Chem 531: ANALYTICAL CHEMISTRY II, Winter 2014

CHEM•I•CAL SEP•A•RA•TIONS

Monday, 6-7:20 PM, Disque 307
Wednesday, 7:30-8:50 PM, Disque 307

Professor Joe Foley

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Office Hours: Feel free to call or e-mail me, or to *stop by in the early to mid-afternoon on any day of the week except Thursday and Friday. I will also be available in the late afternoons on Mondays and Wednesdays from 4:00 - 5:30 pm*. In addition, I am willing to schedule a special appointment for anyone who can't see me during the above office hours.

Course objectives

To understand and apply the general concept of resolution to simple problems

To understand the pressure- or voltage-driven mechanisms of bulk transport (flow)

To understand the 6 most important modes of separation in chromatography and related techniques

To understand the important sources ("mechanisms") of zone-broadening in chromatography

To understand the fundamental resolution equation of chromatography and the concepts therein

To appreciate the most relevant aspects of the components of the instrumentation (equipment) required for gas chromatography (GC) and high performance liquid chromatography (HPLC).

To gain a further appreciation of selected separation modes within HPLC, e.g., reversed phase liquid chromatography

To gain an appreciation of supercritical fluid chromatography (SFC) and capillary electrophoresis (CE)

Text(s): Please purchase the ***required text*** Introduction to Modern Liquid Chromatography, 3rd edition, written by Snyder, Kirkland, and Dolan and published by Wiley (2010, ISBN 978-0-470-16754-0 (hardback)).

The following books are *strictly optional*: Basic Gas Chromatography, 2nd edition, written by H. McNair and J. Miller and published by Wiley (2009, ISBN 978-0-470-43954-8 (hardback), and The Essence of Chromatography, written by Colin F. Poole and published by Elsevier (2003, ISBN 0-444-50198-1 (paperback) or ISBN 0-444-50198-3 (hardbound))

Other materials: Supplementary information will be posted on the Bb Learn website for this course. Examples include selected chapters from the Advances in Chromatography series (now

up to volume 51); Basic Gas Chromatography (McNair and Miller), 2nd edition; Chromatographic Integration Methods (Dyson), 2nd edition; Chromatography (Heftmann), 2nd edition; Multidimensional Liquid Chromatography (Cohen and Schure); and Chiral Separations by Capillary Electrophoresis (Van Eeckhaut and Michotte).

Grading: Your course grade will be determined as outlined below. The percentages are approximate (± 5%). At least 20% of the mid-term will be take-home.

Quizzes	**2 %**
Selected homework (computer exercises/problem sets)	**25 %**
Mid-Term Exam (take-home)	**22 %**
Review topic/article presentations	**16 %**
Attendance at CFDV seminars	**12 %**
Final Exam (March 17 or 19 (TBD), 6-8 PM, AEL 279)	**23 %**

Grading scale: The standard Drexel grading scale is employed, i.e., ≥ 97 = "A+", 93-96 = "A", 90-92 = "A-", etc.

Quizzes: Quizzes will not usually be announced in advance. They are given as an incentive for students to keep up with the reading, in-class activities (lectures, demonstrations, class discussions, etc.), and homework. There are no make-ups for missed quizzes.

Reading assignments: For every topic that we cover in class that is also discussed in the required textbook, I expect you to read the corresponding chapter or section without me having to make a formal assignment.

Computer Exercises/Problem Sets: Up to 5 problem sets will be assigned, collected, and graded during the semester. Problem sets must be submitted in the following format or they will be returned to the student for no credit: (i) 1-2 page summary sheet of the answers to the problems ***in the order assigned***: (ii) detailed solution to each of the problems ***in the order assigned***. Students are strongly encouraged to use some type of spreadsheet (Google, Microsoft Excel, etc.) for statistical or repetitive calculations.

Late problem sets will be penalized up to 5% per day unless there is a legitimate reason (as determined by the instructor).

Exams: If you cannot attend a scheduled exam, you must notify me in advance. If no such notification is given before the exam and no *acceptable* excuse is given afterwards, you will receive a zero for the exam.

Review topic/article presentations: Your assignment is to select, from a list of chapters in the serial monograph Advances in Chromatography that I will provide, an approved review topic/chapter that is of interest to you and summarize it orally via an 12-15 minute PowerPoint presentation, followed by 3-5 minutes of questions from other students and the instructor.

Attendance at CFDV seminars: The Chromatography Forum of the Delaware Valley (CFDV), a local professional society devoted to separation science, has monthly seminars on Tuesdays at 7:30 PM; please consult the website (**http://www.cfdv.org**) for more details. Social hour and dinner prior to the seminar are strictly optional; full-time students are entitled to a 50% discount on dinner, i.e., the cost is $15 with the discount. Please plan to attend the seminars on January 21 and February 18.

