DALHOUSIE UNIVERSITY

Faculty of Science Course Syllabus
Department of Oceanography
OCEA 4130/5130
Chemical Oceanography
Fall 2022

Instructor: Prof. *Doug Wallace* *dwallace@dal.ca* *SOSB 2-35*

Lectures:	*Tues*	*8.35-10.00 am*	*In person*	*LSC C214*
	Thu	*8.35-10.00 am*	*In person*	*LSC C214*
	Wed	*2:35-3.25 pm*	*Online (synchronous). Time/ day may change.*	

Tutorials: *The Wednesday session will be used primarily for group discussion (including of assignments) and Q&A as well as occasional guest lectures or catch up.*

Office hours: *By appointment only; ask in class or E-mail: jackie.hurst@dal.ca*

Course Description

This course covers the major and minor constituents of sea water, controls on the ocean's chemical composition, nutrient cycling, gas exchange and the cycling of dissolved gases, the carbon cycle and the influence of the oceans on atmospheric composition including CO_2 levels. Other topics introduced are chemical tracers (including isotopes), chemical speciation and chemical models of sea water.

Course Prerequisites

OCEA 2000

Course Objectives/Learning Outcomes

At the end of this course students should be able to:

- *Identify the processes at ocean boundaries and within the ocean interior that control the chemical composition of seawater*
- *Understand the role of circulation and source/sinks on controlling the spatial and temporal distributions of chemical species within the world's oceans*
- *Integrate concepts of physical, biological and chemical processes to describe nutrient, dissolved gas and chemical cycling in the ocean, particularly the carbon cycle*
- *Use chemical distributions to infer information about physical and biological processes within the oceans*
- *Understand the key chemical processes and factors that influence the ocean's role with respect to ongoing global environmental change*

- *Be able to assess the basis of proposals to address climate change through manipulation of the ocean carbon cycle*

Course Materials

- *Recommended textbooks are:*
  - *Emerson and Hedges: **Chemical Oceanography and the Marine Carbon Cycle**. Cambridge University Press. (referred to as "E&H" below.). This is the main text.*
  - *An updated version of the main text ("**Chemical Oceanography: Element Fluxes in the Sea**" by Emerson and Hamme) has been published recently. Purchase of the newer text is recommended, but the Emerson and Hedges text will continue to be used this semester.*
  - *Pilson: **An Introduction to the Chemistry of the Sea**. Cambridge University Press.*
  - *Berner and Berner: **Global Environment: Water, Air and Geochemical Cycles**. Prentice-Hall.*
  - *Sarmiento and Gruber: **Ocean Biogeochemical Dynamics***
- *Additional literature and out of print required reading materials will be provided and will also be available on the OCEA 4130/5130 Brightspace site.*

Course Assessment

Students will be evaluated on quizzes, problem sets, essays and exams. Students should be prepared to work both independently and in groups, especially on the problem sets. The problem sets include short answer questions, calculations, and word problems. Students will have one week to complete the problem sets. The time allowed for the final essay will also be at least 1 week but will be agreed upon in class. Short, in-class quizzes on the lecture and reading materials will be given weekly and are designed to ensure that lecture notes from the previous week as well as assigned papers/ chapters have been read. The format for exams and exercises will be explained during the course. As both graduate and undergraduate students are completing the same assignments, undergraduates' final marks will be scaled by 5%.

Component	Weight (% of final grade)	Date
Quizzes	*15%*	*Weekly (Tuesdays)*
Mid-term exam	*15%*	*October 25-27 (tentative)*
Final-term exam	*20%*	*Week of December 9 (tentative)*
Assignments	*30%*	*(mark based on best 3 of 4)*
Problem Set 1		***Assigned:** 20 September*
Problem Set 2		***Assigned:** 11 October*
Problem Set 3		***Assigned:** 1 November*
Problem Set 4		***Assigned:** 22 November*
Essay	*20%*	***Assigned:** 7-11 November (due at end of semester)*

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Conversion of numerical grades to Final Letter Grades follows the Dalhousie Common Grade Scale

A+ (90-100)	B+ (77-79)	C+ (65-69)	D (50-54)
A (85-89)	B (73-76)	C (60-64)	F (<50)
A- (80-84)	B- (70-72)	C- (55-59)	

Course Policies

Health and *Safety:*

Students and lecturer will follow Dalhousie health and safety policy with respect to COVID-19 vaccination and testing requirements, wearing of masks, etc.. The instructor will attempt to ensure that there is adequate ventilation of the classroom and reserves the right to stop teaching if conditions in the classroom are judged unsafe.

