31, 7.39, 7.54, 7.55].

Explain how and why competitive, uncompetitive, and mixed inhibitors differ in their effect on the enzyme reaction and mechanism, and identify the type of inhibition from those effects (7-3) [7.42].

Explain mechanisms for regulation of enzymes, including feedback inhibition, product inhibition, and effectors, and how that regulation influences reaction rate (7-3) [6.68, 7.61, 7.63].

Mastery Objectives

Make predictions about what effect specific mutations might have on the overall reaction rate of an enzyme when provided information about a particular reaction and enzyme [7.39, 7.40].

Use molecular arguments to describe inhibitor effects on reaction rates, including possible enzyme, substrate, and inhibitor complexes, and effects on the reaction mechanism (7-3) [7.41, 7.47].

Describe why transition state analogs can be effective enzyme inhibitors and explain the molecular features that make them effective (7-3) [7.49].

Chapter 11: Carbohydrates

Fundamental Objectives

Define and correctly use the following terms: [11.1, 11.2, 11.7, 11.8, 11.9]

- ABO blood types (11-3)
- aldose (11-1)
- anomer (11-1)
- antibody
- antigen
- biofilm (11-2)
- cellulose (11-2)
- chitin (11-2)
- epimer (11-1)
- glycogen (11-2)
- glycoside (11-1)
- glycosidic bond (11-1)
- glycosylation (11-3)
- hexose (11-1)
- ketose (11-1)
- lectin
- lignin (11-2)
- N-linked oligosaccharide (11-3)
- O-linked oligosaccharide (11-3)
- pentose (11-1)
- peptidoglycan (11-3)
- proteoglycan (11-3)
- reducing sugar (11-1)
- starch (11-2)
- tetrose (11-1)

Draw both the linear and cyclic structures of glucose, galactose, fructose, and ribose (11-1) [1.14, 1.21, 11.10].

Recognize common types of saccharide modifications, such as amination, acetylation, phosphorylation, and oxidation/reduction (11-1) [11.55].

Identify the common roles of polysaccharides, including cellulose, chitin, glycogen, and starch (11-2).

Identify the amino acid residues to which saccharides are commonly attached (11-3).

Conceptual Objectives

Describe how sugars interconvert between linear and cyclic forms, including identifying the atoms involved in the reaction mechanism and the relative stability of cyclic forms (11-1) [11.14, 11.19, 11.20].

Describe how sugars covalently bond into disaccharides and polysaccharides, including identifying the anomeric carbon, identifying the reducing end of a polysaccharide, and explaining the difference between α- and β-linkages (11-2) [11.31, 11.33, 11.34].

Discuss how 3-D structure influences the functional roles of common polysaccharides, such as cellulose, chitin, starch, and glycogen, including the importance of the monomer structure, modifications to the base saccharide monomer, and the effect of anomeric linkages and branch points (11-2).

Discuss the molecular structures, monomer components, protein-saccharide bonds, and roles of saccharide-protein hybrids, including the extracellular matrix, cell walls, and the role of carbohydrates as antigens (11-3) [11.53, 11.57].

Describe the structure and function of antibodies, and how antibodies interact with antigens [8.19].

Mastery Objectives

Discuss the role of carbohydrates in complex life processes, such as cellular signaling and organisms' abilities to recognize their own cells (*e.g.*, as with lectins), and how the diversity of saccharides and modifications to the saccharides contributes to these roles (11-3).

Chapter 8: Lipids

Fundamental Objectives

Define and correctly use the following terms:

- extrinsic membrane protein, peripheral membrane protein (8-3)
- fatty acid (8-1)
- fluid mosaic model (8-4)
- glycerophospholipid, phospholipid (8-1)
- intrinsic membrane protein, integral membrane protein (8-3)
- isoprenoid (8-1)
- lateral diffusion (8-2)
- lipid anchor
- lipid bilayer (8-1)
- lipid raft, membrane raft (8-2)
- lipid-linked protein (8-3)
- sphingolipid (8-1)
- steroid (8-1)
- transmembrane helix (8-3)
- transverse diffusion (8-2)
- triacylglycerol (triglyceride) (8-1)
- β-barrel (8-3)

Identify the different types of lipids and their distinguishing molecular features (8-1) [8.21].

