I. Locator Information:

Instructor: Dr. Daniel E. Autrey  
Course # and Name: CHEM 325 – 01, Physical Chemistry Laboratory  
Semester Credit Hours: 3.0 credits  
Total Contact Hours: 89  
Day and Time Class Meets: MW 2:00 pm – 4:50 pm LS 313  
Office Location: LS 325  
Office Phone: 910-672-1354  
Office Hours: M 10:00 am – 10:50 am  
W 10:00 am – 1:50 pm  
R 11:00 am – 1:50 pm  
Or By Appointment  
Email address: dautrey@uncfsu.edu

FSU Policy on Electronic Mail: Fayetteville State University provides to each student, free of charge, an electronic mail account (username@uncfsu.edu) that is easily accessible via the Internet. The university has established FSU email as the primary mode of correspondence between university officials and enrolled students. Inquiries and requests from students pertaining to academic records, grades, bills, financial aid, and other matters of a confidential nature must be submitted via FSU email. Inquiries or requests from personal email accounts are not assured a response. The university maintains open-use computer laboratories throughout the campus that can be used to access electronic mail.

Rules and regulations governing the use of FSU email may be found at:

http://www.uncfsu.edu/PDFs/EmailPolicyFinal.pdf
II. Course Description:

Physical Chemistry Laboratory (CHEM 325, 3–3–0) involves laboratory investigations involving the determination of enthalpies, equilibrium constants, molecular mass, electromotive force, entropy, reaction rates and activation parameters, solution phenomena, conductance, and the gathering and quantitative interpretation of spectra.  

**Pre-requisites:** CHEM 313 (Physical Chemistry I)  
**Co-requisites:** CHEM 314 (Physical Chemistry II)

III. Disabled Student Services: In accordance with Section 504 of the 1973 Rehabilitation Act and the Americans with Disabilities Act (ACA) of 1990, if you have a disability or think you have a disability, please contact the Center for Personal Development in the Spaulding Building, Room 155 (1st Floor); 910-672-1203.

IV. Textbook:


V. Student Learning Outcomes:

Upon completion of this course, the students will be able to:

- Understand the theory behind the experiment being carried out.  
- Develop proper communication skills in technical writing through laboratory reports written in the style of the *Journal of Physical Chemistry*.  
- Maintain proper records of experimental observation and data by recording them in a laboratory notebook.  
- Identify random and systematic errors in an experiment, as well as evaluate how to minimize or correct for them.  
- Make accurate measurements of mass, volume, and temperature by selecting the proper laboratory equipment.  
- Perform statistical analysis of data (such as linear regression, standard deviation, relative errors, absolute errors, etc.) to estimate the uncertainty of measurements and to propagate those uncertainties to determine the uncertainty of the final result.  
- Use statistical methods (Q-test and T-test) to determine whether an experimental outlier may be excluded from a data set with an appropriate value of confidence.  
- Utilize computers programs (such as Microsoft Excel™, Mathcad™, Maple™, Origin™, SigmaPlot™, etc.) in processing data and generating graphs.  
- Compare their final experimental results to published and accepted literature values, and make a valid assessment of the limitations of their experimental design that account for any discrepancy.  
- Practice safe laboratory practices.
VI. Course Requirements and Evaluation Criteria:

a. Grading Scale:

I hope that each student experiences an acceptable level of success and accomplishment in this course. This depends not only on academic ability, but also on how much time and commitment a student is willing to invest in the course. Your level of accomplishment in CHEM 325 at the end of the semester is indicated by the grade you receive for the course. The grade you receive will be the grade you earn based on your academic performance. In other words, your grade depends on you and how much quality time you put into the course. Your performance in CHEM 325 is not measured against the performance of other students, but rather against course standards established by the instructor. The course standards upon which grades will be based are listed below.

