

UNIVERSITY OF CALGARY  
FACULTY OF SCIENCE, DEPARTMENT OF CHEMISTRY  
COURSE SYLLABUS  
FALL 2021  
CHEM 209, General Chemistry for Engineers

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## 1. Course Contacts

Section	DAY	TIME	INSTRUCTOR	EMAIL	OFFICE HOURS
L01/T01	Thursday	8:00 – 9:50	Dr. Julie Lefebvre	<a href="mailto:jlefebv@ucalgary.ca">jlefebv@ucalgary.ca</a>	All instructors: by appointment. See D2L for a direct booking link.
L02/T02	Thursday	10:00 – 11:50	Dr. Julie Lefebvre	<a href="mailto:jlefebv@ucalgary.ca">jlefebv@ucalgary.ca</a>	
L03/T03	Friday	8:00 – 9:50	Dr. Amanda Musgrove	<a href="mailto:amanda.musgrove@ucalgary.ca">amanda.musgrove@ucalgary.ca</a>	
L04/T04	Thursday	15:00 – 16:50	Dr. Amanda Musgrove	<a href="mailto:amanda.musgrove@ucalgary.ca">amanda.musgrove@ucalgary.ca</a>	
L05/T05	Thursday	13:00 – 14:50	Dr. Julie Lefebvre / Dr. Amanda Musgrove	<a href="mailto:jlefebv@ucalgary.ca">jlefebv@ucalgary.ca</a> <a href="mailto:amanda.musgrove@ucalgary.ca">amanda.musgrove@ucalgary.ca</a>	
Course Coordinator:			Dr. Julie Lefebvre	<a href="mailto:jlefebv@ucalgary.ca">jlefebv@ucalgary.ca</a>	
Lab Coordinator:			Dr. Roxanne Jackson	<a href="mailto:rjackso@ucalgary.ca">rjackso@ucalgary.ca</a>	

Course website can be reached via the course management system, D2L (<https://d2l.ucalgary.ca>).

Departmental Office: SB 605, Tel: 403- 220-5385, email: [chem.info@ucalgary.ca](mailto:chem.info@ucalgary.ca)

## 2. Course Description

Basic chemical concepts. Atomic and molecular structure. Chemical bonding. Chemical kinetics and equilibria. Acid-base and solubility equilibria. Oxidation-reduction phenomena and electrochemistry. The chemistry of water. The chemistry of energy sources. Basic environmental issues.

## 3. Textbook

We will be using an adapted version of the textbook by Paul Flowers, Klaus Theopold, Richard Langley, William R. Robinson: *Chemistry 2e*. OpenStax (2020). This textbook has been adapted to fit the specific needs of CHEM 209.

Free access to the adapted version via this link: <https://wpsites.ucalgary.ca/chem-textbook/table-of-contents-chem-209/>

Other texts are acceptable; however, it is the students' sole responsibility to ensure that they can identify the appropriate chapter readings and practice problems in alternate texts.

#### 4. Topics Included and Suggested Readings

Students are responsible for all material included in the laboratories and workshops (combined lectures/tutorials). Most of the relevant material for these content areas are in the designated sections from the textbook.

Note that some material is regarded as review of high school chemistry and will not be addressed in lectures; however, being fundamental to many other topics in chemistry, knowledge of these topics will be necessary for labs, workshops, and exams.

Detailed readings are not given in the syllabus: only chapter-level references are provided here. Please refer to the weekly Checklists in D2L for the readings corresponding to each course topic.

##### Background knowledge to review before the course begins:

Chapter 1: Essential Ideas

Chapter 2: Atoms, Molecules, and Ions

Chapter 3: Composition of Substances and Solutions

Chapter 4: Stoichiometry of Chemical Reactions

Chapter 5: Thermochemistry

Chapter 9: Gases

##### Big Idea 1: How fast is a reaction?

Chapter 12: Kinetics

##### Big Idea 2: How far does a reaction proceed?

Chapter 13: Fundamental Equilibrium Concepts

Chapter 14: Acid–Base Equilibria

Chapter 15: Equilibria of Other Reaction Classes

Chapter 17: Electrochemistry

##### Big Idea 3: How is structure important?

Chapter 6: Electronic Structure and Periodic Properties of the Elements

Chapter 7: Chemical Bonding and Molecular Geometry

Chapter 8: Advanced Theories of Covalent Bonding

#### 5. Laboratory Experiments

##### Big Idea 4: How is laboratory work an essential component of an experiential science such as Chemistry?

###### 1. Kinetics of the Iodine Clock Reaction

Topic: *How fast is a reaction?* (Essential Skills 1,3,5)

