This course considers the processes that control the chemical composition of the atmosphere. We focus on the basic chemistry of stratospheric ozone depletion, tropospheric oxidation processes, urban air pollution, and acid rain, and then move into more advanced topics such as chemistry-climate coupling, aerosol chemistry, and the role of the biosphere. Emphasis will be given to new research findings, by discussing recent papers from the literature and listening to research seminars.

**Schedule**

Lectures: Tues/Thurs, 9:10 am to 10:00 am. First lecture is on Tuesday, January 10. Please also reserve Fridays from 1 to 2:30 pm (see below). Let the instructor know asap if you are not free at this time on Friday.

**Quercus Page**

This course is taught alongside its undergraduate version, CHM415S. Please email the instructor your UTORID to get access to the CHM415S Quercus page where most course elements will be posted. It is the students’ responsibility to follow announcements coming for both CHM415S and CHM1415S.

**Instructor**

Jon Abbatt, jonathan.abbatt@utoronto.ca, LM324

**Delivery Mode**

The course will be delivered in-person in LM158. I will provide an audio recording after each in-person lecture.

**Grading**

- Problem Sets 15%
- Midterm assessment 15%
- Research seminar questions/take-home messages/discussion board 20%
- Discussion sessions 15%
- Final assessment 35%

**Problem sets** – There will be four problem sets, submitted online. It is ok to submit legible handwritten work that has been digitally scanned. While ok to discuss the PSs with others in the class, you must submit your own work, ie. you must write up the assignment entirely yourself.

**Midterm and Final assessments** – In-person, closed book. Midterm assessment: Thursday March 2 from 9 to 10 am, i.e. during class time in LM158. Final assessment: During the FAS undergraduate final exam period; date TBA.

**Discussion sessions** – We will schedule 5 CHM1415S discussion sessions. They will likely be in LM319, perhaps on Fridays at 1 pm when there isn’t a FACS seminar. It is expected that you will discuss the discussion papers and the seminars you have been watching. Let the instructor know if you will miss a discussion session.

**Research seminar questions/take-home messages/discussion board:** Please register for the Frontiers in Atmospheric Chemistry Seminar series: https://facss.mit.edu/. You are required to attend and post three questions and three take-home messages for five of these talks. These questions are those that you would have asked the speaker if you had the opportunity to do so. The take-home messages are what you would have said to a colleague had you been walking back to your office after having watched the seminar in person, i.e. what did you learn in the seminar? Focus on what you learned, not on the speaker’s Conclusions page! **The questions/comments must be posted within 30 minutes of watching the seminar.** After you post a question/take-home message, you will see the posts from other students in the class. Please respond to them, if you have the answer or a
follow-up comment, within a week of the seminar. Note: Quantity is not as important as depth/quality!

**Penalties** – No credit will be given for late problem sets or posts, or for a late/missing midterm or final assessment unless there is a medical (or equivalent) justification. When there is appropriate justification for a missed problem set or midterm, it will not count and your other scores in the course will be pro-rated accordingly. If you miss the final exam, there will be a makeup.

**Anticipated Learning Outcomes**
After taking CHM 1415S, students will be able to:
1. Demonstrate an understanding of the major concepts in atmospheric chemistry both qualitatively and quantitatively.
2. Apply concepts in chemical kinetics and thermodynamics to describe atmospheric chemistry at a molecular level.
3. Critically analyze and discuss the scientific literature and scientific presentations in atmospheric chemistry, placing them into their correct context

**To get in touch with the instructor**
Office: Lash Miller 324; Tel: 416-946-7358
Email: jonathan.abbatt@utoronto.ca
Please contact me if you have any questions. Conceptual issues are best handled before or after class, at office hours, or by special appointments. Email is good for short questions. Please do not message me via Quercus – use direct email instead.

**Office hours**
Thursdays from 3:30 to 4:30 pm in LM324, or by special arrangement (just email me).

**Textbook** (*these books are available free online*).
You are only responsible for material and papers covered in class, and not for additional material from the textbooks. That said, the recommended textbook for the course may be very useful: *Introduction to Atmospheric Chemistry, D.J. Jacob, Princeton University Press*
[https://acmg.seas.harvard.edu/education/introduction-atmospheric-chemistry](https://acmg.seas.harvard.edu/education/introduction-atmospheric-chemistry)
Note that there is a draft 2nd edition of this book that we will not be using.

Another excellent reference is:
*Chemistry of the Upper and Lower Atmosphere, B.J. Finlayson-Pitts and J. Pitts, Academic Press*
*(available as an e-book through UofT libraries)*

**Course Policies**

**Students with accommodations** - Students with diverse learning styles and needs are welcome! The University of Toronto is committed to accessibility: if you require accommodations for a disability, or have any other accessibility concerns about the course, please contact Accessibility Services as soon as possible. Please remember that some accommodation requests are required to be submitted at least one week in advance of the course element deadline.

**Learning environment** - The University of Toronto is committed to equity, human rights and respect for diversity. All members of the learning environment in this course should strive to create an atmosphere of mutual respect where all members of our community can express themselves, engage with each other, and respect one another’s differences. U of T does not condone discrimination or harassment against any persons or communities.
Privacy issues - Students may create audio-recordings of in person classes only, for their personal use. Such recordings are intended to permit class content review to enhance understanding of the topics presented. Audio-recordings are not substitutes for attending class. Students should note that since audio and video recordings are to be permitted, their voice may be recorded by others during the class. Please speak to the instructor if this is a concern for you. Students agree to the following terms when creating audio recordings of lectures:

- Recordings are not to be distributed without the permission of the instructor via the Internet, using social media such as Facebook, peer-to-peer file sharing such as One Drive or Dropbox, or other distribution channels.
- Recordings are not to be shared with other classmates unless they are to be used in collaborative assignments, or if the instructor permits for other reasons.