<table>
<thead>
<tr>
<th>Percentile Points</th>
<th>Letter Grade</th>
<th>Accomplishment</th>
</tr>
</thead>
<tbody>
<tr>
<td>90 - 100%</td>
<td>A</td>
<td>Excellent</td>
</tr>
<tr>
<td>80 - 89.9%</td>
<td>B</td>
<td>Proficient</td>
</tr>
<tr>
<td>70 - 79.9%</td>
<td>C</td>
<td>Acceptable</td>
</tr>
<tr>
<td>60 - 69.9%</td>
<td>D</td>
<td>Poor</td>
</tr>
<tr>
<td>below 59.9%</td>
<td>F</td>
<td>Unacceptable</td>
</tr>
</tbody>
</table>

b. Interim Grades:

Interim grades will be assigned from the first week of the semester until the deadline for class withdrawals. Interim grades are used for informational and warning purposes only; they are not part of your permanent transcript and have no effect on your grade-point average (GPA). In accordance with university policy, the following changes have been implemented:

1. WN (withdrawal due to non-attendance) grades have been discontinued. This means that it is the student’s responsibility to withdrawal from classes prior to the published deadline.
2. Final grade FN (failure due to non-attendance). This final grade is assigned to students who are on a class roster, but who never attend the class. An FN grade is equivalent to an F grade and adversely affects your GPA.
3. Interim Grade X (No-show). This grade is assigned to students who are on a class roster, but who never attend the class. If you have an X grade, either begin attending class or withdraw from it. If you do not take action in response to an X grade, you will receive a final grade of FN.
4. Interim Grade EA (Excessive Absences). This grade is assigned to students whose class absences exceed 10% of the total contact hours. If you have an EA grade, you are in jeopardy of failure if you do not take immediate actions. Either resume attending the class or withdraw from it.
c. Attendance Requirements:

Class attendance is required for all students. Class absences will be excused only when valid documentation is provided for participation in university sponsored activities, serious illness, and family emergencies. Other absences may be excused at the discretion of the instructor, who may require documentation. The latter may be in the form of a note from a doctor or the university’s student health clinic in the event of serious illness, a note from another Fayetteville State faculty or the athletic department indicating your involvement in an official university-sanctioned event, a bulletin from a funeral service, a note from an employer, etc. In all cases, contact information (i.e., a phone number), must be included. Students must notify the instructor, in advance when possible, of the reasons for the class absence. When prior notification is not possible, students are required to explain the reason for their absence by the next class meeting. When students fail to explain class absences, those absences are unexcused. The university policy concerning absences from class will be strictly enforced. Class attendance is important because of the pace of the course and the abstract nature of many of the topics covered. It is the students’ responsibility to make up any and all missed work.

Students are required to be punctual for each class session. Class will begin promptly at the scheduled time. Students are expected to be in class and ready to perform their experiments at the scheduled time and remain in class until dismissed by the instructor.

d. Assignments and Point Distribution:

Final grades will be based on the following point distribution:

<table>
<thead>
<tr>
<th>Component</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laboratory Reports:</td>
<td>1000</td>
</tr>
<tr>
<td>Final Exam:</td>
<td>100</td>
</tr>
<tr>
<td>Homework:</td>
<td>50</td>
</tr>
<tr>
<td>Laboratory Notebook:</td>
<td>50</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1200</strong></td>
</tr>
</tbody>
</table>

The final grade is predominantly based upon formal laboratory reports. There will be TEN formal laboratory reports, each worth 100 points. These laboratory reports will be written in the style of the Journal of Physical Chemistry. The guidelines for these formal reports are located in Appendix 1: Laboratory Report Guidelines.

