CHEM 326/ENCH 326: Environmental and Green Chemistry
Winter 2024

Instructors: R. Stephen Brown and Hridaynath Bhattacharjee
   Brown E-mail: stephen.brown@chem.queensu.ca
   Bhattacharjee E-mail: h.bhattacharjee@queensu.ca

TA: ███████████████████████

Website: https://onq.queensu.ca

Schedule: ████████████████████████████████

Text: Environmental Chemistry, *5th Edition, Baird and Cann, Freeman & Company.*
(E-text option available, Solutions manual is optional, 4th Edition is acceptable)

Other Literature: (Check for availability through Stauffer Library Circulation Desk)
   Environmental Chemistry, 4th Ed., *Baird and Cann*
   Environmental Chemistry, 8th Ed., *Stanley Manahan*
   Green Chemistry and Catalysis, *R. A. Sheldon et al.*
   Green Chemistry: An Introductory Text, *M. Lancaster*
   Other references will be given throughout the course.

Marking: Problem Sets 10% (6 Weekly problem sets 6.6%; "Screening" problem set 3.4%);
   Assignments 40% (#1-Contaminant Distribution 16%, #2-Life-Cycle Analysis 16%,
   #3-Class presentations 8%); Midterm test 25% (███████████████████);
   Final exam 25%

UDL Consideration: The lowest mark of the 6 weekly problem sets will be dropped.

Learning Objectives: After completing this course, students will be able to:
1. Describe the main chemicals that are important to environmental issues, including their fate and behaviour related to phenomena including ozone depletion, greenhouse gas effects, and toxicity in air and water.
2. Use partition calculations and fugacity-based models to describe the distribution of chemicals between different environmental compartments and relate this to molecular structure and properties.
3. Describe the main approaches for treating contaminated water before drinking or releasing to the environment.
4. Explain the principles of Green Chemistry including the main measures and metrics, including E-factors, environmental impacts, and energy consumption.
5. Design chemical processes using alternative feedstocks and reagents with green synthetic methods and strategies, including solventless conditions or use of preferred organic solvents, water, supercritical fluids, expanded liquids, ionic liquids, and liquid polymers.
6. Prepare a report proposing a green chemical process within a small group and present the this to a peer class including chemists, engineering chemists and chemical engineers.

Course Outline: *Part 1*

1. Overview: define Environmental Chemistry and Green Chemistry; context within chemistry discipline; outline of text; review concentrations and calculations.

2. Chemistry of the Atmosphere: gas-phase reactions; radical reactions and thermodynamics; chlorine radicals and the ozone 'layer'; CFCs and other ozone-depleting contaminants; atmospheric pollution; hydroxyl radicals, ozone production, VOCs, NO_x, and photochemical smog; airborne particulates.

3. Greenhouse effect and global warming: i.r. absorbance spectra and greenhouse effect; major greenhouse gases - CO_2, H_2O, CH_4, N_2O, aerosols, others; predicted effects; energy sources and alternatives.

4. Chemistry of organic contaminants: review of chemical classes; principles of toxicology; persistence, bioaccumulation and toxicity; fate and effects; partition, fugacity and long-range transport.

5. Chemical contaminants: pesticides; dioxins and furans; PCBs, PBDEs and PFAS; PAHs; contaminants of emerging concern including estrogenics, nanomaterials and microplastics.

6. Water: natural waters - oxygen and redox chemistry, acid/base chemistry and carbonate system; drinking water - purification, disinfection, impact of chlorine; groundwater - contaminants and remediation; wastewater - phosphate, oxygen demand, wastewater treatment.

Part 2:

7. Introduction to Green Chemistry: history, goals and principles, economic and legislative drivers.

8. Measures and Metrics: E-factors and related measures, multi-variant assessment of impact, energy consumption.

9. Molecular Design: How to design organic molecules to avoid toxicity, persistence, and other environmental impacts

10. Green Synthesis: Alternative feedstocks (biomass, waste polymers, CO_2), greener reagents, synthetic strategies.

11. Solvents: solventless conditions, preferred organic solvents, water, supercritical fluids, expanded liquids, ionic liquids, and liquid polymers.

Handing in assignments

Assignments must be submitted through onQ on or before the due date. Late submissions will be given a penalty of 5% per day. Extensions will be granted only after an application for academic consideration (see below). Students applying for academic consideration must contact the Instructor **before the due date of the assignment**. For the lifecycle analysis assignment, no late assignments will be accepted after the first presentation by students.

