

**Chemistry 250, Analytical Chemistry**  
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**Course Content.** The field of analytical chemistry involves “classical” and “instrumental” methods. Classical methods of analytical chemistry typically involve volumetric or gravimetric analysis, like titrations, or precipitation reactions, respectively. You were introduced to such techniques in Ch111. However, modern instrumental methods are increasingly important for solving problems in the field of analytical chemistry. This course will provide a foundation for using and understanding various classical and instrumental methods to identify and quantitate various kinds of unknowns. This involves determining the best method obtain samples, assessing the reliability of the measurements (how the sample relates to the whole population, statistical methods, error analysis, etc.) and learning about new instrumental methods. Course content will be largely limited to the textbook chapters listed, with additional lecture notes provided that demonstrate how key concepts are used in recent research in academic and industrial laboratories. Complementary information, including online quizzes, spreadsheets and additional exercises with solutions, can be found at: <http://bcs.whfreeman.com/qca8e/>. You can also find course lecture notes, sample tests and other course information by logging into your moodle account.

**Learning Objectives.**

- Identify and describe general techniques of chemical instrumental analysis
- Understand the meaning of signal-to-noise ratio (S/N) and discuss methods for enhancing S/N in analytical measurements
- Understand the different types of errors associated with chemical measurements, and be able to apply appropriate statistical methods for their evaluation
- Describe figures of merit for analytical techniques, such as accuracy, precision, detection limit and dynamic range
- Identify essential components of optical spectroscopy instruments
- Describe essential components of mass spectrometer systems and differentiate between various types of mass spectrometry methods
- Identify the main components of the various chromatographic systems
- Understand how to optimize the chromatographic separations process
- Understand the basics of electroanalytical methods
- Determine the best instrumental technique(s) to use for given applications and critically evaluate its effectiveness
- Apply their knowledge to developing an experiment of their own design in the laboratory course CH 251, Instrumental Analysis Laboratory

**Office Hours:** 1:00 - 2:00 T & R, or by appointment. Also, feel free to email me with questions, or to set up an appointment.

**Questions in Class:** Please feel free to ask questions during and after class.

**Course Text:** Quantitative Chemical Analysis, 8<sup>th</sup> Ed, by Harris, D. C. Freeman publishers.

**Homework:** There will be a series of homework assignments from the textbook. I encourage you to read ahead and start the homework problems before we cover a topic in class.

**Quizzes:** There will be a series of unannounced in-class quizzes, worth a total of 10% of your grade. These are usually derived from the assigned homework problems and/or previous lectures. The quizzes will generally occur during the first 5 to 10 minutes of class, so arrive early to avoid missing them. There are no makeup quizzes.

**Attendance:** Important announcements about the course will occasionally be made in class. You are responsible for knowing this information, even if you are not in class.

**Grading:** Your course average will be calculated based on the exams, quizzes, presentations and any other assignments, assuming that  $\geq 90 = A$ ,  $\geq 80 = B$ ,  $\geq 70 = C$ , etc. These cutoffs may change due to unforeseen circumstances. Additionally, an effort will be made to adjust the cutoffs to conform to natural gaps in grade distributions.

Your course grade will be assigned based on the exams, quizzes, final and any other assignments. The trend in your performance does not matter, although the final exam is worth 30% of your grade. **If you arrive late for an exam, you may not be allowed to take the exam.**

**Exams:** There will be four in class tests, your three highest scores will each be worth 20% of your overall grade:

There are no “make-up” exams. If you miss an exam, then that is the one you will drop. If you miss two exams, then you are in a precarious situation. The Final will be worth 30% points. It will be a standardized final exam developed by the American Chemical Society (ACS). This will allow you to demonstrate your level of comprehension of analytical chemistry with respect to other students around the country.

**Please do not embarrass yourself by grade grubbing, which is complaining that you need a better grade for some purpose like your perfect GPA, to keep your scholarship, or to graduate. Your grade will reflect your level of work in this course, not any outside influences. Work hard from the start, as small differences in performance can make a big difference in your grade.**

**Chapter 0:** This is an introduction to chemical analysis. It describes sampling, and how we go about doing an analysis. There is also some review material that we will cover briefly, but you will be responsible for, like calibration curves and general steps in a chemical analysis.