Students who are unable to attend the CFDV seminars because they are taking a class on Tuesday evenings will be asked to summarize a book chapter, research article, or review article published recently by the CFDV speaker and suggested by the instructor.

Communication by Bb Learn and e-mail: It is VERY important for me to be able to communicate with each member of the class quickly and efficiently. Reading and homework assignments, usually announced in class, are posted on the Bb Learn Calendar for Chem 531; use the "Create printable view" feature of the Calendar to generate a cumulative list. Please be sure to ***check Bb Learn at least 3 times a week***, e.g., every weekend ***and*** each night before our class so that if you have a question about an assignment, you could ask me about it in class the next day.

You are also welcome to submit a question about Chem 531 to me at jfoley@drexel.edu. If the number of questions submitted by email is not too large, I will reply by email and distribute the answer to the entire class (without revealing your identity!).

If you use an email address or alias other than your official Drexel email address ("firstname.middlename.lastname@drexel.edu"), **it is now university policy that it is your responsibility, not the responsibility of the university or the instructor, to arrange for email to be forwarded appropriately, i.e.,** ***it is your responsibility to make sure that you receive all email messages that are sent to your official email address.***

Academic Policies

Please review the following links provided below

- **Academic Misconduct, Cheating, Fabrication, Plagiarism, Withdrawal of a Degree**
  http://www.drexel.edu/provost/policies/academic_dishonesty.asp
- **Academic Honesty Policy**
  http://www.drexel.edu/studentlife/judicial/honesty.html
- **Course Drop Policy**
  http://www.drexel.edu/provost/policies/course_drop.asp
- **Office of Disability Services**
  http://www.drexel.edu/oed/disabilityResources/
- **Course Change Policy**
  The instructor may make changes to the course during the term at his discretion. If changes are made to the course, students will be notified via BbLearn, email, and will be made aware verbally at the beginning of the next scheduled class.

Schedule of lecture topics for Chem 531, Winter 2014

(the order may vary somewhat)

Introduction

1. Why are separations necessary for analytical chemistry?
2. Introduction to chromatography
3. Rectangular model of separation
4. Resolution
5. Bulk Transport
6. Separative Transport
7. Dispersive Transport

Mechanisms of Bulk Transport

1. Pressure-driven flow (incompressible fluid)
2. Dimensional parameters (e.g., reduced plate height, reduced velocity, Reynolds' number)
3. Pressure-driven flow (compressible fluid)
4. Voltage-driven flow

Mechanisms of Separative Transport

1. Overview
2. Approaches that don't involve/require bulk flow
3. Hydrodynamic
4. Field Flow
5. Chromatographic
6. Electrophoretic
7. **Extractions: liquid-liquid**, solid-phase, supercritical fluid, accelerated-solvent

Mechanisms of Dispersive Transport

1. Overview – rate (kinetic) theory of zone broadening
2. Plate height as a measure of zone spreading; measurement of plate number and plate height; errors in H and N resulting from the assumption of Gaussian zones
3. Diffusion, the Einstein equation, and diffusion coefficients
4. Longitudinal diffusion
5. Eddy dispersion
6. Resistance to (or the finite rate of) mass transfer (RMT)
7. Random walk model for RMT
8. van Deemter relationship for the dependence of plate height on the linear velocity of the mobile phase
9. Specialized van Deemter relationships for open tubular GC and HPLC: the Golay and Knox equations, respectively
10. Estimation of binary diffusion coefficients
11. Final thoughts on dispersive transport and tips for minimizing zone broadening

Theory of chromatographic separations

1. Fundamental resolution equations for isocratic/isothermal chromatography
2. Effect of distance traveled and/or ***plate number*** (column efficiency) on resolution
3. Chromatographic selectivity and its effect on resolution
4. Effect of retention on resolution and analysis time; optimization of retention factor

5. General elution problem; theory for gradient steepness, retention factor, and resolution using temperature-programmed elution (GC) and solvent gradient elution (HPLC)
6. Peak capacity and the statistics of peak overlap
7. Sample dilution
8. Summary of chromatographic relationships
9. Chromatographic isotherms, sample size, and peak shape
10. Thermodynamic description of chromatography
11. Gaussian description of chromatographic peaks and its origin

Quantitative analysis

1. Calibration methods in chromatography
2. Rationale for single point calibration in chromatography
3. Quantitative analysis with *response factors* (external standardization)
4. Quantitative analysis with *relative response factors* (internal standardization)
5. Data acquisition
6. Signal-to-noise ratio in chromatography and methods to increase it
7. Selected examples of errors in integration