Calculator Policy

Calculators will be required for problem sets, assignments, the midterm and final exams. For this purpose, the use of the **Casio FX-991** series calculator is required as it is the **only approved calculator for Applied Science and Arts and Science students**. Only this calculator will be permitted in the Midterm and Final exam. This calculator sells for around $25 at the Queen's Campus Bookstore, Staples and other popular suppliers of school and office supplies. It is

recommended to use this even for problem sets and practice problems to be familiar with using this calculator.
https://www.queensu.ca/secretariat/policies/senate/use-calculators-tests-or-examinations
http://my.engineering.queensu.ca/policy/Calculator.html

Academic Integrity
Queen's students, faculty, administrators and staff all have responsibilities for supporting and upholding the fundamental values of academic integrity. Academic integrity is constituted by the five core fundamental values of honesty, trust, fairness, respect and responsibility (see www.academicintegrity.org) and by the quality of courage. These values and qualities are central to the building, nurturing and sustaining of an academic community in which all members of the community will thrive. Adherence to the values expressed through academic integrity forms a foundation for the "freedom of inquiry and exchange of ideas" essential to the intellectual life of the University. Students are responsible for familiarizing themselves with and adhering to the regulations concerning academic integrity. General information on academic integrity is available at Integrity@Queen's University (https://www.queensu.ca/academicintegrity/), along with Faculty or School specific information. Departures from academic integrity include, but are not limited to, plagiarism, redistribution of copyrighted materials, facilitation, forgery and falsification. Actions which contravene the regulation on academic integrity carry sanctions that can range from a warning, to loss of grades on an assignment, to failure of a course, to requirement to withdraw from the university.

Academic Accommodations
Queen's University is committed to achieving full accessibility for persons with disabilities. Part of this commitment includes arranging academic accommodations for students with disabilities to ensure they have an equitable opportunity to participate in all of their academic activities. If you are a student with a disability and think you may need accommodations, you are strongly encouraged to contact Student Wellness Services (SWS) and register as early as possible. For more information, including important deadlines, please visit the QSAS website at: http://www.queensu.ca/studentwellness/accessibility-services/

Academic Consideration
The Senate Policy on Academic Consideration for Students in Extenuating Circumstances (Academic-consideration-students-extenuating-circumstances-policy) was approved in April, 2017. Queen's University is committed to providing academic consideration to students experiencing extenuating circumstances that are beyond their control and which have a direct and substantial impact on their ability to meet essential academic requirements. Each Faculty has developed a protocol to provide a consistent and equitable approach in dealing with requests for academic consideration for students facing extenuating circumstances. Arts and Science undergraduate students can find the Faculty of Arts and Science protocol and the portal where they submit a request for academic consideration at: https://www.queensu.ca/artsci/undergrad-students/academic-consideration-for-students.
Applied Science students can find the relevant information at:
https://engineering.queensu.ca/Current-Students/absences-accommodations/academic-consideration.html.

Accessibility Statement

Queen's is committed to an inclusive campus community with accessible goods, services, and facilities that respect the dignity and independence of persons with disabilities. To discuss accessibility, please contact either Professor Brown or Professor Jessop via email, phone, or in-person at your convenience.

Course Announcements

Throughout the course, we will routinely post course news in the Announcements section of onQ. You should set onQ to forward Announcement notices by text message or to an e-mail address that you check daily. We will assume that all students are aware of each announcement withing 2-3 hours of it being posted. We will also use onQ announcements to post reminders and additional course information, as well as related activities at Queen's or elsewhere.

Copyright of Course Materials

All course material that is not from the textbook or other reference document is copyrighted by either Dr. R. Stephen Brown (first half of the course) or Dr. Hridaynath Bhattacharjee (second half of the course) and is for the sole use of students registered in CHEM 326 or ENCH 326. The material on the onQ website may be downloaded for a registered student's personal use, but shall not be distributed or disseminated to anyone other than students registered in CHEM 326 or ENCH 326. No posted material or screen-captures should be posted to any third-party websites of any kind. Failure to abide by these conditions is a breach of copyright, and may also constitute a breach of academic integrity under the University Senate's Academic Integrity Policy Statement.