The final grade will also be determined by a comprehensive final exam, worth 100 points, administered during finals week. The final exam will include questions of four types:

a) Questions involving the use of raw data for a hypothetical experiment to obtain final results.

b) Questions about experimental procedure for some of the performed experiments.
c) **Questions about major sources of error** for some of the performed experiments.

d) **Questions concerning the propagation of experimental errors.**

The final grade will include a few homework assignments, worth a total of 50 points of the final grade. These assignments will be based on the statistical treatment of data. These assignments will be **due at the start of class** on the specified due date announced in class. **Late problem sets will not be accepted and graded.**

The final grade will include an evaluation of the laboratory notebook, worth a total of 50 points of the final grade. The laboratory notebook will be submitted at announced times throughout the semester and evaluated based on the criteria of neatness and thoroughness.

e. **Policy on Missed or Late Assignments / Make-ups Exams:**

The following policies have been implemented as a matter of fairness for all students in the course:

Each laboratory report is due one week after the experimental work is scheduled to be completed. However, when the due date falls within a University vacation period, the report is considered due on the first regularly scheduled lab period following that date. **Late submissions are penalized three points per day (15 points per week) to a maximum of 30 points for each experiment.** No lateness penalty will be assessed for weekends and recess days. If you know beforehand that you will be absent, arrange with the Instructor to change your schedule and due date. If you must repeat measurements, check with the Instructor for scheduling and possible due date extension. No laboratory reports will be accepted after the last day of classes, May 2\textsuperscript{nd}, 2014 or April 25\textsuperscript{th}, 2014 for graduating seniors.

**You are expected to take the final exam at the scheduled times. No student will be allowed to take the final exam either before or following the scheduled exam time.** Should an illness, family emergency, official university-sanctioned event or other unavoidable problem necessitate you missing the scheduled final exam, you **may take a make-up final exam provided that (1) the instructor is notified prior to the final exam, and (2) you show verifiable evidence for the condition/situation/event that resulted in your missing the regularly scheduled final exam.** The latter may be in the form of a note from a doctor or the university’s student health clinic in the event of serious illness, a note from another Fayetteville State faculty or the athletic department indicating your involvement in an official university-sanctioned event, a bulletin from a funeral service, a note from an employer, etc. In all cases, contact information (i.e. a phone number) must be included. The make-up final exam will be administered at a time agreed upon by both the student and the instructor. **Note that make-up final exams may be longer, more difficult, and have a different format than the final exam given to the class as a whole.**
f. Other Student Expectations:

The instructor will respect all students and will make every effort to maintain a classroom climate that promotes learning for all students. Students must accept their responsibility for maintaining a positive laboratory environment by abiding by the following rules:

1. **Students are expected and presumed to have met the prerequisites for this course.**
2. **Students are expected to have prepared for the laboratory experiment to be performed prior to coming to the laboratory.** Before doing an experiment, the student must thoroughly read the entire experimental write-up and either review or read ahead the appropriate material in the lecture textbook. The student should plan ahead the preparation of any solutions needed and make the necessary preliminary calculations of amounts to be used, dilution procedures, etc. *Advanced preparation is essential!!* Typically, the unprepared student has difficulty completing the experiment during the allotted class time and must come in outside of class to complete the experiments.
3. **Students are expected to adhere to safe laboratory practices.** (See Appendix 2: Laboratory Safety Rules).
4. **Students are expected to be punctual for each class.**
5. **Students are expected to actively and diligently perform their experiments.**
6. **Students are expected to take the final examination at the scheduled date and time.**
7. **Students are expected to refrain from participating in all forms of academic misconduct** (see below).

**g. Academic Misconduct:**

As members of an academic community, each student is expected to preserve his or her personal integrity by refraining from all forms of academic dishonesty. Academic fraud includes, but is not limited to, the following:

1. Copying answers on an exam, quiz, homework assignment, or laboratory assignment from another student.
2. Plagiarism of written laboratory reports from the textbook, internet webpage, laboratory manual, or other published work. A student must properly cite references.
3. Using notes or a crib sheet on an exam or quiz without the consent of the instructor. This includes writing notes on any part of your body.
4. Asking another student for help or answers during an exam, or providing such help to another student.
5. Having another person take an exam or quiz for you.
6. Stealing or having in one’s possession without permission a copy of an exam or quiz generated by the instructor prior to its administration.
Evidence of academic misconduct will result in an "F" (0 points) for that laboratory or exam. Any student caught cheating more than once could face more severe disciplinary measures, including expulsion from the university, in accordance with university policies as outlined under Disciplinary System and Procedures in the Fayetteville State University Student Handbook. The handbook may be obtained from the Office of Student Affairs located in the Collins Administration Building.

