Syllabus for CTEC 2431 – Applied Instrumental Analysis II

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I. COURSE DESCRIPTION:

CTEC 2431 - Applied Instrumental Analysis II. CIP 4103010003
Study of advanced topics in instrumental analysis. Topics include atomic absorption, inductively coupled plasma, nuclear magnetic resonance, gas chromatography/mass spectrometry, liquid chromatography, and infrared spectroscopy. **Credit Hours:** 4 (3 lecture, 3 lab)

__________________________________________________________  ______________________________
Dr. Judy Chu                                                 Dr. Kirby Lowery

__________________________________________________________  ______________________________
Gary Hicks                                                   Jeff Detrick

August 2019
A. **Prerequisite:** A grade “C” or better in CTEC 1441.

**Required skill level:** College-level reading, writing and math.

II. **COURSE OBJECTIVES**

At the completion of CTEC 2431 the student should be able to:

1. Understand and apply the principles of light absorption and emission in spectrochemical analysis.
2. Apply the theory and operation of the FTIR spectrometer in the identification of organic compounds.
3. Understand and the theory and operation of the UV/Vis spectrophotometer in chemical analysis.
4. Understand the theory of atomic spectroscopy and the operation of the AA spectrometer in trace metal analysis.
5. Understand the theory of mass spectrometry and NMR spectroscopy and the operation of the mass and NMR spectrometer.
6. Understand the theory and operation of the high performance liquid chromatography (HPLC).
7. Understand various physical testing methods such as viscosity measurement, thermal analysis, particle size analysis and hardness testing.
8. Receive a grade of D or better in the laboratory portion of the course.

III. **STUDENT LEARNING OUTCOMES**

Calibrate, operate, troubleshoot, and maintain analytical instruments; prepare and analyze samples; and use data interpretation for troubleshooting.

IV. **LABORATORY OBJECTIVES**

**YOU MUST MAKE AT LEAST A “D” IN THE LABORATORY PORTION OF THIS COURSE IN ORDER TO PASS THE COURSE.**

A. Safety

The student will:

1. Follow all safety guidelines given in lab.
2. Maintain a clean work area.
3. Properly handle all hazardous materials and waste.
4. Promote safety awareness among lab student.
5. Be familiar with material safety data sheets on chemicals used in the lab.

B. Lab Projects

Given the proper laboratory equipment and reagents, the student will:

1. Develop lab procedures including safety procedures for a given project given some general guidelines.
2. Conduct a literature search for a given project.
3. Requisition supplies for a given project.
4. Execute project activities.
5. Evaluate project data.
6. Summarize and report project results.
7. Perform statistical analysis on project data if needed.

C. Sample Analysis
Given the proper laboratory equipment and reagents, the student will:
1. Determine nitrate concentration in a given sample using an UV/Vis spectrophotometer.
2. Determine iron concentration in a given sample using a UV/Vis spectrophotometer.
3. Determine the amount of acetylsalicylic acid in commercially available aspirin tablets using an UV/Vis spectrophotometer.
5. Measure polymer film thickness by FTIR spectrometry.
6. Identify organic unknowns by FTIR spectrometry.
7. Determine sodium concentration in a given sample using an AA spectrometer.
8. Determine the concentration of each component of a given mixture using a gas chromatograph.
9. Determine the concentration of each component of a given mixture using a high pressure liquid chromatograph.
10. Prepare calibration standards for a given analysis.
11. Prepare samples for a given analysis.
12. Calibrate instruments using various standardization methods such as internal standardization, external standardization, and standard addition.
13. Determine the reproducibility of a given instrument.

D. Instrument Operation and Report Generation
Given the proper laboratory equipment, the student will:
1. Perform basic operations required for sample analysis.
2. Enter data.
3. Retrieve data.
4. Provide a printout of analysis if instrument has printout capability.
5. Generate charts and graphs if needed.
6. Understand the basis for mathematical calculations done by computer or integrator.
7. Generate control charts.
8. Calculate errors and bias in data.

E. Trouble-Shooting
Given an instrument with a specific problem the student will:
1. Consult manuals for possible solutions.
2. Identify the problem or at least narrow the possible sources to 2 or 3.
3. Make basic repairs.
5. Ensure the integrity of the equipment once it is repaired.
6. Verify calibration standardization procedure if the problem is a standardization problem.
7. Verify the integrity of the standard reagents if the problem is a standardization problem.
8. Check sample identity.
9. Check calculations.
10. Consult with lab instructor.