Identify the common biological roles of different types of lipids (8-1).

Conceptual Objectives

Explain how the structure of lipids relates to their biological roles and why specific lipids are used for particular purposes from both a structural and a thermodynamic perspective (8-1) [8.17, 8.18, 8.29, 8.33, 8.34, 11.21].

Discuss the role of lipids in lipid bilayers, including glycerophospholipids, sphingolipids, and cholesterol, including formation of lipid rafts and how the hydrophobic effect relates to bilayer formation (8-2).

Describe molecular characteristics of membrane proteins, including the known approaches for associating proteins with the membrane and the role of lipid anchors (8-3) [8.46, 8.47, 8.49, 8.50].

Discuss the fluid mosaic model of membranes, including how it relates to the concept of lipid rafts and why membranes are asymmetric (8-4) [8.43].

Mastery Objectives

Describe the differences between the types of lipid anchors, how those lipids influence the membrane association of proteins, how lipid-linked proteins differ from integral membrane proteins, and how the association of proteins with the membrane relates to underlying thermodynamic principles (8-3) [8.48].

Chapter 9: Membrane Transport

Fundamental Objectives

Define and correctly use the following terms:

- ABC transporter (9-3)
- active transport (9-1)
- antiport (9-2)
- aquaporin (9-2)
- conformational change transporter (9-2)
- gated channel (9-2)
- ion channel (9-2)
- membrane potential, Δψ (9-1)
- Na,K-ATPase (9-3)
- neurotransmitter (9-4)
- passive transport (9-1)
- passive-mediated transport
- porin (9-2)
- secondary active transport (9-3)
- SNARE (9-4)
- symport (9-2)
- uniport (9-2)

Know the following equations:

$$\Delta\psi = \frac{RT}{Z\mathcal{F}} \ln \frac{[\text{ion}]_{in}}{[\text{ion}]_{out}} \quad (9\text{-}1) \qquad \Delta G_{trans} = RT \ln \frac{[X]_{in}}{[X]_{out}} + Z\mathcal{F}\Delta\psi \quad (9\text{-}1)$$

Know how the molecular features of solute structure, solute concentration, and the sign of ΔG for the transport process determine whether a solute will passively diffuse or needs to be transported using passive or active processes (9-1) [2.58, 9.16].

Conceptual Objectives

Explain how membrane potential relates to the distribution and charges of solutes in cells and use the membrane potential to calculate concentrations of ions on either side of a membrane (9-1) [9.1, 9.2, 9.7, 9.9].

Calculate the ΔG value for membrane transport (9-1) [9.3, 9.4, 9.5, 9.10].

Describe the amino acid composition, structure, and solute selectivity of integral membrane proteins involved in passive and active transport, and the possible effects of mutations or inhibitors on the transport (9-2) [9.17, 9.18, 9.20, 9.22, 9.41].

Describe neurotransmitter transport, including the role of membrane fusion and the function of SNARE proteins (9-4) [9.47, 9.48, 9.51, 9.52].

Mastery Objectives

Explain how secondary active transport takes advantage of both active and passive processes, including interpreting or providing concrete examples, and be able to give examples of when secondary active transport is used (9-3) [9.44].

Relate membrane transport to underlying thermodynamic and kinetic processes, and explain how membrane transport can be coupled to other processes such as the generation of ATP.

