

## Atmospheric Chemistry – CHM 415S

This course considers the processes that control the chemical composition of the atmosphere, building upon the introduction in CHM210H. In particular, in that class you learned the basic chemistry of stratospheric ozone depletion, tropospheric oxidation processes, urban air pollution, and acid rain. We will revisit these topics, studying them in much more detail while introducing topics not covered in CHM210, 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 by a requirement to write a literature research paper.

### ***Prerequisite***

I assume that you are comfortable with the atmospheric chemistry component of CHM210. ***Please note that as a fourth-year class, CHM415 is more challenging and quantitative than CHM210. Students who found the material challenging in CHM210 may struggle in CHM415. Please talk to the instructor if you feel you may not have the background for the course.***

### ***Schedule and Classroom***

Lectures: Tues/Thurs, 9:10 am to 10:00 am, SS2105.

Office Hours: Monday from 3:00 to 4:00, LM324. Wednesday from 2:00 to 3:00, via Zoom

<https://utoronto.zoom.us/j/88171396243>

### ***Delivery Mode***

All aspects of the course are in person. An audio recording will be provided for each lecture (please let me know if I forget to turn the recorder on).

### ***Grading***

Problem Sets (average of top three scores from four problem sets)	10%
Midterm assessment (Thursday February 29, closed book, in-class, during class time)	20% or 15%
Literature research paper (2500 words, due Thursday March 28 by 6 pm)	25%
Paper reading posts (by midnight preceding the class discussion, first 5 are graded)	10%
Final assessment (during final exam period)	35% or 40%

**Problem Sets** – It is ok to submit legible handwritten work that has been digitally scanned/photographed. All submissions will be online using .pdf files. There are four problem sets and I will average the top three scores. Problem sets will be assigned at least two weeks before they are due.

**Midterm and Final exam** – These two closed-book assessments/exams total to 55% of the final grade, with the 20%/35% or 15%/40% split determined by whichever combination gives the highest total score. The midterm will be in-person in our normal classroom during class time on Thursday February 29. The final will be during the FAS exam period; date TBA.

**Reading Posts** – In class, we will discuss six papers from the literature. You must post short comments/questions for 5 of the 6 papers by midnight preceding the class discussion; I will average the marks for the first 5 submissions. The posts should demonstrate that you read the paper by providing interesting discussion points and/or by raising valuable questions for the ensuing in-class discussion; do not summarize the paper. The posts should each be roughly 100 words long, but not much longer. The date at which the paper will be discussed in class will be provided one week in advance. You will get one mark for the Reading Posts at the end of the semester, i.e. you will not get individual scores for each post.

**Literature Research Papers** – Please submit a literature research paper (2500 words, not including references; at least 10 references from the scientific literature) on a current research topic in atmospheric chemistry of your choice. Due date is Thursday March 28 at 6 pm. Your topic should be specific, being actively researched, and one for which there are still considerable scientific uncertainties. The content should go well beyond what is in textbooks. Additional details on the format/structure of the paper are provided at the end of this document.

### ***Anticipated Learning Outcomes***

After taking CHM415S, you will be able to:

1. Demonstrate that you understand 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 the scientific literature in atmospheric chemistry, placing it into its correct context
4. Summarize the current state-of-science in an atmospheric chemistry sub-field
5. Demonstrate an appreciation of the value of a strong scientific understanding of environmental phenomena

### ***Contact Information for Jon Abbatt***

Office: Lash Miller 324; Tel: 946-7358

Email: [jonathan.abbatt@utoronto.ca](mailto: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.

### ***Office hours***

Mondays from 3 to 4 pm in LM324, and Wednesday from 2 to 3 pm via Zoom

<https://utoronto.zoom.us/j/88171396243>.

***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 is:

*Introduction to Atmospheric Chemistry, First Edition, D.J. Jacob, Princeton University Press*

<https://acmg.seas.harvard.edu/education/introduction-atmospheric-chemistry>

However, Jacob does not cover everything we study. 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**

Missed or late course elements – Appropriate documentation (e.g. using the Absence Declaration tool <https://www.artsci.utoronto.ca/current/academics/student-absences> and by contacting the instructor) must be provided to avoid penalties. Note that Absence Declaration via ACORN can only be requested once per semester. In particular: *Midterm*: A make-up midterm will not be given, rather your scores on other course elements will be pro-rated accordingly.

*Research Paper*: If your assessments or paper arrive late, marks will be deducted at a rate of 10%/day, i.e. if your assessment would have been graded at 80% and it arrives 25 hours late, it will receive a 60% mark instead.

*Problem Sets*: Late problem sets are not accepted. If you miss one problem set, that is fine because we only average the top three scores. If you are ill for 2 or more problem sets, then please contact the instructor. Note that you must provide appropriate justification (i.e. using the Absence Declaration Tool (or another mechanism) and informing the instructor) for problem sets you miss for illness or equivalent reasons.

*Reading Posts*: Late reading posts are not accepted; they are required to frame the discussion of the ensuing class. However, note that you only have to submit 5 of 6.