V. TEXTBOOK OR COURSE MATERIAL INFORMATION

A. Textbook
2. Applied Instrumental Analysis Class Notes, Chu Judy, BC Custom Publisher, August 2019.
3. Calculator T130XA
4. Safety Glasses

Required course materials are available at the Brazosport College bookstore, on campus or online at http://brazosport.edu/bookstore/home.html. A student of this institution is not under any obligation to purchase a textbook from the college bookstore. The same textbook is/may also be available from an independent retailer, including an online retailer.”

For Distance Education Courses include the following: Contact the Brazosport College Bookstore with a credit card for course materials. Phone: 979.230.3651. Fax: 979.230.3653. Email: bookstore@brazosport.edu. Website: http://brazosport.edu/bookstore/home.html

B. Course Outline

This is a sample outline which may vary with individual instructors. It will also vary based on whether the course is a summer course or a fall/spring course. Students should contact their instructor for the outline of the course they are taking.

<table>
<thead>
<tr>
<th>WEEK</th>
<th>LECTURE T/Thr 5:35 – 6:50 PM</th>
<th>LAB Tuesday 7-9:50 PM</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Introduction to Organic Chemistry</td>
<td>Safety and check-in. See lab syllabus for experiments</td>
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<tr>
<td>2</td>
<td>Chapter 7 – Introduction to Spectrochemical Methods</td>
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<tr>
<td>3</td>
<td>Chapter 8.1-8.5 – UV-Vis Spectrophotometry</td>
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<tr>
<td>4</td>
<td><strong>Exam 1</strong>&lt;br&gt;Chapter 8.6-8.11 – FTIR Spectrometry</td>
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<tr>
<td>WEEK</td>
<td>LECTURE T/Thr 5:35 – 6:50 PM</td>
<td>LAB Tuesday 7-9:50 PM</td>
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<tr>
<td>5</td>
<td>Chapter 8.6-8.11 – FTIR Spectrometry</td>
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<tr>
<td>7</td>
<td>Chapter 9 - Atomic Spectroscopy</td>
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<td>8</td>
<td>Chapter 9 - Atomic Spectroscopy</td>
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<td></td>
<td><strong>Exam 2</strong> – (FTIR and AA)</td>
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<td>9</td>
<td><strong>Spring Break</strong></td>
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<tr>
<td>10</td>
<td>Chapter 10 – Other Spectroscopic Methods – Mass Spectrometry</td>
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<td>11</td>
<td>Chapter 10 – Other Spectroscopic Methods – NMR Spectroscopy</td>
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<td>Chapter 13 – High Performance Liquid Chromatography</td>
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<td>12</td>
<td><strong>Exam 3</strong> – NMR, MS and HPLC</td>
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<td>Chapter 14 – Electroanalytical Methods</td>
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<td>13</td>
<td>Chapter 15 – Physical Testing Methods</td>
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<tr>
<td>14</td>
<td>Polymer Chemistry</td>
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<td><strong>Exam 4</strong></td>
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<td>15</td>
<td>Review for Final</td>
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<td></td>
<td><strong>Final</strong></td>
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</tbody>
</table>

A. Safety
   1. Lab safety rules.
   2. Industrial safety standards
   3. MSDS

B. Introduction to Spectrochemical Methods
   1. Characterizing Light
   2. The Electromagnetic Spectrum
   3. Absorption and Emission of Light
   4. Absorbance, Transmittance, and Beer’s Law
   5. Effect of Concentration on Spectra

C. UV-VIS Spectrophotometry
   1. UV-VIS Instrumentation
      a. Sources
      b. Wavelength Selection
      c. Sample Compartment
      d. Detectors
      e. Diode Array Instruments
   2. Cuvette Selection and Handling
   3. Interferences, Deviations, Maintenance, and Troubleshooting
   4. Fluorometry
D. IR Molecular Spectrometry
   1. IR Instrumentation
   2. Liquid Sampling
   3. Solid Sampling
      a. Solution Preparation
      b. Thin Film by Solvent Evaporation
      c. KBr Pellet
      d. Nujol Mull
      e. Reflectance Method
   4. Gas Sampling
   5. Spectra Interpretation
   6. Quantitative Analysis

E. Atomic Spectroscopy
   1. Instrument Design
   2. Flame Atomic Absorption
   3. Graphite Furnace Atomic Absorption
   4. Inductively Coupled Plasma
   5. Miscellaneous Atomic Techniques
   6. Atomic Absorption Spectrophotometer operation
   7. Atomic Absorption Spectrophotometer Experiments