Non-compliance with these terms violates an instructor’s intellectual property rights and the Canadian Copyright Act. Students violating this agreement will be subject to disciplinary actions under the Code of Student Conduct.

Submission methods
Please look at the Quercus course site for directions on the submission methods.

Technology Requirements
Specific guidance from the U of T Vice-Provost, Students regarding student technology requirements is available here: https://www.viceprovoststudents.utoronto.ca/covid-19/tech-requirements-online-learning/. Advice for students more broadly regarding online learning is available here: https://onlinelearning.utoronto.ca/getting-ready-for-online/ This course requires the use of computers, and of course sometimes things can go wrong when using them. You are responsible for ensuring that you maintain regular backup copies of your files, use antivirus software (if using your own computer), and schedule enough time when completing an assignment to allow for delays due to technical difficulties. Computer viruses, crashed hard drives, broken printers, lost or corrupted files, incompatible file formats, and similar mishaps are common issues when using technology, and are not acceptable grounds for a deadline extension.

Institutional Policies and Support
Academic Integrity - Academic integrity is essential to the pursuit of learning and scholarship in a university, and to ensuring that a degree from the University of Toronto is a strong signal of each student’s individual academic achievement. As a result, the University treats cases of cheating and plagiarism very seriously. The University of Toronto’s Code of Behaviour on Academic Matters (https://governingcouncil.utoronto.ca/secretariat/policies/code-behaviour-academic-matters-july-1-2019) outlines the behaviours that constitute academic dishonesty and the processes for addressing academic offences. Potential offences include, but are not limited to:

In papers and assignments:
1. Using someone else’s ideas or words without appropriate acknowledgement.
2. Submitting your own work in more than one course without the permission of the instructor.
3. Making up sources or facts.
4. Obtaining or providing unauthorized assistance on any assignment.

On tests and exams:
1. Using or possessing unauthorized aids.
2. Looking at someone else’s answers during an exam or test.
3. Misrepresenting your identity.

In academic work:
1. Falsifying institutional documents or grades.
2. Falsifying or altering any documentation required by the University.
All suspected cases of academic dishonesty will be investigated following procedures outlined in the Code of Behaviour on Academic Matters. If you have questions or concerns about what constitutes appropriate academic behaviour or appropriate research and citation methods, you are expected to seek out additional information on academic integrity from your instructor or from other institutional resources (see https://www.academicintegrity.utoronto.ca/). Here is an additional website to look at: http://www.writing.utoronto.ca/advice/using-sources/how-not-to-plagiarize.

In sum, all your work must be your own. It is very easy to identify work that is plagiarized and the ramifications are serious.

Copyright
If a student wishes to copy or reproduce class presentations, course notes or other similar materials provided by instructors, he or she must obtain the instructor's written consent beforehand. Otherwise, all such reproduction is an infringement of copyright and is absolutely prohibited. More information regarding this is available here: https://teaching.utoronto.ca/ed-tech/audio-video/copyright-considerations/.

Accommodations for Religious Observances
Following the University's policies, reasonable accommodations will be made for students who observe religious holy days that coincide with the due date/time of an assignment, tutorial, class or laboratory session. Students must inform the instructor before the session/assignment date to arrange accommodations.

Additional Services and Support
The following are some important links to help you with academic and/or technical service and support:

- General student services and resources at Student Life
- Full library service through University of Toronto Libraries
- Resources on conducting online research through University Libraries Research
- Resources on academic support from the Academic Success Centre
- Learner support at the Writing Centre
- Information for Technical Support/Quercus Support

Acknowledgement of Traditional Lands
We wish to acknowledge this land on which the University of Toronto operates. For thousands of years, it has been the traditional land of the Huron-Wendat, the Seneca and, most recently, the Mississaugas of the Credit River. Today, this meeting place is still the home to many Indigenous people from across Turtle Island and we are grateful to have the opportunity to work on this land.
**Lecture Schedule**

This lecture schedule is a rough outline for where we are heading; dates/content may vary somewhat. Each entry with ** designates discussion of papers from the literature.

**Introduction**
Lecture #1 – Global environmental change, formation, and overall composition of the atmosphere

**Fundamentals**
Lecture #2 – Atmospheric photochemistry and kinetics
Lecture #3 – Atmospheric photochemistry and kinetics
Lecture #4 – Atmospheric chemistry models
Lecture #5 – Atmospheric mixing processes

**Stratospheric Ozone Depletion**
Lecture #6 – Mid-latitude ozone
Lecture #7 – Mid-latitude ozone
Lecture #8 – Polar ozone
Lecture #9 – Current understanding of ozone depletion - ** Ravishankara paper

**Tropospheric Oxidation**
Lecture #10 – Tropospheric chemistry: Introduction
Lecture #11 – Tropospheric chemistry: OH/NO\(_x\)/VOCs/O\(_3\)
Lecture #12 – Tropospheric chemistry: VOC oxidation mechanisms, OH measurements, special topics
Lecture #13 – Tropospheric chemistry: Biogenic VOCs - ** Lelieveld paper
Lecture #14 – Air pollution, aerosols
Lecture #15 – Air pollution, aerosols
Lecture #16 – Air pollution, aerosols – ** Anenberg paper and Lewis paper
Lecture #17 – Air pollution, aerosols – ** Cheng paper
Lecture #18 – Tropospheric Halogens

**Atmospheric Chemistry and Climate**
Lecture #19 – Climate system and radiative forcing
Lecture #20 – Climate system and radiative forcing
Lecture #21 – Clouds and climate
Lecture #22 – Clouds and climate - ** Cziczo paper
Lecture #23 – Geoengineering and wrap-up