CHEC 352 - PHYSICAL CHEMISTRY AND APPLICATIONS II

SPRING TERM, 2015

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Office Hours: One hour before each class

A. COURSE OBJECTIVES/DESCRIPTION

This is a 4-credit course covering selected topics based upon selected topics from electrochemistry and quantum mechanics. Specifically, it will deal with properties of ions in solution under both ideal and non-ideal conditions, the driving forces that influence the operation of batteries, activity effects, the influence of electric fields, concentration gradients, and convection on the motions of ions and neutral molecules, the failures of classical physics to adequately describe atomic systems, and the concepts of quantum mechanics applied to simple systems.

B. PREREQUISITES

(PHYS 211 or PHYS 102 or PHYS 201 or PHYS 153 or PHYS 115) and
(CHEM 252 or CHEM 253 or ENGR 210 or TDEC 202)

C. REQUIRED TEXTBOOK

Physical Chemistry: Thermodynamics, Structure, and Change, 10th Edition by Peter Atkins and Julio de Paula, W.H. Freeman and Company   (2014)

D. CLASS MEETINGS

Monday and Wednesday Evenings from 6:00 P.M. to 7:45 P.M. in Disque Hall, Room 108

E. COURSE LEARNER OBJECTIVES

Upon completion of this course the student should understand:
- the thermodynamic aspects of electrochemical systems
- the similarities and differences between activity and concentration
- the concept of ionic strength and ionic charge implications
- the different types of electrochemical cells, both spontaneous and non-spontaneous
- the effect of temperature of cell potential and the thermodynamic aspects
- the implication of non-standard conditions on electrochemical cell potentials
- Faraday's Law as it applies to Electrolysis Reactions
- the concept of the Electrochemical Series
- electrolyte solutions properties and characteristics such as molar conductivity, ionic mobility, drift speed, ionic velocity, Kohlrausch's Law, ionic conductivity and independent migration of ions, and transference (transport) numbers
- Fick's Laws of Diffusion
- the failures of classical physics when applied to atomic systems, such as blackbody radiation, the Planck distribution, low temperature heat capacity, the photoelectric effect, and both atomic and molecular spectra

- wave-particle duality
- the requirements and interpretation of an acceptable wavefunction
- the concept of normalization of a wavefunction
- the significance and use of operators in eigenfunctions to determine eigenvalues
- commutation of operators
- the concepts associated with the Heisenberg Uncertainty Principle
- the quantum mechanical treatment of translational, rotational, and vibrational motion
- the particle in a box treatment of a wavefunction
- the concept of degeneracy
- the concept of quantum mechanical tunneling

F. ACADEMIC HONESTY POLICY

Drexel University is committed to a learning environment that embraces academic honesty. In order to protect members of our community from results of dishonest conduct, the University has adopted policies to deal with cases of academic dishonesty. Please read, understand, and follow the "Academic Honesty Policy" as written in the official student handbook. Instances of academic dishonesty, such as cheating and plagiarism will be dealt with appropriately.

G. GRADE BREAKDOWN

30% of your grade will come from Exam I, which will cover material on Electrochemistry and will be given on Wednesday April 29 (tentative date)

30% of your grade will come from Exam II, which will cover material from Quantum Mechanics and will be given on Wednesday May 20 (tentative date)

10% of your grade will come from two assignments to be submitted throughout the quarter: one will be on material for the First Exam and the other will be on material for the Final Exam

30% of your grade will come from the Final Exam on Wednesday June 10. The Final Exam will be comprehensive

 NOTE: THERE IS ONE HOLIDAY NIGHT THIS QUARTER: MONDAY MAY 25 IS MEMORIAL DAY

During the exams you will be provided with a reference sheet containing constants, conversion factors, and fundamental equations related to the subject matter. **NOTHING OTHER THAN THIS REFERENCE SHEET MAY BE USED DURING THE EXAM. IF YOU ARE FOUND USING ANYTHING ELSE IT WILL BE CONFISCATED AND YOU WILL RECEIVE A GRADE OF "F" FOR THE COURSE**

NOTE: NO EXAMS WILL BE GRADED OR RETURNED TO ANY STUDENT NOT OFFICIALLY ENROLLED IN THE CLASS.

DURING THE EXAMS THERE WILL BE NO TEXTING, USE OF CELL PHONES, LISTENING DEVICES OF ANY KIND, LAPTOPS, PDAs, AND/OR ANY TYPE OF ELECTRONIC DEVICE OTHER THAN A STANDARD CALCULATOR. CELL PHONES MUST BE TURNED OFF AND STUDENTS CANNOT LEAVE AND RE-ENTER THE ROOM FOR ANY REASON.

