

Chemistry 38: Atmospheric Chemistry
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Course Description: As global environmental issues such as stratospheric ozone depletion and global warming have arisen, the impact of mankind on the environment, particularly the atmosphere, has become a pressing concern for both the public and scientific communities. Addressing these large-scale and highly complex problems demands a greater scientific understanding of the earth system. In this course, students will investigate Earth's atmosphere and the chemical and physical principles that shape it. Fundamental processes that determine atmospheric composition and climate, including multistep reaction mechanisms, chemical kinetics, molecular spectroscopy, photolysis, and heterogeneous chemistry, are introduced. Specific topics treated will include atmospheric composition, structure, and motion; element cycling; the transfer of solar and longwave radiation; stratospheric composition and chemistry; tropospheric oxidation processes; air pollution; and the role of human activity in global change. Laboratory, computational, and field experiments complement the lecture material.

Prerequisites: This course will rely heavily upon the basic principles of chemical kinetics and thermodynamics introduced in Chemistry 12, which is listed as a formal prerequisite. Chemistry 11 or 15 and Mathematics 11 are prerequisites for Chemistry 12, and are therefore de facto prerequisites for Chemistry 38 as well. When certain limited applications of more advanced mathematical and physical concepts, such as simple differential equations and their solutions, are encountered, the required techniques will be integrated into the course material.

Lecture: Monday, Wednesday, and Friday 11:00 to 11:50 am, Merrill 315.

Discussion: Monday, 2:00 to 2:50 pm, Merrill 315.

Office Hours: Tuesday 10:00 – 12:00 and Friday 1:30-2:30, Merrill 517. You may also make an appointment to meet with me outside of the regular office hours.

Course Materials: Handouts, assignments, and other materials will be available through the course website. Hard copies of handouts will also be available in the Chemistry Department Office, Merrill 507, Monday through Friday from 8:00 am - 4:00 pm.

Course Website: (Should be accessible to registered students through 'My Amherst' page.)
<https://www.amherst.edu/academiclife/departments/courses/1011S/CHEM/CHEM-38-1011S>

Texts: Michael B. McElroy, *The Atmospheric Environment: Effects of Human Activity*, by Princeton University Press, Princeton and Oxford, 2002. (required)

Daniel J. Jacob, *Introduction to Atmospheric Chemistry*, Princeton Univ. Press, Princeton, NJ, 1999. (Supplemental text. Problem sets may also be drawn from this book. It is available for free online at: <http://acmg.seas.harvard.edu/publications/jacobbook/index.html>.)

The texts will be supplemented occasionally by readings from other texts, selected articles from the primary literature, and scientific panel reports. Readings will be listed on the weekly assignment sheet. Copies of both texts will be on reserve in the science library.

Supplementary Material: Due to the critical policy implications of atmospheric research, international bodies of scientists are convened regularly to assess the state of the science in two key areas: stratospheric ozone and climate change. These documents, which summarize the most

up-to-date research in these fields, are readily available to the general public on the worldwide web. Links to these documents are accessible through the course website. I encourage you to explore them on your own. Readings and recent research findings will also be drawn from these reports. They are:

World Meteorological Organization, *Scientific Assessment of Ozone Depletion: 2006*, Global Ozone Research and Monitoring Project – Report No. 50, 572 pp., Geneva, 2007. http://www.wmo.int/pages/prog/arep/gaw/ozone_2006/ozone_asst_report.html

IPCC, 2007: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 996 pp. <http://www.ipcc.ch/>

Additional Texts: The following books on atmospheric chemistry are available in Keefe Science Library.

John H. Seinfeld and Spyros N. Pandis, *Atmospheric Chemistry and Physics*, 2nd Ed., John Wiley and Sons, Inc., New York, 2006. (On reserve.)

Paul J. Crutzen and Thomas Graedel, *Atmosphere, Climate, and Change*, W. H. Freeman and Co., 1995.

Guy P. Brasseur, John J. Orlando, Geoffrey S. Tyndall, *Atmospheric chemistry and global change*, Oxford University Press, 1999. (On reserve.)

Richard P. Wayne, *Chemistry of atmospheres: an introduction to the chemistry of the atmospheres of Earth, the planets, and their satellites*, 3rd Ed., 2000. (On reserve.)

Laboratory: Tuesday or Wednesday, 2:00 to 6:00 pm, Merrill 419.

(Note that the lab times are listed erroneously by the registrar. This class has a 4-hour lab.)

You will complete nine laboratory experiments over the course of the semester. The labs are organized into three groups of three experiments on related topics. Some experiments may require more than one lab period to complete. Hence, after each group of experiments, an extra lab day has been scheduled to allow additional time for data analysis and follow-up questions. Due to the instrument-intensive nature of the experiments, some labs will be run on a rotating basis so that only one or two laboratory groups are working on each experiment on any given day. You and a partner will be assigned to a laboratory group during the first week of class.

Please purchase a bound (not spiral!) notebook for use in the lab. The laboratory manual, which contains the experimental procedures and general guidelines, will be handed out at the beginning of the second week of class. You should come to lab fully prepared to perform the experiment. This includes having read the procedure and completed the prelab assignment in your laboratory notebook. Laboratory notebooks will be handed in to me three times, at the end of each lab rotation. The due dates are Feb. 25, Apr. 8, and May 6.

The usual safety precautions are to be followed at all times in the laboratory. This includes dressing appropriately. Do not wear shorts, sandals, or open-toed shoes to lab. Safety glasses will be available to each student and must be worn at all times in the laboratory.

