CBE 154: Chemical Engineering Laboratory

Spring 2019 Course Syllabus

Instructional Staff

Name	*Role*	*Email*	*Office/lab*	*Office hours*
Dr. Marjorie Went	Instructor	mswent@berkeley.edu	313 Gilman Hall	Tuesday 10 am – 11 am
Prof. Susan Muller	Instructor	muller2@berkeley.edu	201E Gilman	Thursday 11 am - noon
Prof. Markita Landry	Instructor	landry@berkeley.edu	106 Gilman	Tuesday 5 – 6 pm
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Course Goals

This course is one of the two capstone courses in the chemical engineering curriculum, along with Chemical Process Design (CBE 160). In these courses you begin to prepare for a role as a professional chemical engineer in industry or academia. As a result, this course differs from most of your previous ones. Rather than teaching a specific set of fundamental relations and concepts governing a particular subject (i.e., thermodynamics or transport) this course requires that you integrate and apply knowledge from your previous courses to design experiments, collect data, analyze results and make recommendations. Importantly, you will also work on developing your oral and written technical communication skills.

In this course students will learn to:

- design experiments to obtain relevant data
- troubleshoot processes
- conduct experiments utilizing typical CBE process equipment
- utilize numerical software packages to simulate transport phenomena and thermodynamics
- make, test, and justify assumptions
- analyze data appropriately to extract parameters of interest
- characterize, quantify, and report error in results and calculations
- apply analysis to answer questions, design scale-up
- present technical information effectively in written and verbal form

You will achieve these goals by performing a set of **six experiments** over the course of the semester. The mechanics of this course are complicated, so please read through the syllabus to obtain necessary information about how the course will run, what assignments you must complete, how you will be graded, and other important course policies.

Course Website & Computing Resources

The course website is maintained on bCourses and contains lab manuals, references, and announcements. You should be enrolled automatically. Please contact Dr. Landry if you have access problems.

The Chevron Computing Facility in 175 Tan Hall provides computer access, including COMSOL and Aspen, for all enrolled students. Log in with your CalNet ID and password. Please refer to the facility website for its hours. Note this facility is first come – first served for our students, when not reserved for a specific course.

Course Outline

Schedule

The semester schedule is posted in an Excel file on bCourse. Labs begin the second week and the semester is packed, so download the schedule and identify which labs your group must complete. The Excel file shows the daily lab schedule as well as the due dates and times of all

deliverables: written reports and oral presentations. Note important dates in your calendar and contact the instructor ASAP if you have pre-planned conflicts. Labs are Monday/Wednesday (Section 101) and Tuesday/Thursday (Section 102) from 1-5 pm in either S1 Gilman Hall or 33 Lewis Hall. We will only accommodate requests to switch between lab sections before the start of labs, and only if space allows.

Lectures

At the beginning of the semester, the instructors will give introductory lectures for each section during the first week's scheduled lab times in specified rooms, followed by weekly lectures on Mondays 12:10 - 1 pm in 180 Tan. These lectures will cover technical communication, error analysis, professionalism, safety and ethics. The lecture schedule is on the bCourses site under *Pages > Lecture Schedule*.

Groups

You will work for the entire semester in 3-member groups (with the exception of a few 4-member groups.) This semester you will have two options: 1) you may form your own groups during the first week, following the introductory lectures or 2) you may fill out a very short survey regarding your availabilities to work with other team members and communication/teamwork skills by the end of the first week. If you choose to form your own teams, consider carefully those peers with whom you will work closely throughout the semester, making sure schedules align and leadership styles and skill sets are complementary. We encourage you to consider being placed on a team through the survey, as experience working with new people can be rewarding and a very valuable addition to your professional skill set.

Each group must complete all of the experiments and assignments together unless otherwise noted. We expect all group members to contribute equally. Honest communication among group members is necessary for optimal group functioning, so please address any group issues before they grow. Peer evaluations collected during the semester serve to assess individual contributions to the group assignments. They form part of your course participation and teamwork grade.

Experiments and Rooms

Each group completes 6 experiments during the semester. You are allotted 4 lab periods to collect data for each experiment. If you finish a lab early, please communicate with the GSIs so that we know you will not be coming to the lab. Groups are pre-assigned a sequence of experiments at the beginning of the semester. This information can be found in the schedule posted on bCourse. Table 1 lists the experiment names and codes categorized by topic along with the requirements. The experiments with duplicate setups are numbered (i.e., HT1, HT2 or DIST1, DIST2). Signs on the wall or on the setup indicate the apparatus number. Check the schedule to see which apparatus your group is scheduled to use.