Gas chromatography

1. Components of a gas chromatograph
2. van Deemter comparisons of 3 common mobile phases (H_2, He, N_2)
3. Packed columns
4. Open tubular (capillary) columns
5. Effect of column or stationary phase dimensions on resolution and analysis time
6. Effect of the chemical composition of the stationary phase on GC separations
7. Retention index and effective carbon number
8. Selectivity comparison of GC stationary phases
9. Examples of achiral and chiral GC separations
10. Sample introduction: split/splitless, solid-phase microextraction (SPME), purge-and-trap, headspace
11. Survey of GC detectors including the mass spectrometer
12. Appendix – calculations in GC

High-performance liquid chromatography – principles & RPLC

1. Hardware/instrument design
2. Effect of column or stationary phase dimensions on resolution and analysis time
3. Effect of the chemical composition of the ***stationary*** phase on HPLC separations
4. Effect of the physical and chemical properties of the ***mobile*** phase on HPLC separations
5. Mobile phase issues and effects
6. Controlling retention in reversed-phase liquid chromatography
7. Effect of %B on retention, selectivity, and resolution in *isocratic* separations
8. Illustrative comparison of *isocratic* and *gradient* separations
9. Flow-chart selection of HPLC separation mode for small and large compounds
10. Survey of HPLC detectors and selected applications
11. General approach to method development for *isocratic* or *gradient* HPLC
12. Systematic optimization of two *isocratic* separations in reversed-phase HPLC (RPLC): 7 aromatic compounds; 6 steroids
13. Systematic optimization of *gradient* separations in RPLC: 8 aromatic compounds
14. Selected applications of bonded-phase HPLC

15. Overview of supercritical fluid chromatography (SFC)

High-performance liquid chromatography – additional separation modes

1. Overview
2. Normal phase liquid chromatography (NPLC)
3. Hydroph**il**ic interaction chromatography (HILIC)
4. Hydroph**ob**ic interaction chromatography
5. Ion exchange chromatography (IEC)
6. Ion chromatography (IC) – a specialized and powerful form of IEC
7. Ion-pairing chromatography – a specialized form of reversed-phase HPLC
8. Chiral HPLC
9. Size exclusion chromatography
10. Affinity chromatography

Supercritical fluid chromatography (1 class period only)

1. Definition and properties of supercritical fluids
2. SFC in the context of GC and HPLC
3. Instrumentation for SFC
4. Stationary phases/columns for SFC
5. Experimental variables in SFC
6. Simplex, factorial, and mixture design in the optimization of SFC separations
7. Chiral separations by SFC

Capillary electrophoresis

1. Overview
2. Capillary zone electrophoresis (CZE)
3. Electrokinetic chromatography (EKC)

Two-Dimensional Separations

1. Overview
2. Peak capacity of two-dimensional separations
3. Examples

Other topic(s) not listed here (time-permitting)

Cumulative reading assignments

1. Lecture notes – all posted modules

2. Snyder, Kirkland, and Dolan, Introduction to Modern Liquid Chromatography, 3rd edition, Wiley, 2010

Chapter 1. Introduction: all sections, with particular emphasis on sections 3 and 4
Chapter 2. Basic concepts and the control of separation: sections 1, 2, 3.1, 3.2, 4, 5.1-5.3, 7.1-7.2, and 7.5-7.7).
Chapter 3. Equipment: sections 1, 8 (skim), 9
Chapter 4. Detection
Chapter 5. The column: sections 1-4
Chapter 6. Reversed-phase chromatography for neutral samples: sections 1-3, 5, 6
Chapter 7. Ionic samples: reversed-phase, ion-pair, and ion-exchange chromatography
Chapter 8. Normal-phase chromatography: sections 1, 3, and 6
Chapter 9. Gradient elution: sections 1, 2.1, and 2.2
Chapter 11. Qualitative and quantitative analysis
Chapter 13. Biochemical and synthetic polymer separations: section 8
Chapter 14. Enantiomer separations: sections 1-5, 6.1, 6.4, 6.5, and 6.7
Chapter 16. Sample preparation: sections 1-8

3. McNair and Miller, Basic Gas Chromatography, 2nd edition, Wiley, 2009

Chapter 1. Introduction
Chapter 2. Instrument overview
Chapter 3. Basic definitions: all sections except Retardation Factor (pp. 33-34), Redefinition of H (pp. 50-51)
Chapter 7. Detectors: all sections except *Sensitivity* (p. 112)