F. Other Spectroscopic Methods
   1. X-Ray Diffraction Spectroscopy
   2. X-Ray Fluorescence Spectroscopy
   3. Nuclear Magnetic Resonance Spectroscopy
   4. Mass Spectrometry

G. Gas Chromatography
   1. Instrument Design
   2. Sample Injection
   3. Columns
   4. Other Variable Parameters
   5. Detectors
   6. Qualitative Analysis
   7. Quantitative Analysis
   8. Troubleshooting
   9. Mechanism of separation
  10. GC operation
  11. Resolution
  12. Theoretical plates
  13. Integration and calculation
  14. GC experiments
H. High-Performance Liquid Chromatography
   1. Comparison with Gas Chromatography
   2. Mobile Phase
   3. Solvent Delivery
   4. Sample Injection
   5. Column Selection
   6. Detectors
   7. Qualitative and Quantitative Analyses
   8. Troubleshooting
   9. Experiments with HPLC

I. Physical Testing Methods
   1. Viscosity
   2. Thermal Analysis
   3. Refractive Index
   4. Optical Rotation
   5. Density and Specific Gravity
   6. Particle Sizing
   7. Mechanical Testing
   8. Tensile Test
   9. Hardness

J. Polymers
   1. Introduction to Polymers
   2. Polymer Synthesis
   3. Monomers and Repeating Units
   4. Step Growth Polymers
   5. Chain Growth Polymers
   6. Polymer Characterization and Testing

**Homework Assignments:** A maximum homework grade of 10 points will be assigned to completed homework assignments handed in on time (prior to the start of the exam). These points will be added to the corresponding exam grade as bonus points.

**For Exam 1: Due before Exam 1**
Organic Exercise Sets 1, 2, 3, and 4 (handout)
7 (3, 7, 18, 19, 20, 21, 22, 23, 25, 43, 51, 60, 63, 65))
8 (1, 3, 8, 18, 20, 26, 28, 31)

**For Exam 2: Due before Exam 2**
8 (50, 52, 53, 56, 57, 58, 59, 63, 64, 66, 69, 75, 76)
9 (3, 7, 9, 10, 12, 17, 20, 23, 49, 50)
For Exam 3: Due before Exam 3
10 (2, 3, 5, 6, 7, 9, 12, 13, 15, 17, 21, 26, 29, 30, 31, 32, 33, 34, 35, 41, 43, 44, 45)
13 (1, 7, 8, 13, 19, 22, 36, 45, 49, 56, 60, 61)

For Exam 4: Due before Exam 4
14 (2, 3, 7, 8, 9, 12, 19, 26, 59)
15 (3, 8, 9, 10, 13, 15, 17, 19, 22, 26, 29, 31, 33, 35, 39, 41, 42, 47, 50)

Polymer Chemistry Problem Set

Important Semester Dates:
Last Day to Withdraw from Classes– Check BC Academic Calendar -
http://catalog.brazosport.edu/index.php

VI. LAB REQUIREMENTS
1. Visorgogs or safety goggles, must meet ANSI Z87.1-1989 certification.

To pass the course, the student must successfully complete the laboratory experiments with a grade of D or better.

Experiments for Applied Instrumental Analysis II Lab

Grading:
1. Come prepared to the lab. The introduction (objective, discussion), safety, material and apparatus, should be written in the Laboratory Notebook prior to the beginning of the experiment. The format for the lab notebook is described in detail in the handout (Report Format for CTEC 2431). This pre-lab write-up (30 points) must be checked and initialed by me prior to the start of each experiment.

2. Experimental data and observations must be recorded in the Laboratory Notebook. The data sheets and observations (20 points) must be completely filled out in ink and initialed by me before you leave the lab. When you make an error, cross it out with a single line. Do not use liquid paper or obliterate the error. For example: error error

3. After a lab is finished, write the date that you finished the lab on the lab sign-up sheet. This signifies that your lab report will be due one week from that date.

4. Analysis of the data, calculations, including any tables and graphs, and summaries and conclusions (50 points) are due one week after the conclusion of the experiment.