NOTE: EXAM DATES ARE TENTATIVE AND SUBJECT TO CHANGE AS THE TERM PROGRESSES. ANY CHANGES WILL BE ANNOUNCED IN CLASS.

ALL COURSE GRADES WILL BE DETERMINED EXCLUSIVELY FROM EXAM AND ASSIGNMENTS GRADES. THERE IS NO EXTRA CREDIT OR OTHER ASSIGNMENTS THAT WILL INFLUENCE THE COURSE GRADE UNLESS OTHERWIDE INDICATED BY THE INSTRUCTOR. ANY OTHER ASSIGNMENTS WILL BE FOR THE ENTIRE CLASS AND NOT ON A BASIS FOR INDIVIDUAL STUDENT(S) EXCLUSIVELY.

H. ATTENDANCE POLICY

Considering the needs of part time students occasionally having to miss class for any of various reasons, attendance will not affect your grade. If you miss a class for any reason, it is your responsibility to determine what work you missed.

I. MAKING UP MISSED EXAMS

A single make-up exam will be given to replace either Exam I or Exam II. **This exam will be given at 3:00 on Wednesday May 27 and it will end at 5:00. Report to my office to take this exam. This is the only time a makeup exam will be available. If you miss either Exam I or Exam II and do not take the makeup exam you will forfeit 30% of your grade.** The makeup exam will cover material from <u>both</u> exams. This means that regardless of whether you miss either Exam I or Exam II, the make-up exam you take will cover material from both exams. The make-up exam will replace one exam only, so that if you miss both exams and take the make-up exam you will forfeit 30% of your grade. **No make-up exams will be permitted at any other time. THE MAKE-UP EXAM IS TO REPLACE A MISSED EXAM, NOT A POOR GRADE.**

J. GENERAL INFORMATION

The last day to <u>drop</u> this course using an Academic Advisor's assistance is Friday April 10. If you do not need your advisor's permission you can drop it by using Drexel One no later than 11 P.M. on Sunday April 12. The last day to <u>withdraw</u> from this course is Friday May 15. Before you drop or withdraw from a course you should check with your advisor, as there may be consequences. Dropping or withdrawing from a course may affect your academic standing or your financial situation. It may have serious effect on billing at Drexel, financial aid, VA benefits, NCAA athletic eligibility, immigration status for foreign students, and other possible consequences. As a student you are responsible for transactions against your academic record.

http://www.drexel.edu/provost/policies
http://www.drexel.edu/src/financialaid/info/eligibility
http://www.drexel.edu/studentlife/get_involved/international_students_scholars/

http://www.drexel.edu/src/about/veterans

Different policies apply to dropping a course and withdrawing from a course. Dropping a course results in the course being removed from your transcript. Withdrawing from a course results in a grade of W on your transcript. Students should consult their Advisors (<u>both Academic and Financial Aid)</u> and, in some cases, the instructor before dropping or withdrawing from the course.

In order to drop or withdraw from a course, you should have the "Add/Drop/Withdraw" form signed by the course instructor and the student's Academic Advisor. Dropping or withdrawing from the course may affect your billing and academic record. Forms are available in many Department offices, in the lobby of Goodwin College and at

http://www.drexel.edu/src/forms
http://www.drexel.edu/provost/policies/course_drop.asp

Consult "Course Withdrawal Policy", "Course Drop Policy", "Code of Conduct", and other important information at http://www.drexel.edu/provost/policies and

http://www.drexel.edu/provost/

Incomplete Grade (I) or No Grade Reported (NGR) or No Credit. You must take responsibility to meet the University's policies and deadlines for requesting an incomplete grade and completing a course before the deadline passes. If you stop attending a course, you are not automatically removed from the course. It is your responsibility to complete, drop, or withdraw from the course. If you register for a course and do complete, drop, or withdraw from it, eventually an NGR grade will turn to a grade of F. An Incomplete grade will turn to an F grade if the student does not complete the course.

http://www.drexel.edu/provost/policies/grades.asp

If a student has an Incomplete Grade or No Grade Reported, the student should see the instructor for the course and the student's Academic Advisor immediately.

If you do not meet your financial obligations to the University, you will not receive a grade.