Chapter 10: Cellular Signaling

Fundamental Objectives

Define and correctly use the following terms:

- agonist (10-1)
- antagonist (10-1)
- cAMP (10-2)
- eicosanoid (10-4)
- G protein (10-1)
- G protein coupled receptor (10-1)
- hormone (10-1)
- kinase (10-1)
- nuclear receptor (10-4)
- phosphatase (10-2)
- receptor (10-1)
- receptor tyrosine kinase (10-1)
- second messenger (10-1)
- signal transduction (10)
- transcription factor (10-3)

Know the roles of different types of signaling molecules in cellular signaling (10-4).

Identify the molecular classes of signaling molecules, including recognizing the structural changes involved in creating amino acid-derived hormones from the original amino acids (10-4) [10.22].

Conceptual Objectives

Describe the mechanisms and importance of signal amplification, signal duration, and reset mechanisms in signal transduction (10-1) [10.19, 10.20, 10.33].

Use binding plots and the principles of equilibrium to describe receptor-ligand binding (10-1) [10.5].

Describe the structure and function of G proteins and GPCRs, and the general signaling mechanism of GPCRs, including the role of second messengers (10-2) [10.17, 10.18].

Describe the function of receptor tyrosine kinases and their general signaling mechanism (10-3).

Describe the function of nuclear receptors and their general signaling mechanism (10-4).

Explain how phosphorylation can affect protein structure and function, on what residues phosphorylation is observed, and the role of kinases and phosphatases (10-2, 10-3, 10-4).

Explain how the structure of a ligand determines the type of receptor that will likely bind to the ligand (10-2, 10-3, 10-4) [8.51, 10.1, 10.2].

Mastery Objectives

Explain how signaling processes relate to the basic principles of thermodynamics, protein structure, ligand binding, and enzyme catalysis discussed throughout the course, and the role of these principles in complex signaling behavior such as competition between signals [10.34, 10.55, 10.59, 10.60].

Additional Resources (Interactive Tools, Animations, Tutorials, etc.)

Chapter 1

Equilibrium Tutorial: http://www.chemcollective.org/tutorials.php

Chapter 2

Acid-Base Tutorial: http://www.chemcollective.org/tutorials.php

Chapter 3

DNA: http://www.hhmi.org/biointeractive/chemical-structure-dna

Site-directed mutagenesis: http://higheredbcs.wiley.com/legacy/college/voet/0470129301/animated_figs/ch03/3-30.html

Transcription and translation:
http://higheredbcs.wiley.com/legacy/college/voet/0470129301/guided_exp/guided_exploration_1/transc_transl.html

DNA replication: http://www.wiley.com//legacy/college/boyer/0470003790/animations/replication/replication.htm

DNA sequencing: http://higheredbcs.wiley.com/legacy/college/voet/0470129301/guided_exp/guided_exploration_2/dna_sequence.html

PCR: http://higheredbcs.wiley.com/legacy/college/voet/0470129301/guided_exp/guided_exploration_3/pcr_mutagenesis.html

PCR: http://www.wiley.com//legacy/college/boyer/0470003790/animations/pcr/pcr.htm

PCR: http://www.hhmi.org/biointeractive/polymerase-chain-reaction

Cloning: http://www.wiley.com//legacy/college/boyer/0470003790/animations/cloning/cloning.htm

Chapter 4

Amino acid apps: many apps to learn amino acids are available for mobile devices, check the app store

Secondary structure:
http://higheredbcs.wiley.com/legacy/college/voet/0470129301/guided_exp/guided_exploration_8/protein_secondary_struc.html

The α-helix: http://higheredbcs.wiley.com/legacy/college/voet/0470129301/animated_figs/ch06/6-7.html

The α-helix: http://higheredbcs.wiley.com/legacy/college/voet/0470129301/guided_exp/guided_exploration_6/alpha_helix.html

β-sheets: http://higheredbcs.wiley.com/legacy/college/voet/0470129301/animated_figs/ch06/6-9.html

β-sheets: http://higheredbcs.wiley.com/legacy/college/voet/0470129301/guided_exp/guided_exploration_7/beta_sheets_h_bond.html