**Chapter 1:** SI units, the unit factor method, calculations of concentration, and the preparation of standard solutions. Chemical concentrations, preparing solutions, solution stoichiometry and introduction to titrations.

**Chapter 2:** There is a section on safety and how you handle chemicals. This is the most important section in the book. We try to structure the teaching labs to be safe, but you should always exercise care when dealing with concentrated reagents and protect yourself at all times. This chapter also covers tools commonly used in an analytical laboratory. You should read this material before you attend your first lab.

**Chapter 3:** Introduction to experimental error, where it comes from, what kinds there are, how to reduce it and how to take it into account. We will start with significant figures, which should be review. There are also sections on propagation of errors in successive calculations.

**Chapter 4:** Statistics. Some of the errors we encounter in our analyses are called indeterminate

errors, and we can't get rid of them. Instead, we use statistics in order to account for them. We will cover Gaussian distributions, and the statistics of small sets of numbers. We will learn about the student t test to help us determine how much confidence to put into our numbers. We will use a Grubbs test to see if we should keep data that looks suspect. We will learn about how you draw a best straight line in a set of data using the method of least Squares.

**Chapter 5:** Calibration methods. Powerful techniques, such as standard addition and internal standards, which allow us to get more reproducible and accurate results.

**Chapter 6:** This chapter involves chemical equilibria, and is in part a review of material you studied in General Chemistry. However, in this course the emphasis will be on the types of equilibria that must be considered for various types of analysis. We will start with a review of equilibrium constants, thermodynamics and Le Chatelier's principle. Then we will work at solubility product constants. These are important in gravimetric analysis, where we precipitate a compound and weigh it to determine how much of a component is present. The common ion effect will be discussed as it helps us obtain more complete precipitation of an analyte. We will also learn about acid-base chemistry.

**Chapter 7:** Activity: How the concentration of ions affects the tendency for species to interact. The "effective concentration" frequently deviates from what you expect it to be. The effect of a solutions ionic strength on the solubility of ionic salts.

**Chapter 26:** Gravimetric analysis. Using mass measurements to determine how much of something is present. This most commonly involves precipitation reactions.

**Chapter 8:** Monoprotic acid-base chemistry. Buffers and buffer capacity.

**Chapter 9:** Polyprotic acid-base chemistry. Equilibria equations. Fractional composition.

**Chapter 10:** Acid-base titrations. Graphical treatments of various forms of acid-base titrations. Instead of using an indicator to find the endpoint, you can make a graph of pH vs. volume of titrant added. We will cover how to use the 1<sup>st</sup> and 2<sup>nd</sup> derivative of a titration curve for endpoint determination.

**Chapter 13:** Electrochemists get a charge out of things. Fundamentals of electrochemistry, standard potentials, batteries, reference electrodes, the Nernst equation, other basic concepts.

**Chapter 14:** Ion-selective electrodes, the pH electrode, junction potentials.

**Chapter 15:** Electroanalytical techniques, i.e. electrogravimetric analysis and cyclic voltammetry.

**Chapters 17 & 18:** Go toward the light. Light can be used to perform analysis. We refer to this as spectrophotometry. If an analyte turns a solution green, then a solution that is light green contains less of it than one that is dark green. Beer's law is a way of saying this in a quantitative way.

**Lecture Handout:** Signals and noise. Thermal (Johnson noise), shot noise, flicker (1/f) noise, S/N enhancement, lock-in amplifiers.

**Chapter 22:** Introduction to analytical separations and high performance liquid chromatography (HPLC). Solutes can be separated and quantitated due to their varying affinities for the mobile

vs. stationary phases; theory and applications.

**Chapter 23:** Gas chromatography. More on the separation process. Injection ports and detectors.

**Lecture Handout:** The atomic force microscope (AFM) is used to obtain quantitative information about systems that are too small to be visualized by other types of microscopes.

### **Academic Honesty**

**We expect students at the Cooper Union to adhere to the highest standards of academic honesty and integrity. All work presented by you in this course is expected to be your own best effort, unless you are specifically instructed to work with other students on a particular problem. Copying of the work of others, and particularly plagiarism, which is the use of the work of others without proper credit or citation, will not be tolerated. The penalty for plagiarism or other academic dishonesty can include a judicial hearing and likely assignment of a grade of F in the course, or even expulsion.**