Table 1: Experiment categories, names, codes, and rooms. Notes in parentheses indicate required

experiments from each category.

Category (# required labs from category)	**Experiment Name**	**Code(s)**	**Room**
Transport (2 of 4 experiments)	Heat-Transfer Modeling	HT1, HT2	Lewis
	Mass-Transfer Modeling	MT1, MT2	Lewis
	Immersion Heat Exchanger	IHX	Lewis
	Heat Exchanger Modeling	HX1, HX2	Gilman
Chemical Reactions (1 of 3 experiments)	Absorption with Reaction	AR	Gilman
	Sucrose-Inversion Kinetics	CEU	Lewis
	Fermentation Kinetics	FERM1, FERM2	Lewis
Separations (2 of 3 experiments)	Distillation	DIST1, DIST2	Gilman
	Membrane Separation	MS1, MS2	Gilman
	Reverse Osmosis	RO	Gilman
Fluid Mechanics (1 of 3 experiments)	Centrifugal Pump	CP	Gilman
	Flow Measurement	FM	Gilman
	Fluidized and Packed Beds	FB	Gilman
Total (6 of 13 experiments)			

The experiments are housed in S1 Gilman Hall and 33/35 Lewis Hall. Access to S1 Gilman is only available via the external door on the south side of Gilman Hall. Please review the maps uploaded to bCourse (under *Files*) that show the location of experiments, emergency exits, and first-aid/safety equipment in each room. A GSI will always be present in each room. The landline phone numbers for the rooms are:

S1 Gilman: (510) 642-0358
33/35 Lewis: (510) 642-5862

For technical help on any experiment, see the GSI in the lab that hosts that experiment during lab hours and/or the instructor responsible for that experiment during lab hours (when the instructor is not hearing oral presentations) or office hours.

Fermentation project

A biotech project track intended for students with the biotech concentration or those who are interested in project-based learning related to brewing is an option for up to two 3-person groups in each section. The project focuses on learning the fundamentals of yeast fermentation and their application to fermented beverage production. The experiments are time-intensive and occasionally require spending extra time in lab outside of class time. The semester culminates with a project to produce and analyze beer or another fermented beverage.

Lab Notebooks and Data Collection

All students must maintain a formal laboratory notebook over the course of the semester. **The notebook must have numbered pages, a table of contents in the beginning, and be permanently bound.** Pre-lab exercises, brief procedures, raw data, observations, sample calculations, error analysis, and important results should be included in the laboratory notebook. At least one group member must record raw data ***in pen***; other group members may indicate in

their notebooks where to find the original data. At the beginning of a new experiment, the GSIs check each group member's lab notebook to confirm that the pre-lab exercises are completed. Students must bring their lab notebooks to every lab period. The notebook section for each experiment must be complete by the oral presentation. We grade the lab notebooks at the end of the semester according to the rubric available on the course website. For more information on acceptable lab notebook formats and practices, please see the "Lab Notebook Dos and Don'ts" .pdf file on the course website. For additional guidelines on lab notebook practices, see *Writing the Laboratory Notebook* by H. M. Kanare (full reference in **Textbooks** section of syllabus).

Assignments

Each experiment in this course carries at least one graded report, possibly two. Four experiments (reactions, fluid mechanics, and both separations) culminate in a group oral report delivered to the instructor one or two lab periods after experiment completion. See the schedule for details. For the transport experiments (HT, MT and HX), groups deliver an oral presentation during the third lab period. After both transport experiments, students turn in individual written reports two lab periods after completion of the experiment. Details on each type of assignment are included below.

Pre-lab exercises

Listed in the manual for each experiment are required pre-lab exercises that familiarize students with the concepts, apparatus, and safety issues relevant to that experiment. These questions **must be completed before the group may begin any experiment**. At the beginning of the first day of each new experiment, the GSIs will confirm that all group members have the pre-lab exercises completed in the lab notebooks. No group member may use the lab equipment unless they have been cleared by the GSI.