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 don't forget that some accommodation requests are required to be submitted at least one week in advance of the course element deadline. Note also that it is not possible to make exemptions for late Reading Posts because those elements involve the full class and are required for the class discussion to proceed (but remember that you only need to post for 5 of the 6 discussion papers). Also, requests for extensions for Research Papers will only be granted to students with accommodations if they can demonstrate that they have already made substantial progress on the assignment, i.e. most

of the research has been done (in particular, you will need to send the instructor your full reference list) and half of the writing is complete. In other words, the expectation is that you will start this assignment long (at least two weeks) before it is due.

Artificial intelligence tools - The use of generative artificial intelligence tools or apps for assignments in this course, including tools like ChatGPT and other AI writing or coding assistants, is prohibited.

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 recordings are 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.**

### Plagiarism Detection

Normally, students will be required to submit their course essays to the University's plagiarism detection tool for a review of textual similarity and detection of possible plagiarism. In doing so, students will allow their essays to be included as source documents in the tool's reference database, where they will be used solely for the purpose of detecting plagiarism. The terms that apply to the University's use of this tool are described on the Centre for Teaching Support & Innovation web site (<https://uoft.me/pdt-faq>).

### 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<sub>x</sub>/VOCs/O<sub>3</sub>

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 – Geoengineering and wrap-up – \*\* Keith Video

Lectures #22, #23 (offline, on video) – Clouds and climate

## Literature Research Paper

You are required to submit a literature research paper on a research topic in atmospheric chemistry of your choice. The topic must be being actively researched and still have significant scientific uncertainties. To get feedback on your topic, please email the instructor the tentative paper title with a short paragraph describing the content to be covered.

### *What is a Literature Research Paper?*

This is a paper that summarizes what is known about a scientific topic. It is not a paper where you do original (i.e. primary) research yourself. Nor is it an essay or a paper where you make and defend a thesis. Instead, you will delve deeply into and summarize the scientific literature. The paper goes beyond the level of detail provided in a textbook and it is on a more specific topic. For example, exciting topics would be: “Current understanding of the role of chlorine in urban air pollution” or “Evidence for the impact of ocean biology on marine clouds”. Topics that are too general are “The Ozone Hole”, “Acid Rain in North America”, “Air Pollution in East Asia”, and “Greenhouse Gases and Climate”. The topic should be current, still being researched.

### *How should I use references?*

You need a full reference list at the end of the paper, where most of your references should come from the primary scientific literature. Use of a couple of review articles is fine, as would be a couple of authoritative government reports. However, the majority of your sources should be peer-reviewed articles from scientific journals. You should add references throughout your paper, using either superscripts<sup>x</sup> or by author date (Abbatt, 2022). In particular, you must reference factual statements in your report, not only those involving numbers (e.g. “Population of Canada is xx million people<sup>x</sup>”) but also when you describe specific experimental results or findings (e.g. “The work of so and so demonstrated that so and so was true (Ref y).”) The sources of all figures taken from the scientific literature have to be referenced. You should also include sources that informed you in a general manner in your final reference list, which should include at least 10 papers/sources but probably more. Old papers are not necessarily better or worse than new papers; the field builds upon itself but sometimes our understanding changes abruptly. That being said, you are researching an ongoing research field so you must have a substantial number of references from the last 5 years or so. Please use the following formatting style for journal articles – authors, article title, journal title, volume, page numbers, year. For example: **Hems RF, Schnitzler EG, Liu-Kang C, Cappa CD, Abbatt JPD. Aging of Atmospheric Brown Carbon Aerosol, *Earth Space Chem.* 5, 722–748, 2021.** However, if you prefer to use another standard formatting style, such as APA, that is fine too. Note that some journals no longer use page and/or volume numbers. In that case, please provide the doi number instead.

### *Should I use Figures?*

Use of a few figures is strongly encouraged; they can greatly enhance a paper. If you use figures taken from the literature, they must be referenced, a caption must be provided, and they must be actively described or referred to in the paper.

### *Is there a formal structure and style that I should use?*

This is not an essay where you make personal statements or comments. The writing style is objective and in the third person. It greatly helps the paper to give it structure with headings and sub-headings, such as “Introduction”, “Background Material”, “Topic X”, “Sub-topic Y”, “Uncertainties in the Field”, “Conclusions”. Always use a grammar and spell checker. Position your figures into the text and don’t simply add them to the end of the report.

### *What length should it have?*

No more than 2500 words (not including references). Please provide a word count. An important point is that a short (2000 words), concise paper will be graded higher than a long (3000 word), verbose paper. You should have 10 references (or more) from the scientific literature.

### *Plagiarism?*

It is plagiarism to use words taken directly from a literature source unless they are placed in quotations and a reference is given. In other words, all the writing in your paper must be your own. Please see the statement above about the use of the University’s automated plagiarism detection tool.

### *How will the paper be graded?*

This is what I will be looking for: Was the topic current and important? Was considerable literature research done? Is the science accurately described? Are the references strong? Is the paper clearly written? Are there any grammar or spelling mistakes? Does the paper have good structure? Have figures been incorporated appropriately?

### *Artificial intelligence tools?*

The use of generative artificial intelligence tools or apps for assignments in this course, including tools like ChatGPT and other AI writing or coding assistants, is prohibited.