

# BCMB 307      Fall 2007

## Physical Chemistry for the Life Sciences

**Instructor:** Dr. Codrina Popescu

Office: Pfahler 303D Telephone: x2676; e-mail: cpopescu@ursinus.edu

**Class Schedule:** MWF 11:00 -11:50 am in Thomas 319

Optional problem solving sessions -upon agreement with the class- are to be held at least before scheduled exams.

**Office Hours:** Monday: 1:30-4:00 pm; Thursday 11:00-12:00; Friday 1:30-3:30 or by appointment (made personally or by e-mail).

Prerequisites: Chemistry 206; Math 112; Physics 111Q

**Textbooks:** Required are two books, available in the bookstore and library:

*Tinoco, Sauer, Wang and Puglisi, Physical Chemistry: Principles and Applications in Biological Sciences* (This is the textbook for the course.);

*Barrante, James R., Applied Mathematics for Physical Chemistry (1998)* – a necessary mathematics complement.

**Other useful books:** (check library) *David M. Eisenberg and Donald S. Crothers, Physical Chemistry with Applications for the Life Sciences (1979);*

*Ira N. Levine, Physical Chemistry, Fifth Ed. (2002);*

*P.W. Atkins and De Paula, Physical Chemistry (2002).*

<b>Grading</b> Homework Assignments: Problem Sets (8)	100p
Scientist reports and final presentation	50p
Quizzes (6 quizzesX25p)	150p
Exam I, II, III	3X100p
<u>Final Exam</u>	<u>200p</u>
Total	800 p

Approximate cutoffs: A >85% (superior)

B: >75% (very good)

C: >65% (average)

D: >55% (below average)

Under 55%: F (unsatisfactory)

**Examinations:** there will be three exams during the semester and one final exam. Exams start promptly at 11:00 am. According to our first day agreement they will end after 1hr or 1hr and 15 minutes.

Exam I: September 26

Exam III: November, 28

Exam II: October 24

**Final: December, 15, 2006, 9-12am, Thomas 319.**

**Objectives and brief description:** This course gives an exposure to Physical Chemistry to students who have chosen the Biochemistry, pre-med and other life sciences tracks. We will cover chemical thermodynamics, equilibrium and kinetics (including enzyme kinetics), with problems that emphasize their significance for Chemistry, Biochemistry and Biology.

What distinguishes this class from CHEM 309? While the fundamental theory is the same, all the applications in *P-Chem for the Life Sciences* are selected directly from biochemistry. Examples of such applications are the study of the thermodynamics of metabolism, biological redox reactions, double strand formation in nucleic acids, equilibrium and energetics of protein denaturation, buffers, osmosis and dialysis, enzyme kinetics, etc.

**Goals:** - To build the *vocabulary of terms and concepts* in Physical Chemistry.

- To *connect fundamental theories of chemistry and physics with biological processes* and emphasize the global nature of the former. Understanding the chemical and physical mechanisms at the root of biological processes is the key to modern research and development in the life sciences.

- To develop *logical reasoning and deduction skills*, specific to the physical sciences. This thinking style is based on understanding concepts behind natural physical laws (e.g. the laws of Thermodynamics).

- To build *problem solving skills and independent thinking*. Solving problems in this course may be different from other courses; it is not algorithmic (that is, one cannot provide a general set of steps that could be employed for all problems). Each problem may necessitate a different approach, that must be deduced based on concepts learned.

- To develop *integrative abilities*. What you learn in one chapter forms the basis for the next chapter. Thus, you are expected to study every week and to not forget from one chapter to the next.

### **Description of Assignments and Policies:**

1. *Problem sets* (6-8 in total, 10% of grade) *are obligatory*. You must turn in ALL the problems sets that are handed out. They will be handed out in class and will be collected on the “due date”. Two or three *representative* problems from each problem set will be graded. Due dates will be written on assignments, posted and announced in class. Late homework will not be accepted, unless exceptional circumstances have been announced (sickness, justified absence, etc.).

2. *Practice problem sets are optional*, but strongly recommended. These are additional problem sets that will not be collected, nor graded.

**Homework policy:** You are encouraged to work together on homework assignments. However, the work you submit cannot be copied directly from another student’s work and cannot be submitted through e-mail, faxed etc, unless specific emergency procedures have been approved prior to submission. Each assignment must indicate the names of all group members. If identical work is submitted by people who did not belong to the same group, both students will receive no credit for the assignment. All group members must participate in good faith in preparing solutions to the problem sets. It is a serious breach of ethics to include the name of someone who did not contribute.

3. *Independent project* (5% of the grade, emphasis on “independent”) – see page 6.