Collaboration:

Students are encouraged to discuss problem sets in groups. However, each student must write and submit their own independent answers, rationale, and solutions to problem sets. Essays and quizzes must be exclusively the student's own work.

Late assignments-

Students will lose 5% of the total mark for the assignment per day if an assignment is handed in late. An assignment is considered late if it is not submitted by the time that it is due, which will be clearly marked (including specification of time zone) with every assignment.

Course Content

The following is a chronological flow of the course. Material not covered in one lecture session will be continued in the following session. Typically lectures will take up 2 of the 3 weekly time-slots: these will be offered in-person. Lecture slides will also be made available online before the lecture. One of the weekly slots (presently scheduled for Wednesday but timing could be changed if class is in agreement) will be reserved for online group discussion (e.g. of assignments) via Zoom videoconferencing or for occasional guest lectures or practical demonstrations from the laboratory. This time slot will not be used every week and cccasionally will be used for catch-up lectures (class will be notified in advance).

Exact timing of the assignments may change and will be discussed/ explained in class.

*Dates of lectures **in bold***

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Week 1 (**6**, 7, **8** Sep):

Lecture 1: *Introduction. Informal Quiz (not graded) and Info. Sheets.* Introduction to Chemical Oceanography. Reading: E&H, 1.1 to 1.3
Lecture 2: Seawater composition and basic concepts- *water structure; ions in seawater; units; steady-state vs. equilibrium; 1-box model; residence time*

Recommended reading:Emerson and Hedges, Chapter 3.1; or Pilson Chapter 2.1

Week 2 (**13**, 14, **15** Sep):

Lecture 3: Salinity: *definitions; measurement history and principles; accuracy and precision: certified methods and reference materials; practical salinity and absolute salinity.*
Recommended reading: R. Pawlowicz; Key Physical Variables in the Ocean: Temperature, Salinity, and Density
https://www.nature.com/scitable/knowledge/library/key-physical-variables-in-the-ocean-temperature-102805293/

Lecture 4: Why is the Sea Salty? *A: rain to river; rainfall composition; B: sea salt aerosol and cyclic salt; C: chemical weathering of crustal rocks; dissolved vs. particulate partitioning; river chemical composition and major ion sources.*

Recommended reading: Berner and Berner Chapters 2, 3 and 4

Week 3 (**20**, 21, **22**): ****September 20. Problem Set 1 assigned (Due Sept 27)**

Lecture 5: Why is the Sea Salty? *D: Coastal processes. Estuaries; clay minerals and ion exchange; evaporite formation.*
Recommended reading: Berner and Berner Chapter 7.

Lecture 6: Why is the Sea Salty *E. Hydrothermal sources and sinks at the sea floor boundary*;
Berner and Berner, Chapter 8. Emerson and Hedges, Chapter 2.3

Week 4 (**27**, 28, **29** Sep):

Lecture 7: Why is the Sea Salty? F. *biogenic processes I-biogeochemical reactions, rain ratio, carbonate precipitation and dissolution; carbonate sedimentation.*

Lecture 8: Why is the Sea Salty? G. *biogenic processes II-redox reactions and sulfate removal; reactions and transport in sediments; I:summary of sources/sinks.*
Pre-recorded guest lecture by Prof. Per Hall (Univ. Goteborg, Sweden).
Recommended reading: Berner and Berner Chapters 8;

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Week 5 (**4**, 5, **6** Oct.):

Lecture 9: Major nutrients*; I- nitrogen in the ocean; chemical forms; nitrogen cycle; vertical and temporal nutrient distributions; transformations*
Recommended reading: Pilson Chapters 8

Lecture 10: Major nutrients; *II*-Phosphorus- *speciation and temporal distribution in surface water; remineralization; 2-box model of nutrient cycling; nutrient limitation concept; sources and sinks*
Recommended reading: Redfield Revisited; Weber and Deutsch 2012
Redfield 1934; Redfield 1958; Emerson and Hedges Chapter 5.