Oral reports

For all experiments, the group delivers an oral presentation to the instructor describing the important findings of the experiment. Each group member has the opportunity to be the lead presenter for one report. For a particular experiment, the lead presenter is expected to organize the team's efforts for data collection, data analysis, and presentation of the results and conclusions. All members are expected to work equally for each experiment, regardless of who is lead. During the oral presentation, the lead presenter must deliver the entire presentation. However, all group members contribute to answering questions following the presentation.

In 3-member teams, the two transport reports and a fourth report will be shared presentations with all members presenting. In 4-member teams, the two transport reports will be shared presentations with all members presenting (see Table 2 for the grade distribution within a team).

Oral reports concluding the separations, reactions, and fluid mechanics experiments occur after experiment completion. See the schedule for exact timing.

Oral reports take place ***in the instructor's office*** at the times listed in the schedule on the course website. Within the 45-min time slot, 15 min are allotted for the presentation, while the

remainder is reserved for questioning from the instructor and feedback.

Each presentation must contain no more than 10 content slides, not including the title slide. The title slide must include the presentation title, all team member names, the lead presenter noted (if applicable), the team number and date. Please bring to the presentation one printed copy of the presentation and a copy of the appendices containing the experimental data and detailed calculations. **Submit a copy of the presentation in PowerPoint and .pdf on bCourse no later than 10 AM on the day of the presentation.** ***Note: we will use Turnitin on all submitted presentations.*** The file name must indicate the group number, the experiment abbreviation, and the ORPT tag, i.e. '*MW1-DIST1-ORPT.*' Instructors will have student presentations loaded and ready on their laptops for students to begin presenting immediately at the allotted time. Groups will have access to the instructor's laptop, a projector, blackboard, and wireless presentation remote/laser pointer.

Purpose, context, audience: The format of these presentations is analogous to a new engineer in a company presenting to their boss during a project-review meeting. The oral report is a presentation of the student group's data, the conclusions derived from those data, and the reasoning used to reach those conclusions. Each presentation should tell a **coherent story**; do not simply answer analysis questions in order. Presentations should include the experimental objectives, a brief description of the experimental approach, relevant theory and literature, important results, and conclusions (not necessarily in this order). We recognize that the data collected within the four lab periods may not match ideal expectations. Address inconsistencies between data and expectations in the report and provide conclusions and suggestions for improvement. Students should expect in-depth questions that may extend beyond the narrow area of the presentation and into any aspect of the theory and experiment. Keep in mind that technical ideas are often best communicated in equations and diagrams; therefore, students are encouraged to utilize the board when answering instructor questions.

During the second week period of the HT, MT and HX experiments, students deliver a group oral report summarizing briefly their experimental approach, analysis, and important findings. Students are expected to compare their experimental results to theoretical expectations and literature predictions and to display important trends in the data. The 15-min presentation is followed by a discussion with the instructor to help assess the technical understanding of the lab and to assist in the completion of the COMSOL modeling and the written report, both of which are completed individually.

Oral reports are graded using the "Oral Report Rubric" located under the *Rubrics & Templates* folder in the *Files* section of the bCourse site.

Written reports

The HT, MT, and HX experiments conclude with a written report to be completed individually by each student. Written reports are due in class two lab periods after completion of the transport experiments. Hand in a stapled copy of the written report to your GSI at the beginning of the lab period. Additionally, turn in a copy of the written report in Word and .pdf on bCourses before lab starts on the due date of the report. ***Note: this semester we will use***

Turnitin on all reports. The file name must indicate the group number, the experiment abbreviation, and the WRPT tag, i.e. '*MW1-DIST1-WRTP*'.

Any reports turned in on time but not meeting the criteria outlined above will be considered unacceptable and must be resubmitted the next day subject to a 10 point penalty. Subsequent late days follow the regular 10 points/day penalty (see policy on late assignments).

We will grade written reports using the "*Written Report Rubric*" located on the bCourse site. We will return detailed comments with the report. The instructors keep copies of the written report for the departmental records.

Purpose, context, audience: Reports should be written from the point of view of a new engineer at a company tasked with assessing the feasibility of utilizing COMSOL software to simulate specific transport phenomena. The focus is on the simulation and its agreement with the experiment and theory.

Format: The written reports should follow the template provided online entitled "*Written Report Template*". Within the template are descriptions of what information to include in each section. The main body of the report must be no longer than 5 pages including tables and figures; accordingly, include only the most important results in the main body. The report may include up to 10 pages of appendices consisting of tables, figures, equations, and/or text that support the main body. For more information about style and conventions in technical writing, the American Chemical Society (ACS) provides a useful online guide called The ACS Style Guide. Information on figures, tables, grammar, writing style, references, etc. will be useful for your writing in this course.