4. *Quizzes* (15% of the grade, 5 quizzes). Quizzes are not formally announced, but tentative dates are sketched in the syllabus, for your benefit. Typically, they are announced one class in advance. Do not expect the exact same problems from class or homework to show up in the quizzes. ☺

5. *Exams* (45%+25%). The dates and times are indicated below. No make up exams are given. Always be on time. If you arrive late after the first student has finished, you will not be allowed to take the exam and will have a zero in that exam. In case of legitimate reasons for absence in the exam, you will notify me in advance and we will schedule you to take the exam EARLIER than the scheduled time. In case of a sudden illness or event that precludes you from taking the exam at the scheduled time, you must notify me as soon as the situation permits. Naturally, I will work with you to reschedule the exam.

Exams have the largest ponder in your grade in this class. However, you will need to work on problem sets every week much more than you work before an exam.

*Note on formulae sheets: Create your own list of formulae, within one half of an 8”/11” sheet. Show list to me before exam. Only approved formulae are allowed.*

5. *Problem Sessions:* I found it useful to gather the whole class in problem solving sessions outside the normal class schedule. For this to work, you must agree upon a common time and place to meet. The second requirement is that you do the problems and come with pertinent questions. Usually the first extra session is a review of calculus.

6. *Feedback about the class:* I urge you to express your opinions about the course, as the class progresses. Do not hesitate to come to me and indicate what works or does not work for you. I am always open to your suggestions regarding the style, the pace and even (when appropriate) the contents of the class.

7. *Attendance:* According to the college policy, I hereby establish the attendance policy. If you miss over six class sessions (with no justification) you run the risk of failing the class; you will get warning slips starting with the fourth unjustified absence. Beyond six absences you will need a note from your advisor and the dean in order to continue attending this class.

8. *Class notes* and assignments are of prime importance for preparation and success in this course.

9. *Class participation:* I intentionally refrain from delivering long monologues. I encourage your participation by asking questions and pertinent comments. However, class participation is not graded.

10. *A final note:* Physical Chemistry has a reputation of being difficult. I do not deny that it can be hard at times. This has not stopped the majority of the students who took this class from enjoying it and being successful. Is there a way to make this easy? Perhaps not easy, because all the successful students testify that they worked hard. But work was enjoyable and success gave great satisfaction. What is the trick? Some will say, it's calculus. In part, yes, that is why we start this semester with a primer of calculus. I would argue that knowing calculus before you start the class is not essential. But if you know that you don't know it, you must work hard from the beginning and not give up when it gets hard.

I make a pledge that I will give you the tools, (calculus, elements of physics) the theory, (laws, theorems, formulae derivations, logic of experiments) and sometimes examples to guide you through the rough spots. Your job is to take notes, ask questions, and put 100% effort outside of class in working with the notes and the book, until you feel that you can attack problems. Independent work is the key to problem solving. In my experience, students who do not work at least nine hours a week are not successful in this class. And again, whenever you feel like talking, even if you don't quite know how or what to ask, drop by my office. I will be either in, or close by.

#### ◆ **Rules and Expectations**

Main rule #1: My responsibility is to teach, your responsibility is to learn. Be proactive about having your questions and concerns answered.

Main rule #2: If you hand in your work on time, it is my first priority to bring it back graded within two weeks. If you hand in work late, it will be at the bottom of my grading pile and I do not guarantee a date of return.

My goal is to make you comfortable in the encounter with problems and questions that require independent thinking. You are expected to **be active in class and work on your own out of class**. I require your commitment to invest time and effort.

My minimal expectations from you:

- 1) In class: Take notes and ask questions; be active; I often use short-hand notation, so you must pay attention. Your notes will not always look clean, complete and legible. See item 2.
- 2) When the class is over, read and correct any mistakes you find in your notes. When you study, take the textbook and your notes and make a clean, complete copy of your notes in a notebook or on new sheets of paper. This way, you will know what you don't understand from class and will be immediately able to ask questions in office hours or the next class. Keep your notes and homework sets organized.
- 3) Check Blackboard every week. Solve all the problems posted. Be proactive about getting the answer keys to problems.
- 4) Read the notes from the past class when you come to class. It is your responsibility to keep the continuity of the material in your head and to make connections.
- 5) *Have a current list of all formulae given in class.* If I indicate that a derivation is important, make sure you know it.

- 6) Solve all the problems assigned; attempt all problems in the book. Come to ask questions if you don't know how to solve a problem. Keep a current record of your problems, which you can reuse when reviewing for exams.
- 7) Work at the pace of the class, do not fall behind. The pace of the lectures will vary, but it is usually alert.
- 8) Get help promptly if you fall behind. Ask all the questions you have! There is no such thing as a stupid question.

### College policies that apply to this class:

**Inclement weather:** Commuting students will identify themselves to me and give me a phone number at which they can be reached in case of class cancellation. The college has a special number (610-409-3700) where students can call to get a message from the dean about "inclement weather days". If classes are canceled for inclement weather, commuter students will be excused in case of absence.