Protein disulfide isomerase: http://higheredbcs.wiley.com/legacy/college/voet/0470129301/animated_figs/ch06/6-42.html

Protein folding: http://www.wiley.com//legacy/college/boyer/0470003790/animations/protein_folding/protein_folding.htm

Protein folding game: http://fold.it/portal/

Protein sequence determination:
http://higheredbcs.wiley.com/legacy/college/voet/0470129301/guided_exp/guided_exploration_4/protein_sequence.html

Chapter 5

Oxygen binding in hemoglobin: http://higheredbcs.wiley.com/legacy/college/voet/0470129301/animated_figs/ch07/7-6.html

Movement in hemoglobin: http://higheredbcs.wiley.com/legacy/college/voet/0470129301/animated_figs/ch07/7-8.html

The Bohr Effect: http://higheredbcs.wiley.com/legacy/college/voet/0470129301/animated_figs/ch07/7-11.html

Effect of BPG on hemoglobin: http://higheredbcs.wiley.com/legacy/college/voet/0470129301/animated_figs/ch07/7-13.html

Kinesin walking: https://www.youtube.com/watch?v=YAva4g3Pk6k

Chapter 6

Serine proteases:
http://higheredbcs.wiley.com/legacy/college/voet/0470129301/guided_exp/guided_exploration_10/serine_proteases.html

Enzyme specificity: http://www.wiley.com//legacy/college/boyer/0470003790/animations/enzyme_binding/enzyme_binding.htm

Transition state binding: http://higheredbcs.wiley.com/legacy/college/voet/0470129301/animated_figs/ch11/11-15.html

Chapter 7

Progress curves for enzyme-catalyzed reaction:
http://higheredbcs.wiley.com/legacy/college/voet/0470129301/animated_figs/ch12/12-2.html

Michaelis-Menten kinetics:
http://higheredbcs.wiley.com/legacy/college/voet/0470129301/guided_exp/guided_exploration_11/michaelis_menten.html

Michaelis-Menten kinetics: http://www.wiley.com/college/pratt/0471393878/instructor/animations/enzyme_kinetics/index.html

Plot of initial velocity versus substrate concentration:
http://higheredbcs.wiley.com/legacy/college/voet/0470129301/animated_figs/ch12/12-3.html

Enzyme inhibition: http://www.wiley.com//legacy/college/boyer/0470003790/animations/enzyme_inhibition/enzyme_inhibition.htm

Double-reciprocal (Lineweaver-Burk) plot:
http://higheredbcs.wiley.com/legacy/college/voet/0470129301/animated_figs/ch12/12-4.html

Lineweaver-Burk plot of competitive inhibition:
http://higheredbcs.wiley.com/legacy/college/voet/0470129301/animated_figs/ch12/12-7.html

Lineweaver-Burk plot of uncompetitive inhibition:
http://higheredbcs.wiley.com/legacy/college/voet/0470129301/animated_figs/ch12/12-8.html

Lineweaver-Burk plot of mixed/noncompetitive inhibition:
http://higheredbcs.wiley.com/legacy/college/voet/0470129301/animated_figs/ch12/12-9.html

Plot of v_0 versus [aspartate] for ATCase: http://higheredbcs.wiley.com/legacy/college/voet/0470129301/animated_figs/ch12/12-10.html

Chapter 11

Glucose transport: http://higheredbcs.wiley.com/legacy/college/voet/0470129301/animated_figs/ch10/10-13.html

Chapter 9

Cellular transport:
http://www.wiley.com//legacy/college/boyer/0470003790/animations/membrane_transport/membrane_transport.htm

ATP synthase: https://www.youtube.com/watch?v=3y1dO4nNaKY

Chapter 10

Signal transduction:
http://www.wiley.com//legacy/college/boyer/0470003790/animations/signal_transduction/signal_transduction.htm