5. Carbon copies of the complete experimental write-up are due the week after you finish the experiment.

6. Grading will be based on completeness of the experiments and the submitted report write-up.

1) UV-Vis
a) Experiment 23: Determination of Nitrate in Water by UV Spectrophotometry. (Kenkel, page 234, and Handout)
b) Experiment 19: Colorimetric Analysis of Prepared and Real Water Samples for Iron. (Kenkel, page 197)
c) Colorimetric Determination of Aspirin. (Handout)
d) Analysis of Analgesic Tablet for Caffeine by UV Spectrophotometry (Handout)
2) FTIR
   a) IR Tutor (Interactive tutorial on the computer)
   b) Experiment 25: Qualitative Analysis by Infrared Spectrometry - Liquid Sampling. (Kenkel, page 235, and Handout)
   c) Experiment 26: Qualitative Analysis by Infrared Spectrometry - Solid Sampling. (Handout)
   d) Experiment 28: Measuring the Pathlength of Various IR Cells (Kenkel, page 237, and Handout)

3) AA
   a) Experiment 34: The Determination of Sodium in Soda Pop by Atomic Absorption. (Kenkel, page 271, and Handout)
   b) Experiment 32: The analysis of Snack Chips for Sodium by Atomic Absorption (Kenkel, page 270, and Handout)

4) GC-Mass Spectrometry

5) Viscometry
   a) Measuring the Viscosity of Polystyrene using a Capillary Viscometer (Handout)

6) HPLC
   a) The Quantitative Determination of Methyl Paraben in a Prepared Sample by HPLC.
      i) Determination of the Optimum Mobile Phase Composition
      ii) Methyl Paraben Quantization

7) FTIR Analysis and Thickness Determination of Various Polymer Samples

Safety:
1. Safety goggles must be worn at all times in the laboratory.
2. Know the locations of eyewashes, showers, fire extinguishers and exits.
3. Use common sense.
4. Bare feet are NOT allowed into the laboratory. Open sandals and shoes are discouraged.

Laboratory Housekeeping:
1. Arrange apparatus neatly and compactly. Keep all books except the laboratory manual and laboratory notebook off the laboratory workbench.
2. Do not throw paper or solid materials into the water troughs or sinks.
3. Keep all reagent bottles clean (especially acids and bases).
4. Keep the lab bench area clean. Pay particular attention to keeping the balances clean and in order. If you spill chemicals, clean them up immediately. Put caps back on reagent containers.
5. At the end of the laboratory period, clean off your workspace with a sponge or wet paper towel. Perform proper shutdown of the instruments. Check to see that the gas and water have been turned off. You are responsible for keeping the area neat. Repeated failure to do so may result in loss of credit.

CLEAN UP AND INSTRUMENT SHUTDOWN STARTS 10 MINUTES BEFORE THE OFFICIAL END OF THE CLASS PERIOD.
When the time is up, you are supposed to be out of the laboratory. Failure to properly budget your time is presumptive of poor planning and your grade may suffer.

VII. STUDENTS WITH DISABILITIES
Brazosport College is committed to providing equal education opportunities to every student. BC offers services for individuals with special needs and capabilities including counseling, tutoring, equipment, and software to assist students with special needs. For student to receive any accommodation, documentation must be completed in the Office of Disability Services. Please contact Phil Robertson, Special Populations Counselor at 979-230-3236 for further information.

VIII. TITLE IX STATEMENT
Brazosport College faculty and staff are committed to supporting students and upholding the College District’s non-discrimination policy. Under Title IX and Brazosport College’s policy FFDA (Local), discrimination based on sex, gender, sexual orientation, gender identity, and gender expression is prohibited. If you experience an incident of discrimination, we encourage you to report it. While you may talk to a faculty or staff member at BC, please understand that they are “Responsible Employees” and must report what you tell them to college officials. You can also contact the Title IX Coordinators directly by using the contact information below. Additional information is found on the Sexual Misconduct webpage at www.brazosport.edu/sexualmisconduct

IX. ACADEMIC HONESTY
Brazosport College assumes that students eligible to perform on the college level are familiar with the ordinary rules governing proper conduct including academic honesty. The principle of academic honesty is that all work presented by you is yours alone. Academic dishonesty including, but not limited to, cheating, plagiarism, and collusion shall be treated appropriately. Please refer to the Brazosport College Student Guide for more information. This is available online at http://brazosport.edu/students/for-students/student-services/

Academic dishonesty violates both the policies of this course and the Student Code of Conduct. In this class, any occurrence of academic dishonesty will be referred to the Dean of Student Services for prompt adjudication. Sanctions may be imposed beyond your grade in this course by the Dean of Student Services.