Exams: There will be two three-hour evening midterm exams and a take-home final exam. The two midterm exams will be given Thursday, March 3, and Thursday, April 14, from 7 – 10 pm. The final exam will take place during exam week.

Problem Sets: Problem sets will be assigned from the text about once a week. Brief (about one page) writing assignments based on the supplemental readings may also be given as part of the weekly assignment. Assignments will be posted on the website one week before the due date and solutions will be posted after the assignments are turned in. Problem sets will be due in class on Monday (before discussion). I will do a quick check for completeness and return your work to you in discussion on Monday afternoon. We will then have a chance in discussion to go over any problems that caused difficulty. Problem sets will be scored on a scale of 1 – 5. Full credit (4 points) will be awarded for a significant effort at completing all the problems. A bonus point (5 points total) will be awarded for having most or all answers correct.

Class Participation: Attendance and participation in class are important components of this course, and will constitute 5% of the final grade.

Grading: Your grade in the course will be based on two mid-term examinations and one final exam, problem sets, laboratory notebooks and reports, and class participation weighted as follows:

Exams (15%, 15%, and 20%)	50%
Problem Sets	20%
Labs	25%
Class participation	5%

Intellectual Responsibility: Students enrolled in Chemistry 38 are expected to abide by the Amherst College Statement of Intellectual Responsibility (http://www.amherst.edu/academiclife/dean_faculty/fph/policies/sir). Particular attention should be paid to the statement, "...the College considers it a violation of intellectual responsibility to submit work that is not one's own or otherwise to subvert the conditions under which academic work is performed by oneself or by others." The specific implications of the statement for Chemistry 38 are:

1. **Laboratory Work:** Experiments are done with a partner, and you are encouraged to discuss experimental design and interpretation with your classmates. However, the data you record and the written reports you submit, including answers to the questions posed in the laboratory manual, must be your own. You will not receive credit for a lab report identical to that of your lab partner or another student. Copying of the lab manual or other students' lab reports, or using data that does not appear in your own lab notebook, constitutes a violation of the code of intellectual responsibility. If you have collaborated in obtaining data or discussed the results of an experiment, you must acknowledge the collaboration in the report, generally by listing the name(s) of your lab partner(s) in your laboratory notebook and on any written report. If you have used data other than your own, the source of the data should be indicated.
2. **Problem Sets:** You are encouraged to discuss the problems with your classmates. However, when your discussions are over, you are expected to be able to work through all problems by yourself. The solutions that are submitted should represent your mastery of the problems.
3. **Exams:** Giving or receiving assistance during an exam is dishonest. All work submitted must be your own. This applies to both regularly-scheduled and make-up exams, and to any subsequent discussion concerning the exams.

Chemistry 38: Atmospheric Chemistry Course Overview

The Composition of the Atmosphere

Gas laws and properties, pressure, measures of gas concentration; Sources, sinks, and chemical properties of important atmospheric species; Water; Aerosols.

Reading: McElroy, Chapter 2, 4, 5; Jacob, Chapter 1, 4, 8; Excerpts from IPCC AR4, 2007

Atmospheric Radiation, The Greenhouse Effect, and Climate

Blackbody radiation; The fate of solar radiation; Radiative equilibrium; The absorption spectra of atmospheric species; Greenhouse gases; Global warming; Climate feedbacks; Water vapor and clouds; Radiative effects of aerosols; Climate past and future.

Reading: McElroy, Chapter 6, 10, 19, 20; Jacob, Chapter 7; Excerpts from IPCC AR4, 2007

Atmospheric Structure and Motion

The hydrostatic equation and vertical structure; Atmospheric temperature profiles; Vertical transport; The general circulation.

Reading: McElroy Chapter 7, 8; Jacob, Chapter 2, 4

Biogeochemical Cycles and Models

Simple box and plume models; Atmospheric lifetimes; Biogeochemical cycles of carbon, nitrogen, phosphorous, sulfur. The hydrological cycle.

Reading: McElroy, Chapter 11, 12; Chapter Jacob, Chapter 3, 6

Chemical Kinetics and Photochemistry

Elementary reactions and reaction rate laws; Reaction mechanisms; Equilibrium; The steady-state approximation; Absorption and photolysis; Heterogeneous chemistry.

Reading: Jacob, Chapter 9

Stratospheric Chemistry and Ozone Depletion

Stratospheric composition; Stratospheric aerosols; The Chapman mechanism; Distribution of ozone in the stratosphere; Catalytic ozone loss cycles; Polar and midlatitude ozone loss.

Reading: McElroy, Chapter 13 – 16; Jacob, Chapter 10, Excerpts from WMO, 2002

Molina, M. J., and F. S. Rowland, "Stratospheric sink for chlorofluoromethanes: chlorine atom-catalysed destruction of ozone," *Nature*, **249**, 810-812, 1974.

Tropospheric Chemistry

Tropospheric oxidation: OH, nitrogen oxides, and ozone; the CO and methane oxidation cycles; Anthropogenic effects on the oxidative capacity of the troposphere; photochemical smog and ozone pollution; pollution control strategies.

Reading: McElroy, Chapter 17; Jacob, Chapter 11 and 12, Excerpts from IPCC AR4, 2007

Acid Rain (time permitting)

Sources of atmospheric acid content; acid deposition.

Reading: McElroy, Chapter 18; Jacob, Chapter 13