Read about Academic Integrity, Plagiarism and other topics at
www.drexel.edu/studentaffairs/community_standards/studentHandbook/general_information/code_of_concuct/

For the "Americans with Disabilities Act" Drexel University has the Office of Disability Services at 3201 Arch Street, Suit 210 and online at
http://www.drexel.edu/oed/policies
http://www.drexel.edu/oed/disabilityResources.
This office is to be contacted by the student if special course accommodations, emergency medical information or building evacuations are need. This office will also verify any special needs and give a form to the student to give to the instructor. The student should make the arrangements with this office and inform the instructor within the first two weeks of the term or when a new situation occurs.

HOMEWORK PROBLEMS

CHAPTER 6 - EQUILIBRIUM ELECTROCHEMISTRY
Exercises   5F.1b, 5F.2b, 5F.3b, 6A.11b, 6C.1a, 6C.2b, 6C.3a, 6D.1b, 6D.2a,
Problems   6D.2, SP1, SP2
Integrated Activities   6.2

CHAPTER 19 - MOLECULES IN MOTION
Exercises   19B.2b, 19B.3b, 19B.4b, 19B.5b, 19B.7b, 19C.6b
Problems   19B.4, 19B.5

CHAPTER 7 - QUANTUM THEORY: INTRODUCTION AND PRINCIPLES
Exercises   7A.2b, 7A.3b, SP3, 7A.5b, 7A.6b, 7A.9b, 7A.11a, 7C.7b, 7C.8b,
Problems   7A.4, 7B.4, 7C.3, 7C.5   (NOTE: in both 7C.3 and 7C.5 also add in cos(kx) as
                        another function to consider)

CHAPTER 8 - QUANTUM THEORY: TECHNIQUES AND APPLICATIONS
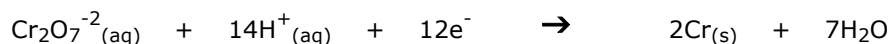Exercises   8A.3b, 8A.4b 8A.7b (in three dimensions), 8B.1b, 8B.2b
Problems   8A.1, 8B.1

THESE ASSIGNMENTS MAY BE MODIFIED AS THE QUARTER PROGRESSES

SP = SUPPLEMENTARY PROBLEMS LISTED BELOW

SUPPLEMENTARY PROBLEMS

SP1) Chromium metal can be electroplated from an aqueous solution of potassium dichromate. The reduction half-reaction is

$$Cr_2O_7^{-2}{}_{(aq)} + 14H^+{}_{(aq)} + 12e^- \rightarrow 2Cr_{(s)} + 7H_2O$$

a) How many grams of Cr will be plated by 1.00×10^5 coulombs?

b) How long will it take to plate 1.00 gram of Cr using a current of 6.00 amp?

c) If the applied voltage is 4.5V, how many kilowatt-hours (kWh) of electrical energy are required to plate 1.00 gram of Cr?

SP2) A metallurgist wants to goldplate a thin sheet having dimensions of 1.5 in x 8.5 in x 0.0012 in. The goldplate must be 0.002 inches thick.

a) How many grams of Au (density = 19.3 g/cm^3) are needed?

b) How many minutes will it take to plate the gold from a solution of Au$^+$ using a current of 7.00 amp?

SP3) Calculate the linear momentum of photons with a wavelength of 350 nm. What speed does a hydrogen molecule have to travel to have the same linear momentum?

TOPICS TO BE COVERED DURING THE QUARTER

CHAPTER 6 - EQUILIBRIUM ELECTROCHEMISTRY
Thermodynamic Functions of Formation (Section 3C.2) - Ion Activities and the Debye-Huckel Limiting Law (Section 5F) - The General Concept of an Equilibrium Constant - Half Reactions and Electrodes - The Daniell Cell - Varieties of Cells - Fuel Cells - Batteries - Standard Cell Potentials - Electrochemical Series - Reactions at Electrodes - Standard Cells - Non-Standard Cells and the Nernst Equation - Solubility Products - Thermodynamic Functions from Cell Potential Measurements - Specific Examples of Electrolytic and Voltaic Cells - Electrolysis and Faraday's Law

CHAPTER 19 - MOLECULES IN MOTION
Conductivities of Electrolyte Solutions - Strong and Weak Electrolytes - Ion Mobility and Ionic Conductivities - Transport Numbers - Conductivities and Ion-Ion Interactions - Thermodynamic View of Diffusion - The Laws of Diffusion

CHAPTER 7 - QUANTUM THEORY: INTRODUCTION AND PRINCIPLES
Origins of Quantum Mechanics and Failures of Classical Physics - Blackbody Radiation - Planck Distribution - Heat Capacities - Atomic and Molecular Spectra - Wave-Particle Duality - Photoelectric Effect - Schrödinger Equation - Interpretation of Wavefunctions - Normalization of Wavefunctions - Quantization - Probability Density - Operators, Eigenvalues, and Eigenfunctions - The Uncertainty Principle