**Academic Honesty: Plagiarism and cheating:** All writing assignments must be prepared individually. Do not copy solutions from the solution manual. Should you include any written material from the World Wide Web, original articles or books in your assignments, exercise particular care in using proper citation and precise references.

The college imposes severe penalties on students who cheat. Please read the *Student Handbook* on academic honesty, plagiarism, and procedures for suspected academic honesty violations for further details. The students will read and sign the attached "Statement of Academic Honesty", they will keep one copy and return the other to me in the first week of class.

### TENTATIVE SCHEDULE of TOPICS (Subject to updates, as necessary)

(dates for problem sets are APPROXIMATE; always pay attention to announcements made in class)

M	W	F	Chapters/Reading (Tinoco page #)
Week1 8/27 PS 1 (3 parts: a, b and c) 1. Introduction to PChem.	8/29 2. Review of elements of calculus applied to Thermodynamics: 1. Partial derivative	8/31 3. Exact Differentials. Euler's Criterion for exactness, State Functions	Chapter 1- independent reading  Selections, Barrante Ch. 2/15-18, 29-36
Week 2 9/03 PS 2 4. More differentials: identities with partial derivatives in the (P,V,T) space	9/05 5. Some properties of gases, derived from state functions: $\alpha$ , $\kappa$ , $C_p$ , $C_v$ .	9/07 6. Work and Heat	18-28  28, 29, 36
Week 3 9/10 7. The First Law. Enthalpy, heat capacities	9/12 8. Perfect Gases and the First Law of Thermo. Calculation of first law quantities)	9/14 9. Phase changes. Thermal Equilibrium	36-47  47-56
Week 4 9/17 10. Thermochemistry (Reaction enthalpies)	9/19 11. Dissociation energies <b>Up to Lecture 11 for Exam I</b>	9/21 12. Carnot's Cycle and heat engines.	53  Whole Chapter 2
Week 5 9/24 Second Law of Thermodynamics <b>PS3</b> out	9/26 <b>Exam I</b>	<b>9/28</b> Entropy	69-75  73-81
Week 6 10/01 14. Entropy changes in processes of the ideal gas and phase changes	10/03 PS 4 15. The Third Law Entropy changes in reactions	10/05 16. Intro in Gibbs and Helmholtz energy	Read: 87-97  Indep. Reading 97-106; 91-95
Week 7 10/08 <b>PS3 due</b> PS4 out 17. Temperature and pressure dependence of $\Delta G$	10/10 <b>QUIZ 2: On Entropy</b> 18. Applications of $\Delta G$ ( $\Delta A$ ) to some biochemical processes (non-covalent interactions)	10/12 19. Relations among partial derivatives (the Gibbs equations, the Maxwell rel.)	106-111  112-113

Week 8 10/15 Fall Break <b>No class this Monday</b>	10/17 <b>PS4 due</b> 19. Relations among partial derivatives (the Gibbs equations, the Maxwell rel.) 20. Calculations of changes in state functions	<b>10/19 QUIZ 3</b> 20. Calculations of changes in state functions PS5 <b>FIRST REPORT</b>	<b>Ch.4/120-127</b> 127/Example 4.2  131-137
Week 9 10/22 21. Free Energy and Chemical Equilibria – Chemical Potential	10/24 <b>Exam II</b> <b>Material up to chemical potential, including the definition of Chemical Potential</b>	10/26 PS6 22. Equilibrium constant in ideal gas reactions. Relation of $\Delta G^\circ$ with K Activity, standard states	144-150
Wk 10 10/29 Activity, standard states Give OUT PS5; PS 6 <b>SECOND REPORT</b>	10/31 Standards; Calculation of equilibrium concentration: buffers Free energy of Galvanic cells	11/01 Applications of $\Delta G$ and K to some biochemical processes (ATP hydrolysis)	142-149 153-158
Week 11 11/05 <b>PS 5 due</b> Van't Hoff's Equation	11/07 <b>Quiz 4 ☺</b>  Van't Hoff Physical Equilibria:	11/09 Physical Equilibria Colligative properties <b>THIRD REPORT</b>	150-153 187-191 <b>Ch 5:</b> 193-195
Week 12 - 11/12 26. Ligand binding. Osmotic pressure; <b>PS 6 due</b> PS 7	PS7 due 11/14 27. <b>Chemiosmotic theory, ion gradients etc.</b>	11/16 <b>Quiz 5</b>  28. Kinetics: Experimental Determination of rate laws	236-241  314-338
Week 13 11/19 <b>29. Ch.7: Kinetics:</b> Kinetic Rate constant Types of reaction rates by order <b>BRING OUTLINE TO CLASS; COME FOR SHORT MEETING AFTER 1 PM</b>	<b>11/21</b> Thanksgiving	<b>11/23</b>	338-340  <i>Outline discussed in office</i>
Week 14 11/26 30. Reaction mechanisms: rate determining step in a sequence of reactions. Consecutive reactions	11/28 <b>Exam III</b>	11/30 31. Complex reactions and approximations	341-350  351-354 <b>DISCUSS DRAFT OF PRESENTATION</b>
Week 15 12/03 <b>Presentations</b>	12/05 <b>Quiz 6</b> PS 8 due 32. Arrhenius Law + Enzyme kinetics	12/07 33. Michaelis-Menten kinetics FINAL EXAM 11/15, 9-12	354-359 400-411