X. ATTENDANCE AND WITHDRAWAL POLICIES
Class attendance contributes to your final grade, but you must attend class to successfully complete the course. If you are unable to complete this course, you must complete and submit a withdrawal form with the registrar’s office. If the student decides to drop out of the class it is the responsibility of the student to initiate a withdrawal before the withdrawal deadline in order to get a “W” on their transcript. If this is not done the student will receive a grade based on test grades and class grades earned during their attendance and absence (i.e. zeros on all missed materials, exams, skills tests, and final exam).
XI. COURSE REQUIREMENTS AND GRADING POLICY
TESTING MAKE-UP POLICY

For this class you complete the following:

**Exams:** There will be a total of four exams. Each exam will last approximately one hour during class. The exact date of each Exam will be announced in class prior to the actual date of the exam. Students are allowed to bring a one-page, hand written notes containing equations, etc., to the exams.

**Homework:** As assigned by the instructor. A maximum homework grade of 10 points will be awarded as bonus points to the exam for homework assignments handed in on time. Due date for homework is the day of the exam. **All work must be shown to obtain full credit for the homework assignments.**

**Lab:** The laboratory portion of the course consists of weekly 3 hour labs which the student must attend. **To pass the course, the student must successfully complete the laboratory experiments with a grade of D or better.**

**Final Exam:** The final will be given at the end of the course. The final exam is comprehensive.

Each of the above requirements counts toward your final grade as follows:

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Percentage</th>
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<tbody>
<tr>
<td>Exams</td>
<td>40%</td>
</tr>
<tr>
<td>Attendance</td>
<td>5%</td>
</tr>
<tr>
<td>Lab</td>
<td>40%</td>
</tr>
<tr>
<td>Final</td>
<td>15%</td>
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</tbody>
</table>

Grades are assigned as follows:

<table>
<thead>
<tr>
<th>Grade</th>
<th>Final Average</th>
</tr>
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<tbody>
<tr>
<td>A</td>
<td>90-100</td>
</tr>
<tr>
<td>B</td>
<td>80-89</td>
</tr>
<tr>
<td>C</td>
<td>70-79</td>
</tr>
<tr>
<td>D</td>
<td>60-69</td>
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<tr>
<td>F</td>
<td>Below 60</td>
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</table>

A. Testing

See the class calendar for the chapters and dates of the tests. Students are allowed to bring one page of handwritten notes containing equations, etc., to the exams. The material to be covered on each exam is as follows:

<table>
<thead>
<tr>
<th>Exam</th>
<th>Chapters</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>Intro to Organic Chemistry, Spectrochemical methods, UV/Vis</td>
</tr>
<tr>
<td>2</td>
<td>FTIR, AA</td>
</tr>
<tr>
<td>3</td>
<td>NMR, Mass Spectrometry, HPLC</td>
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<tr>
<td>4</td>
<td>Electroanalytical Methods, Physical Testing Methods, Polymers</td>
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<tr>
<td>Final</td>
<td>Comprehensive Exam</td>
</tr>
</tbody>
</table>
B. Make-Up Policy

There will be no make-up exams. The lowest exam grade will be replaced by the final exam grade, if higher. The final exam grade will replace one missed exam grade.

XII. STUDENT RESPONSIBILITIES

Students are expected to fully participate in this course. The following criteria are intended to assist you in being successful in this course:

1. Understand the syllabus requirements
2. Use appropriate time management skills
3. Communicate with the instructor
4. Complete course work on time, and
5. Utilize online components (such as Desire2Learn) as required.

XIII. OTHER STUDENT SERVICES INFORMATION

Information about the Library is available at http://brazosport.edu/students/for-students/places-services/library/about-the-library/ or by calling 979-230-3310.

For assistance with online courses, an open computer lab, online and make-up testing, audio/visual services, and study skills, visit Learning Services next to the Library, call 979-230-3253, or visit http://brazosport.edu/students/for-students/places-services/learning-services/.

For drop-in math tutoring, the writing center, supplemental instruction and other tutoring including e-tutoring, visit the Student Success Center, call 979-230-3527, or visit http://brazosport.edu/students/for-students/student-success-center/.

To contact the Physical Sciences and Process Technologies Department call 979-230-3618.

The Student Services provides assistance in the following:

- Counseling and Advising 979-2303040
- Financial Aid 979-230-3294
- Student Life 979-230-3355

To reach the Information Technology Department for computer, email, or other technical assistance call the Helpdesk at 979-230-3266.