h. Drop Deadline:

No student will be allowed to drop the class after the official university drop deadline listed in the Academic Calendar, 2013-2014, which is Friday March 28th, 2014 for this term. If a student stops attending class after this date, they will receive a final grade of FN (failure due to non-attendance). An FN grade is equivalent to an F grade in the calculation of your grade-point average (GPA).

VII. Academic Support Resources:

The Learning Center in the H. T. Chick building in Room 216C is available to assist students with writing, mathematics, and reading comprehension.

VIII. Course Outline and Assignment Schedule:

<table>
<thead>
<tr>
<th>Date(s)</th>
<th>Experiment</th>
</tr>
</thead>
<tbody>
<tr>
<td>January 13</td>
<td>Check in and Laboratory Safety instructions</td>
</tr>
<tr>
<td>January 15</td>
<td>Error Analysis in Physical Chemistry</td>
</tr>
<tr>
<td>January 20</td>
<td>Martin Luther King Jr. Birthday Holiday</td>
</tr>
<tr>
<td>January 22</td>
<td>Error Analysis in Physical Chemistry</td>
</tr>
<tr>
<td>March 10 – 14</td>
<td>Mid-Semester Break</td>
</tr>
<tr>
<td>March 28</td>
<td>Last Day to Withdraw from Class</td>
</tr>
<tr>
<td>April 18</td>
<td>Spring Holiday</td>
</tr>
<tr>
<td>April 25</td>
<td>Last Day to Withdraw from the University</td>
</tr>
<tr>
<td>April 28</td>
<td>Final Exam for Graduating Seniors (2:00 pm – 4:50 pm)</td>
</tr>
<tr>
<td>May 5</td>
<td>Final Exam for Non-Graduating Seniors (2:00 pm – 4:50 pm)</td>
</tr>
</tbody>
</table>

Students will be working in pairs on these experiments. However, the instructor will post a rotating schedule to give everyone a chance to work with one another. Because you will be working with another student, it is imperative that you are punctual for class and prepared to do each laboratory experiment. Also, it is imperative that you finish the experimentation by the scheduled date so that any instrumentation and supplies will be ready for the next group.
MODULE 1 (January 27th & 29th, February 3rd & 5th)
- Experiment 16: Surface Tension Properties of Liquids
- Experiment 17: Viscosity of Liquids Part I: Low Viscosities

MODULE 2 (February 10th & 12th, February 17th & 19th)
- Experiment 6: Liquid-Vapor Equilibrium in an Azeotropic Mixture (Sime).
- Experiment 22: Kinetics of a Reversible, First-Order, Consecutive reaction: The Reduction of Cr(VI) by Glutathione

MODULE 3 (February 24th & 26th, March 3rd & 5th)
- Experiment 5/6: Bomb Calorimetry: Heat of Formation of Naphthalene or Sucrose
- Bomb Calorimetry: Determination of the Resonance Energy of Benzene
- Experiment 12: Activities of a Solvent from Freezing-Point Measurements (Sime).

MODULE 4 (March 17th & 19th, March 24th & 26nd)
- Experiment 40: Computational Chemistry: The calculations of $\Delta G^\circ$, $\Delta H^\circ$, and $\Delta S^\circ$ for the Reaction $\text{N}_2\text{O}_4 \rightleftharpoons 2\text{NO}_2$
- Experiment 36: Rotational-Vibrational Spectrum of HCl

MODULE 5 (March 31st & April 2nd, April 7th & 9th)
- Experiment 15: Adsorption of Acetic Acid by a Solid (Sime).
- Experiment 19: The pKa of a Weak Acid (Sime).