CHAPTER 8 - QUANTUM THEORY: TECHNIQUES AND APPLICATIONS
Translational Motion of Particles with Boundary Conditions - Rotational Motion of Particles with Boundary Conditions - Vibrational Motion of Particles with Boundary Conditions - Degeneracy - Tunneling - Quantum Numbers

ANSWERS TO EXERCISES AND SUPPLEMENTARY PROBLEMS

ELETROCHEMISTRY ASSIGNMENTS

5F1.b) 0.320

5F2.b) 45 g KNO_3 and 38.8 g $Ba(NO_3)_2$

5F.3b) Activity Coefficient = 0.661 (when reported as NaCl--must designate with respect to which one)

6A.11b) -128.84 kJ/mol

6C.1a) (a) +1.56V   (b) +0.40V   (c) -1.10V

6C.2b) (a) +1.88V   (b) +0.54V   (c) +0.83V

6C.3a) -0.616V

6D.1b) (a) 1.65×10^{16} (b) 8.3×10^{-7}

6D.2a) (i) 8.66×10^{-17} (ii) 9.3×10^{-9}M

19B.2b) 4.09 mS-m^2/mol

19B.3b) 1.92×10^{-4} m/sec

19B.4b) 21.68 mS-m^2/mol

19B.5b) F$^-$ = 5.74×10^{-8}, Cl$^-$ = 7.913×10^{-8}, and Br$^-$ = 8.09×10^{-8} (all in m^2/V-sec)

19B.7B) 1.09×10^{-9} m^2/sec

19C.6b) 2.07×10^{-10}m   (or 207 pm)

SP1)   (a) 8.98 grams   (b) 30.9 minutes   (c) 0.0139 kWh

SP2)   (a) 16.1 grams   (b) 18.8 minutes

QUANTUM MECHANICS ASSIGNMENTS

7A2.b) (a) 9.93×10^{-19}J, 598 kJ/mol   (b) 1.32×10^{-15}J, 7.98×10^5 kJ/mol   (c) 1.99×10^{-23}J, 0.012 kJ/mol

7A3.b) (a) 17.3 km/sec   (b) 630 km/sec   (c) 0.0773 km/sec

SP3) 1.89×10^{-27}kg-m/sec,   0.565 m/sec   7A.5b) (a) 3.52×10^{17} sec^{-1} (b) 3.52×10^{18} sec^{-1}

7A6.b) (a) no kinetic energy or velocity (below threshold value)   (b) 6.84×10^{-19} J, 1.23×10^6 m/sec

7A.9b) 1.3×10^{-5} m/sec

7A.11a) (i) 6.6×10^{-29}m   (ii) 6.6×10^{-36}m   (iii) 9.97×10^{-11}m (or 99.7 pm)

7C.7b) The minimum uncertainty in position is 100 pm and for speed it is 5.8×10^5 m/sec

7C.8b) 5.8×10^{-6}m

8A.3b) (a) 2.14×10^{-19}J   (b) 3.48×10^{-19}J

8A.4b) (a) 0.031   (b) 0.029

8A.7b) $L = \left(\dfrac{3}{8}\right)^{1/2} \dfrac{h}{mc} = \left(\dfrac{3}{8}\right)^{1/2} \lambda_c$

8B.1b) 3.92×10^{-21}J

8B.2b) 260 N/m

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I have read and understand all of the course requirements that are detailed in this course syllabus. By my signature below I am indicating that I understand the requirements as state in the course syllabus, including but not limited to each of the following:

- When exams will be given (at least tentative dates).

- The make up time for a missed exam is on Wednesday May 27 at 3:00 and no make-up exams will be permitted at any other time. Failure to take a makeup exam (for a MISSED exam only) results in forfeiting 30% of the course grade. Also, it is understood that the make-up exam will cover material from both Exam I and Exam II so I may be tested twice on some topics. The make-up exam will replace ONE EXAM ONLY so if I miss both Exam I and Exam II, 30% of my grade will be forfeited.

- The policy that all course grades will be determined from exam grades and assignments only. Extra credit assignments are not available on an individual basis.

- The only reference material that can be used during any exam is a sheet containing constants, conversion factors, and select equations that will be provided with the exam. Attempting to use anything else will result in a grade of "F" <u>FOR THE COURSE</u>

- It is my responsibility to find out what was missed if I miss a class.

NAME (printed) _____

SIGNATURE _____

DATE_____