Week 6 (**11**, 12, **13** Oct.): ****October 11: Problem Set 2 Assigned. Due October 18.**

Lecture 11: Major Nutrients III-Silicon- *speciation, solubility, dissolution; vertical and horizontal distribution; remineralization; sources and sinks; Importance of micronutrients.*
Recommended reading: Redfield Revisited; Tregueir et al., 2021

Lecture 12: Major Nutrients (catch-up).

Week 7 (**18**, 19, **20** Oct.):

Lecture 13: Gases. Introduction– - *concentrations; partial pressures and mole fraction; composition of the atmosphere; circulation of the atmosphere; gas solubility and Henry's Law*
Recommended reading: Emerson and Hedges Chapter 10; Broecker and Peng Chapter 3 pg. 110-161

Lecture 14: Gases: *seawater dissolved gas composition; simple gases; sources and sinks of simple dissolved gases; exchanges at the boundaries; air-sea gas exchange kinetics*
Recommended reading: Pilson, Chapter 5;

Week 8 (**25**, 26, **27** Oct): ** **Mid-Term Exam scheduled this week**

Lecture 15: Oxygen- *internal sources/ sinks; processes creating non-equilibrium conditions; photosynthesis / respiration; AOU*; *ocean de-oxygenation?*
Recommended Reading: Emerson and Hedges

Lecture 16: Dissolved gases/ oxygen (continued). Ocean de-oxygenation.
Recommended Reading: Emerson and Hedges, Chapter 6.2-6.4

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Week 9 (**1**, 2, **3** Nov): ****November 1: Problem Set 3 Assigned. Due November 7.**

Lecture 17 and 18: Carbon cycle and the Anthropocene. *Role of ocean chemistry in climate change. Intro to CO_2- Keeling Curve; temporal variations of atmospheric CO_2; latitudinal distributions; sources and sinks (global carbon budget).*
Recommended reading:

Week 10 (7-11 Nov): **Reading/Study Week. No classes!!**
**** Essay topic will be assigned; due at end of semester.**

Week 11 (**15**, 16, **17** Nov.):

Lecture 19 and 20: CO_2 Systems I- *reactions in seawater; measuring the CO_2 system; processes affecting CO_2 speciation; buffering;*
CO2 Systems II- *pCO_2, global cycling of carbon species, concept of anthropogenic CO_2, effects of anthropogenic CO_2; including ocean acidification.*

Recommended reading: Emerson and Hedges Chapter 4; Pilson Chapter 7.

Week 12 (**22**, 23, **24** Nov.): **Problem set #4 assigned. Due November 29.**

Lecture 21 and 22: Introduction to chemical tracers including use of isotopes.
Stable and radioactive isotopes as tracers of physical, chemical and biological processes.
Chlorofluorocarbons as tracers.

November 24 In-person Guest Lecture by Dr. Dariia Atamanchuk

Recommended reading: Emerson & Hedges: Chapter 5; TBA

Week 13 (**29** Nov, 30, **31**): Lecture 30&31:

Lecture 23: Use of tracers to estimate anthropogenic CO_2 or other carbon-cycle topics.
Lecture 24: Negative Emission Technologies and natural climate solutions.

Recommended reading: TBA

Concluding summary and course review.

** *December 9-20:* **FINAL EXAM #1 (EXACT DATE TBA)**

DALHOUSIE UNIVERSITY

Faculty of Science Course Syllabus (Section B) **(revised June-2021)**

Fall/Winter 2021-22

Course name & number

University Policies and Statements

This course is governed by the academic rules and regulations set forth in the University Calendar and by Senate

Academic Integrity

At Dalhousie University, we are guided in all of our work by the values of academic integrity: honesty, trust, fairness, responsibility and respect (The Center for Academic Integrity, Duke University, 1999). As a student, you are required to demonstrate these values in all of the work you do. The University provides policies and procedures that every member of the university community is required to follow to ensure academic integrity.