Get the information you need – when you need it. Click http://geni.us/BRAZO to install BC Connect on your mobile device to receive reminders, explore careers, map your educational plan, be in the know about events, find out about scholarships, achieve your goals and much more.
REPORT FORMAT for CTEC 2431

I. Introduction
   A. Objective
   B. Discussion
      I. Theory of operation performed (what happens in the analysis to obtain results).
      II. Brief write-up of procedure.
      III. Reactions if any.
      IV. Method used to calculate or to obtain results.

II. Safety precautions involved.

III. Materials and Apparatus
   A. Reagents used. Equipment used (glassware etc.) used.
   B. Instrument (type - model number etc.) used.

IV. Results
   A. Raw Data and Observations
      This is the data obtained in the procedure (weights, titrations, sample volumes, any data used to obtain results). The read out charts from the instrument determinations and graphs are attached to the reports. The data from them is shown here too, such as peak sizes, etc. No results here! Any deviation from the procedure should be included here.
   B. Calculations and/or Results
      All calculations, if any, are shown here.
      Results are shown here.

V. Summary and Conclusion
   A. Short summary of experiment. Results are included in the summary too!
   B. Comments pertaining to: Was objective obtained? How did the experiment go? Any problems? Your evaluation of the experiment, etc.

**Grading:**

- Objective 10 points
- Discussion 10 points
- Safety 5 points
- Materials & Apparatus 5 points
- Raw Data 20 points
- Calculations & Results 30 points
- Summary & Conclusion 20 points

Reports on experiments are due one week after they are finished. Each week that the report is turned in late, 5 points will be taken off the grade.
An Example Report:

I. Introduction
   A. Objective
      To determine % ppm or what is in an unknown.
   B. Discussion
      1. Theory
         In a chromatographic determination, the components are separated by their
         interaction between the mobile and the stationary phases as they move through
         the column. Temperature, carrier gas flow rate and the type of packing in the
         column affect the separations. (This is in your book as are all theories of the
         other methods. If it is a titration, tell what a titration is.)
      2. Procedure
         Short procedure. Do not put all the steps you do in order to get an instrument
         ready for the analysis.
      3. Reactions
         Reactions if any.
      4. Calculation formulas
         How results are arrived at, calculations etc.

II. Safety

III. Materials and Apparatus

IV. Results
   A. Raw Data and Observations
      Sample weights.
      Area counts and calculations as in the internal standards method.
      Milliliters of titrations.
      Linear regression calculations if needed.
      Anything that is used to get the results.
      Dilutions.
      Any deviations from the written procedure.
   B. Calculations and Results
      Calculations for results.
      Titration calculations.
      Results are shown here. Do not refer to charts, graphs or readouts. They are
      backup data only.

V. Summary and Conclusion
   A. Summary
      Short write up of what was done. Results are shown here too.
   B. Conclusion
      How did it go? Was objective obtained? Problems? Anything good or bad about
      the experiment.
Working With Your Lab Partner

Lab Partner’s Name_____________________________________________________________

Best way to contact (phone, email)________________________________________________

To become a productive lab partner, develop and fine-tune the following skills and abilities:

1. RESPONSIBILITY. Before leaving the lab, make sure both you and your lab partner have completely filled out both you and your partner’s data sheets. This is your insurance policy.

2. LISTENING SKILLS. You must be able to put your own thoughts aside and listen without interrupting or interpreting what your partner is saying. Try it - it’s not easy.

3. SELF-CONFIDENCE. You must believe in yourself and in the worth of your contributions. Speak up!

4. OPEN-MINDEDNESS. Welcome change, and listen to the ideas others bring.

5. CREATIVITY. Try stretching yourself outside of your routines. Try a different method. It might work better than your current method.

6. THOUGHT. Keep your goal in sight. Instead of following the lab manual like a recipe, consider the instructions to be a guide. When you make an error, how can you adapt the manual’s procedure to still reach your goal? Which type of balance will give you enough significant digits?

7. RELIABILITY. Do what you say you’re going to do.

8. OBJECTIVITY. Assess ideas, thoughts, and opinions from all sides, not just yours.

9. OPTIMISM. Look at problems as opportunities. Knocking over the beaker containing your product can lead to learning about purification techniques.

10. COOPERATION. You must be able to accept team decisions and work just as hard on other people’s ideas as you do on your own.

Adapted from Ern, B. L. and Lawley, C. M. (1992). The office professional as a team player. Office Hours, 229, 1.