### Independent Project:

This is an independent reading, research, writing and oral communication assignment. The idea behind this assignment is to make us talk about science beyond what we study in class. The emphasis is on *independent* original work. Students approach this project in one of two ways. One is to start from a personality. Let's say you have heard in Biochem about Linus Pauling and you want to know more about the elucidation of the helical structure of proteins. You should find and use primary sources (original articles) about his scientific pursuit; you should also read about Pauling's life, perhaps find anecdotes and stories about how he came up with the helical structure; present these in written short reports and a final talk. Other students start from a scientific discovery (say, PCR, or nervous signal transduction) and search the most important scientist in that field. Your task will be to present the discovery and the person(s) behind it.

Below are only a few examples of scientists whose names come to mind. You should choose a biochemist or a chemist that inspires you to read more about her/his work. **You need to have my approval of the scientist you will work on!**

Kary Mullis (see book "The Unusual Origin of the Polymerase Chain Reaction," Scientific American, April 1990, pp. 56-65.); Linus Pauling, Watson and Crick, Dorothy Hodgkins, Max Delbruck, Gunter Blobel, Arvid Carlsson. For more scientists please visit <http://www.nobel.se/medicine/laureates/2003> and <http://www.nobel.se/chemistry/laureates/2003>

**Schedule:**

**Report 1:** Search and find 1-2 great (or at least significant!) achievements of the scientist, based on which you consider him/her great.

- Who is she/he?
- Why did you choose her/him?
- What are the greater scientific achievements?
- What consequences had the discoveries they made for the history of science and human kind?
- One story or anecdote from her/his life.

**Report 2:** At this stage I will meet with you to see where each of you is going.

- Search and find the original paper describing the discovery your scientist made.
- Discuss the scientific principles at the basis of the discovery, in your own words. Make one-two schemes describing the machine, experiment, apparatus that was used. (For instance if your scientist is Ernest Rutherford, depict the experiment in which he focused the beam of  $\alpha$  particles onto a gold sheet and describe what was he looking for (how atoms are built) the previous assumptions that were made at the time (people thought in those days that the electrons in an atom are like the raisins in a round cake), the basic principle that emerged from his experiment (the planetary model for the atom).
- Explain the principles to someone else. Discuss this with colleagues regardless of their major.
- Write **a report** (one page) on your discussion.

**Report 3:** Now focus on the experimental section. What materials, methods, what instruments were available, described and used by your scientist.

- Write a report in scientific style, (one-two pages, figures and schemes required) as if you were describing the discovery to a committee of scientists. If the discovery is a formula and there is no experimental section, make a good attempt to understand the proofs, the applications etc. Come see me.

**Final Synoptic Report:** (peer reviewed) Based on the reports you have written for the past three meetings, write a 1 page bulleted outline on the great discovery and the scientist you have studied. Prepare the important things you want to include in your 7 -10 minutes presentation.

**Guidelines:** 1. The reports will be one page. Always proof read your work. Your colleagues will grade on content, but points will be subtracted for sloppy writing, spelling errors and typos.

2. Generally, devote most of the time to the science and less to the personal aspects. Discuss with me. Bring drafts, etc.

3. Do not copy text sections from the Internet. Use your own writing skills. If you copy a sentence or a section from any source, put it in quotation marks and give the reference.

4. Be CLEAR, PRECISE and CONCISE.

**The Synoptic Report:** 1. Introduction: See Report 1.

2. Main discussion: historical scientific context and the breakthrough made by your scientist.
3. Conclusion: impact on the development of scientific ideas of today.

**The talk** will have the same structure with the synopsis; it will be based on all your findings during the semester. In my experience in 10 minutes you may cover at most 5 slides if they contain concepts, sometime 6 or 7 if some of them are only pictures to be shown for 10 seconds. Limit yourself to 5-7 slides, including title and acknowledgments. We will make arrangements to accommodate you if your talk is longer (15 minutes, maximum).

**Grading:** You will not be given final grades for individual reports. I will make an estimate in percent to give a relative grade for each report. I will also make comments and suggestions of what you need to improve in your next report. I hope this way the last report will be perfect.