Office hours and help

In addition to our scheduled office hours (see first page), the instructors and the GSIs are generally available for questions during lab time Mon-Thu 1-5 pm. Check the presentation schedule to make sure that they are available and not meeting with students. We are happy to help clarify the experimental objectives and tasks and to point you in the right direction. However, we will not tell you exactly what to do or whether you're "doing the right thing". There are multiple ways of approaching a problem and you must practice exercising your own judgment. We will address logistical questions (i.e., scheduling issues, assignment clarifications) via email, but we *will not* do the same for technical questions. You should utilize the 16 hours of weekly class time to address technical questions. Likewise, you are responsible for informing the GSIs or instructors early on if your data or simulations do not make sense. This way we can address any problems well before the reports are due.

Should you have issues with the equipment (pH meter, calibration curves, thermocouples, GC) bring them to the attention of your GSI as soon as possible. Most issues will have a simple resolution; ***equipment malfunction is not an excuse for missing data***. We strongly suggest that you run calculations (crunch the numbers) on the data you collect before each time you return to the lab so that you can modify your data collection methods if needed.

Lab Safety

It is critical that students follow proper safety protocol at all times while in lab. This includes completing pre-lab safety exercises prior to beginning each experiment, following laboratory rules, and knowing where to find safety information and equipment in the laboratory.

Before each lab, students must read the lab manual to ensure familiarity with proper safety protocols for that lab. Please review all Standard Operating Procedures (SOPs) associated with hazardous chemicals to be used in a particular experiment prior to arriving in lab. SOPs can be found in the folder labeled *Standard Operating Procedures (SOPs)* on bCourses.

It is imperative that students wear lab safety goggles and a lab coat at ALL times while in lab. Wear closed-toed shoes and long pants; avoid wearing loose clothing; tie back long hair. Only bring required material (i.e., lab notebook, pen, calculator, laptop, etc.) into the lab area. Backpacks and other personal items must be left in the designated areas. **Food and drink are not allowed in the lab at any time.** Before beginning an experiment, note the location of exits, first-aid kits, and emergency eyewash stations. These locations are shown in the maps of each room uploaded to bCourses. During the experiment, use common sense and ask the GSI if you have any questions or concerns about the safe operation of the lab equipment. Some experiments contain pressurized vessels, moving parts, noxious chemicals, and hot surfaces, so please exercise caution. Additionally, each experimental station must be run by a minimum of <u>two</u> students; it is unsafe to run an experiment by oneself. Groups that have absences of more than one group member must reschedule their data acquisition for that lab.

The GSI supervising the lab is in charge of lab equipment and student activity in the lab. All students must comply with any and all GSI instructions. Any safety violation or failure to comply with safety procedures or GSI instructions may result in you being asked to leave the lab with a zero for lab attendance that day; further consequences to your grade for that lab are possible.

Training certificate: In recognition of the importance of process safety for all chemical engineers, we require that students in Chem Eng 154 complete Level 1 certificate training in the AIChE SAChE (American Institute of Chemical Engineers Safety and Chemical Engineering Education) program. This program is highly endorsed by industry professionals, and options to continue your education in this area to earn higher level certificates are available if you so choose: http://sache.org/student_certificate_program.asp. You must first register with AIChE as a student member here (free) https://www.aiche.org/community/students. Then log into the eLearning portal through AIChE to complete the online training. To earn your points for the course, submit certificates of completion for all four components of Level 1 training: ELA950, ELA951, ELA952, and ELA953, through the bCourses Assignment upload.

Course Policies

Grading

Detailed grading rubrics are available on bCourse for written reports, oral reports, and lab notebooks. We strongly advise you to look through these rubrics to understand how we assess your assignments. You receive completed rubrics after each assignment so that you may identify areas for improvement. The grade reflects both the technical content of the report and the quality

of the writing or presentation. Scores are uploaded to bCourse periodically during the semester. Please check these against your records.

Tables 2A and 2B describe the grade breakdown for each experiment and each group member for 3- and 4-member groups. The percentages listed are the partial contribution of each assignment to an individual's overall course grade. Three of the oral reports require a team leader (points in red) and the rest assign points equally among the group members. See the *Oral Reports* section for information on the leader's role. Groups may decide which member is lead for each report.