Due to the availability of supplies, the instructor reserves the right to move or replace some experiments.

IX. Teaching Strategies:

Because this is solely a laboratory course, the focus will be on “hands-on” learning. Because not every student is doing the same experiment each week, a pre-lab discussion of the theory behind the laboratory experiment **WILL NOT** be given at the beginning of class. However, your instructor will assist you in going over any safety concerns, data acquisition protocol, and the proper disposal of any waste material. If you have any questions with regard to the theory of the experiment, you should ask your instructor prior to lab.

X. Bibliography:

XI. Disclaimer:

To accommodate emergent circumstances, the professor reserves the right to make reasonable changes in the syllabus while the course is in progress. Any understandings between a student and the professor including, but not limited to, changes, expectations, or modifications to course requirements or procedures must be in writing and must be signed by both parties. Any question of interpretation of course requirements or of understandings between a student and the professor will be at the discretion of the professor.
Appendix 1: Laboratory Report Guidelines.

Although you will be working in pairs, each student must submit their own individually written laboratory reports.

Reports must be typewritten (with the exception of complex equations within the text).

The Garland, Nibler, and Shoemaker textbook (Chapter 1) give an excellent elaboration on what is expected in each section of the laboratory report. The continuity, style, tense, voice, grammar, etc. will affect your grade.

Each laboratory report should have seven major components:

1. **Title Page** –
   The title page should include an original and descriptive title of the experiment, your name, the name of any experimental partners, the date on which the report is submitted, the actual due date, and should identify the report as a physical chemistry laboratory report.

2. **Abstract** –
   The abstract is a brief statement (50 – 100 words) of the results of the experiment and the method used. You should include actual numerical results with confidence limits should be included.

   *Example* – “The enthalpy of combustion of sucrose was calculated using adiabatic bomb calorimetry. The heat capacity of the bomb was measured to be 10,625 ± 15 J/g from combustion trials of calorimeter grade benzoic acid (99.999% purity). The molar enthalpy of combustion of sucrose was calculated to be -5653 ± 19 kJ/mol, which compares well to the literature value of -5645 kJ/mol.”

3. **Introduction** –
   In general, it is assumed that the theory and procedure given in the text for the experiment were followed. Your report need not contain a detailed outline of theory, however sufficient information should be given to put the investigation into perspective for the reader. The introduction should summarize the relevant theory. It should introduce the important concepts that will be germane to the discussion at the end of the report.

4. **Experimental** –
   This section is used to describe the instrument, materials, and the methods used. Purity of materials should be given. Any differences of the procedure or methods of calculations which were actually used to that of the text should be detailed.

5. **Data and Calculations** –
   Data and calculations logically precede the results. They may be presented either in the body of the report, or in an appendix. This section
includes a summary of the data and calculations leading to the final results reported, along with the corresponding estimates of error. Explain your calculations.

One sample illustrating each type of calculation must be shown. For each type of calculation, state the equation, define the symbols used, show substitutions, and give the calculated result accompanied by units and an estimate of experimental error. The sample should also show how the error was calculated. Arithmetic detail should be omitted.

Consider carefully the number of significant digits carried in a calculation. You must be sure to carry enough digits to preserve the accuracy of the data. A good rule is to retain one or two doubtful digits through the intermediate calculations. The question as to which digits are doubtful is determined from the estimated error. If you find that after making the error estimates that you have carried unnecessary digits, round these off before reporting the final value. Error estimates should be rounded off to one or at most two digits. The value itself and the estimated error should be rounded off consistently (e.g. 32.14 ± 0.05).

All the essential items should appear in the body of the report, usually in tabular form, though in a few cases a plot of the raw data may be appropriate. Units and an estimate of the error should accompany each item. Only minor reductions (such as subtractions of weightings or burette readings) should be carried out on the data sheet. When repeated multiple-step calculations are involved, it is helpful to make a table with results from each of the major steps in a different column. Estimates of experimental error should be attached to the various table entries. If the error is the same for all entries in one column, the estimate can be placed at the head of the column or with the first entry. Otherwise, errors should be given for several cases so as to illustrate the variation.