Information: https://www.dal.ca/dept/university_secretariat/academic-integrity.html

Accessibility

The Advising and Access Services Centre is Dalhousie's centre of expertise for student accessibility and accommodation. The advising team works with students who request accommodation as a result of a disability, religious obligation, or any barrier related to any other characteristic protected under Human Rights legislation (Canada and Nova Scotia).

Information: https://www.dal.ca/campus_life/academic-support/accessibility.html

Student Code of Conduct

Everyone at Dalhousie is expected to treat others with dignity and respect. The Code of Student Conduct allows Dalhousie to take disciplinary action if students don't follow this community expectation. When appropriate, violations of the code can be resolved in a reasonable and informal manner—perhaps through a restorative justice process. If an informal resolution can't be reached, or would be inappropriate, procedures exist for formal dispute resolution.

Code: https://www.dal.ca/dept/university_secretariat/policies/student-life/code-of-student-conduct.html

Diversity and Inclusion – Culture of Respect

Every person at Dalhousie has a right to be respected and safe. We believe inclusiveness is fundamental to education. We stand for equality. Dalhousie is strengthened in our diversity. We are a respectful and inclusive community. We are committed to being a place where everyone feels welcome and supported, which is why our Strategic Direction prioritizes fostering a culture of diversity and inclusiveness

Statement: http://www.dal.ca/cultureofrespect.html

Recognition of Mi'kmaq Territory

Dalhousie University would like to acknowledge that the University is on Traditional Mi'kmaq Territory. The Elders in Residence program provides students with access to First Nations elders for guidance, counsel and support. Visit or e-mail the Indigenous Student Centre (1321 Edward St) (elders@dal.ca).

Information: https://www.dal.ca/campus_life/communities/indigenous.html

Important Dates in the Academic Year (including add/drop dates)

https://www.dal.ca/academics/important_dates.html

University Grading Practices

https://www.dal.ca/dept/university_secretariat/policies/academic/grading-practices-policy.html

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Faculty of Science Course Syllabus (Section C) **(revised June-2021)**

Fall/Winter 2021-22

Course name & number

Student Resources and Support

Advising

General Advising https://www.dal.ca/campus_life/academic-support/advising.html

Science Program Advisors: https://www.dal.ca/faculty/science/current-students/academic-advising.html

Indigenous Student Centre: https://www.dal.ca/campus_life/communities/indigenous.html

Black Students Advising Centre: https://www.dal.ca/campus_life/communities/black-student-advising.html

International Centre: https://www.dal.ca/campus_life/international-centre/current-students.html

Academic supports

Library: https://libraries.dal.ca/

Writing Centre: https://www.dal.ca/campus_life/academic-support/writing-and-study-skills.html

Studying for Success: https://www.dal.ca/campus_life/academic-support/study-skills-and-tutoring.html

Copyright Office: https://libraries.dal.ca/services/copyright-office.html

Fair Dealing Guidelines https://libraries.dal.ca/services/copyright-office/fair-dealing.html

Other supports and services

Student Health & Wellness Centre: https://www.dal.ca/campus_life/health-and-wellness/services-support/student-health-and-wellness.html

Student Advocacy: https://dsu.ca/dsas

Ombudsperson: https://www.dal.ca/campus_life/safety-respect/student-rights-and-responsibilities/where-to-get-help/ombudsperson.html

Safety

Biosafety: https://www.dal.ca/dept/safety/programs-services/biosafety.html

Chemical Safety: https://www.dal.ca/dept/safety/programs-services/chemical-safety.html

Radiation Safety: https://www.dal.ca/dept/safety/programs-services/radiation-safety.html

Scent-Free Program: https://www.dal.ca/dept/safety/programs-services/occupational-safety/scent-free.html

Dalhousie COVID-19 information and updates: https://www.dal.ca/covid-19-information-and-updates.html