Table 2A: Point breakdown for 3-member team, where red indicates the team leader.

Experiment category	***Report type***	***Member 1***	***Member 2***	***Member 3***
1st transport modeling	Oral	5%	5%	5%
1st transport modeling	Written	15%	15%	15%
2nd transport modeling	Oral	5%	5%	5%
2nd transport modeling	Written	15%	15%	15%
Chemical reaction/ Separations/ Fluid mechanics	Oral	16%	10%	10%
	Oral	10%	16%	10%
	Oral	10%	10%	16%
	Oral	12%	12%	12%
Participation	N/A	5%	5%	5%
Lab notebook	N/A	5%	5%	5%
Safety certificate	online	2%	2%	2%

Table 2B: Point breakdown for 4-member team, where red indicates the team leader.

Experiment category	***Report type***	***Member 1***	***Member 2***	***Member 3***	***Member 4***
1st transport modeling	Oral	5%	5%	5%	5%
1st transport modeling	Written	15%	15%	15%	15%
2nd transport modeling	Oral	5%	5%	5%	5%
2nd transport modeling	Written	15%	15%	15%	15%
Chemical reaction/	Oral	15%	11%	11%	11%
Separations/ Fluid mechanics	Oral	11%	15%	11%	11%
	Oral	11%	11%	15%	11%
	Oral	11%	11%	11%	15%
Participation	N/A	5%	5%	5%	5%
Lab notebook	N/A	5%	5%	5%	5%
Safety certificate	online	2%	2%	2%	2%

Table 2C: Point breakdown for 3-member brewing team, where red indicates the team leader.

Experiment category	***Report type***	***Member 1***	***Member 2***	***Member 3***
Mass transport modeling	Oral (tORPT1)	5%	5%	5%
Mass transport modeling	Written (WRPT1)	15%	15%	15%
Project	Meeting (tORPT2)	5%	5%	5%
Project	Oral (ORPT4)	12%	12%	12%
Project	Written (WRPT2)	15%	15%	15%
FERM	Oral	16%	10%	10%
IHX	Oral	10%	16%	10%
DIST	Oral	10%	10%	16%
Participation	N/A	5%	5%	5%
Lab notebook	N/A	5%	5%	5%
Safety certificate	online	2%	2%	2%

The lab notebook score is based on overall quality of your lab notebook assessed at the end of the semester. The lab-notebook grading rubric appears on bCourse.

Your attendance, lab preparation, and peer-evaluation scores all contribute to your participation score. GSIs keep track of lab attendance and prelab preparation. You will receive email links to submit peer evaluations of your group members two times during the semester. These evaluations are required.

Late assignments/rescheduling

The course organization is complicated, so rescheduling presentations is difficult. With the exception of family and medical emergencies, no late assignments will be accepted for full credit. For planned medical or other absences, please notify both instructors as early as possible.

Oral reports: Presentations begin at the time indicated on the schedule. **"Berkeley time" does NOT apply.** Any unexcused absences may be rescheduled within 1 week of the scheduled time for 50 % credit. Electronic submissions of oral reports after 10 am are considered late and subject to a 10-point penalty.

Written reports: Both the electronic and hard copies of written reports are due at 1:10 pm on the due date. Late submissions are subject to a penalty of 10 points per day. Reports are not

accepted more than 3 days late. Submit late reports Mon-Thu to the GSI in S1 Gilman or 33 Lewis at the usual time. If you need to submit any reports on a Friday place them in the appropriate instructor's mailbox inside 201 Gilman Hall and inform them by email. You may turn in reports on the weekends online through bCourse. If we receive an identical hard copy on Monday, then the electronic submission date will be recorded as the official submission date. If not, then the day the hard copy arrives will be the official submission date.

Expectations of Academic Integrity and Ethics

We are privileged to participate in the pursuit of knowledge and truth in higher education at UC Berkeley, and students and instructors are expected to maintain academic integrity and an environment of respect for the course of study and one another at all times. Our class is a safe space for people diverse in traits and ideology to exchange ideas and grow in experience and knowledge. Concerns about classroom environment should be addressed immediately to the instructors.