If a graph is drawn, the values for the points are to be included in a table preceding the graph. It is good practice to draw bars through experimental points to show the experimental error. While it may be advisable to draw the curves first lightly in pencil so that changes can be desired, the final curve should be traced over in ink or strongly colored pencil. In fitting a line or curve to the points, one should take into account the experimental error in the various points. Reasonable care should be taken to see that the curve is smooth, while representing the data as fairly as possible. The estimate of error in slope or intercept can be made by inspection from the graph or by regression techniques.

When you expect a linear relationship, use the method of least squares to find the “best” line representing the data and the uncertainties of the parameters. The calculated line should be shown on the graph. The quality of the fit can be judged by inspection. For example, any significant systematic deviations should be evident, and should be noted in the report. A comparison may be made between models by consideration of the correlation coefficient.

6. Results and Discussion –

The discussion should include an evaluation of the quality of your data and results. This is based partly on evidence within your own data and
experience, and partly on comparison of your results with literature values. Reviewing your own data, you should ask yourself whether the internal consistency is as good as it should be according to the error estimates made. Identify the primary source(s) or error. Is there internal evidence of systematic error – for example, a much larger discrepancy between parallel runs than the apparent errors within each run? Are there unexpected trends in the data?

If your results are not as good as you think that they should be, review your calculation – especially check numerical work, equations used, and units. Mistakes in calculations are common and generally inexcusable. If you are uncertain about some part of the calculation, consult with the Instructor and try to be sure the calculations are correct before completing the report. If the fault is in the data, you may wish to repeat some of the measurements.

Be sure that you have used the proper number of significant figures in your results and that you have given the correct units for each. Your final results should be collected together and presented along with the estimated uncertainties. Whenever possible, literature values should be given for comparison. Often the results and literature values can be placed in a single table. **Always cite the literature references from which values were obtained.**

Comparing with the literature data, do you find that your results agree as well as should be expected from your quantitative error estimates? If not, do you see evidence of systematic error – for example, are your points consistently low or high? Are there clear trends in the errors?

In any case, you **should explain** possible systematic errors and other factors which might contribute significantly to the error of the experiment but which were not allowed for in your quantitative error estimates. (For example, in measuring heat of combustion, incomplete combustion of the sample will inevitably tend to give a low result.) In some cases, you will need to consider the calculations carefully in order to predict the direction of an effect on the final results.

7. **References**

You may reference literature information from your laboratory manual, physical chemistry textbooks, other books on physical chemistry, and published peer-reviewed journal articles. It is not acceptable to cite information from Internet pages or websites.
Appendix 2: Laboratory Safety Rules.

1. Learn the location of the safety equipment and how to use it. The laboratory is equipped with fume hoods, a fire extinguisher, an eye-wash fountain, and a safety shower.

2. Each student must arrive on time at the start of each experiment and be present when any modifications to procedures are being explained.

3. Come prepared to do your experiment by reading your experimental procedure and calculating how to prepare any solutions. If you have any questions, you should have these ready at the beginning of the class period.

4. Students must wear approved eye protection at all times in the laboratory. These lessen chances of eye injury. There will be no exception to this rule.

5. **DO NOT BRING FOOD OR BEVERAGES INTO THE LABORATORY. Some chemicals are readily absorbed even from the atmosphere by food and/or drink.**

6. Keep your work area clean and neat. This is good, standard operating procedure for any laboratory--You avoid contaminating your sample and lessen the possibility of damage to clothing, skin, etc. from chemicals and broken glassware.

7. Clean all glassware after use and return them to the appropriate storage place.

8. Adhere to all waste disposal procedures. If there is some doubt, ask your instructor.

9. Do not mix any chemicals without authorization.

10. Wash your hands with plenty of water at the end of the laboratory session.