The student community at UC Berkeley has adopted the following **Honor Code:** "As a member of the UC Berkeley community, I act with honesty, integrity, and respect for others." We fully expect that you will adhere to this code. http://teaching.berkeley.edu/berkeley-honor-code

Plagiarism: Plagiarism is the presentation of the work or words of others as your own. Any item submitted by you and that bears your name is presumed to be your own original work. We will assess all written and oral reports for evidence of plagiarism using ***Turnitin***. We may compare electronic versions of presentations and written reports against reports turned into CBE 154 this year and in previous years. If we detect plagiarism you will receive a grade of **zero**. Additionally, forging of data—whether through data fabrication or using data not collected by your group—will be treated as plagiarism. We will report instances of plagiarism to the UC Berkeley Office of Student Judicial Affairs (http://sja.berkeley.edu). Please see this link from Dr. C. Barnbaum at Valdosta State University for helpful information on types of plagiarism and how to avoid them. Also see the library webpage for additional information on plagiarism and how to avoid it.

Accommodation of Special Situations and Needs

Campus policies regarding accommodation of student special needs in disability, illness, hardship, sexual harassment and sexual violence, religious creed, and conflicts between extracurricular and academic commitments can be found here: https://teaching.berkeley.edu/academic-calendar-and-student-accommodations-campus-policies-and-guidelines#anchor10

If you need accommodations related to physical, psychological, or learning abilities, please speak to one of the instructors after class or during office hours. Because of the fast-paced nature

of this course, we will not grant extensions on deliverables of more than one week.

If you must miss class because of religious observation, holy day, student-athlete or student-performer commitment or off-site interview please inform the instructor in writing by the end of the second week of the term in order to arrange to submit work early or reschedule an oral report. Should an anticipated absence, for a job interview for example, arise during the semester, please inform the instructors as soon as possible so we can adjust the ORPT schedule if needed. We trust that you will determine an equitable distribution of work for the lab if you missed part of the data collection time with your team members.

The link to UC Berkeley's policy is on the Religious Creed section of the Academic Calendar webpage. Here are the complete guidelines on schedule conflicts.

Help is available for students

College can be a simultaneously rewarding and challenging experience. To support students in the College of Chemistry, Dr. Yu Bi, a licensed psychologist from UC Berkeley's Counseling and Psychological Services, will be holding office hours in B-52 Hildebrand Hall (entrance is in the elevator lobby off the Breezeway) on Tuesdays to Fridays. You can make an appointment by contacting her at 510-664-7723 or drop-in on Tuesday afternoons 2-4 pm and Friday mornings 10am-12pm. Also, at UC Berkeley counseling services are available to you through the Tang Center, https://uhs.berkeley.edu/counseling.

Peer Tutoring

The CoC offers Peer Tutoring in Bixby Commons. The space was recently renovated to better serve this need. Excellent CBE 154 students may wish to consider contributing as a tutor. The site will be updated near the start of the semester with the new schedule of availability: https://chemistry.berkeley.edu/ugrad/current-students/tutoring

Textbooks

Primary texts:

McCabe W.L., Smith J.C., Harriott P. *Unit Operations of Chemical Engineering*, 7th ed.; McGraw-Hill: New York, 2005. "MSH", *CHM

Seader J.D., Henley E.J., Roper D.K. *Separation Process Principles*, 3rd ed.; Wiley: New York, 2011. "SHR", *CHM

Tebeaux, E., Dragga, S. The Essentials of Technical Communication, 3rd ed.; Oxford University Press: New York, 2015. "T&D"

Other suggested texts:

Bird R.B., Stewart W.E., Lightfoot E.N. *Transport Phenomena*, 2nd ed.; Wiley: New York, 2002. "BSL", *CHM

Kanare H.M. *Writing the Laboratory Notebook*; American Chemical Society: Washington DC,

1985. *CHM

Smith J.M., Van Ness H.C., Abbott M.M. *Introduction to Chemical Engineering Thermodynamics*, 7th ed.; McGraw-Hill: New York, 2005. "SVA"

Taylor J.R. *An Introduction to Error Analysis*, 2nd ed.; University Science Books: Herndon VA, 1997. *CHM

Welty J.R., Wicks C.E., Wilson R.E., Rorrer G. *Fundamentals of Momentum, Heat, and Mass Transfer*, 4th ed.; Wiley: New York, 2001. "W3R", *CHM

"XX" = book abbreviation, *CHM = on reserve in the Chemistry library