Skills: Making solutions / handling glassware, determining rate law, making observations

###### 2. Investigation into Equilibrium

Topic: *How far does a reaction proceed?* (Essential Skills 10-15)

Skills: UV-VIS spectrometry, solution preparation, graphical data analysis

###### 3. Determination of the Acid Number of Food Oils

Topic: *How far does a reaction proceed?* (Learning Objectives 16-19)

Skills: Acid-base titrations, sample preparation, analytical reporting

## 4. Making Anodized Aluminum Products

Topic: *How far does a reaction proceed?* (Learning Objectives 23-29)

Skills: Safety, electrolysis and anodization, experimental design

## 5. Properties of Surfactants

Topic: *How is structure important?* (Learning Objectives 36, 38, 42, 43)

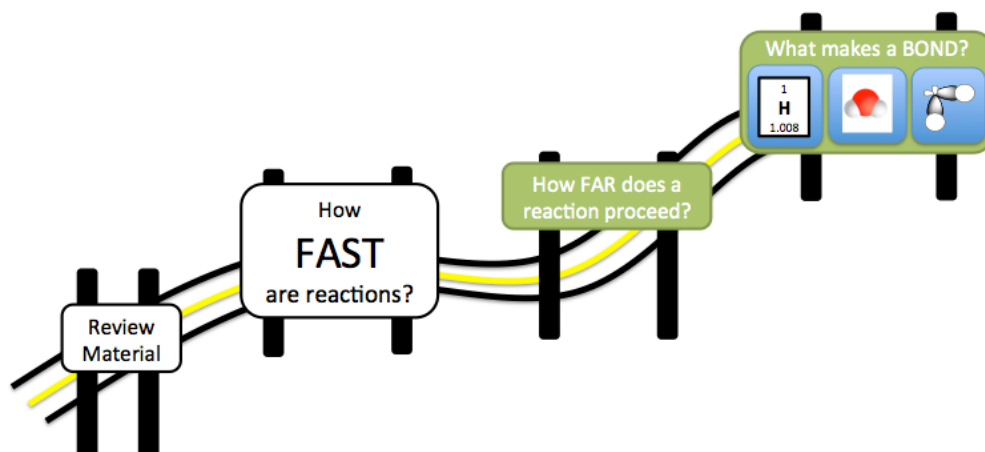
Skills: Making a surfactant, filtration, observations

## 6. Course Outcomes (Essential Skills)

Aims

During this course, you will develop an understanding of four Big Ideas in Chemistry:

	Essential Questions
How FAST are reactions?	What affects reaction speed? How can we depict reaction speed with symbols? How can we explain reaction speeds at the molecular level? How is reaction speed important to engineers?
How FAR does a reaction proceed?	What affects reaction extent? How can we depict reaction extent with symbols? How can we explain reaction extent at the molecular level? For our key examples (acids & bases, buffers & solubility, electrochemistry), how do different reactions behave? How is reaction extent important to engineers?
What makes a BOND?	How can we depict the electronic structure of an atom or ion? How can we depict the electronic structure of a molecule or polyatomic ion? How can we explain properties and shapes using electronic structure? Why is an understanding of bonding important to engineers?
How is laboratory work an essential component of chemistry?	How does one recognize valid observations and data? How does one analyze observations and data and link them to the course content? What predictions are formulated based on the analysis of observations and data? How does one evaluate the validity of a prediction?



Big Idea: How FAST are reactions?

KEY CONCEPTS	ESSENTIAL SKILLS
Chemical reactions occur at certain speeds.	1. Qualitatively <i>describe</i> the factors that affect the speed of a reaction at both the macroscopic and molecular level.
The speed of a reaction is measured by looking at concentration changes over time.	2. <i>Use</i> concentration versus time data to <i>determine</i> the instantaneous and average rate of reaction. 3. <i>Generate</i> a rate law for a reaction. 4. <i>Explain</i> the effect that each component of a rate law (concentration, $k$ , and order) has on the rate of a reaction. 5. Given experimental data, <i>determine</i> the components of a rate law ( $k$ and order), using the method of initial rates. 6. <i>Use</i> integrated rate laws to <i>determine</i> the amount of product produced (or reactant remaining) at any given point within a reaction and <i>determine</i> the half-life of a reaction.
The speed of a reaction depends on the mechanism of the reaction and can be altered by changing temperature or using a catalyst.	7. <i>Determine</i> the rate law given the mechanism of a reaction, and vice versa - for reactions with a slow first step only. 8. <i>Draw and interpret</i> a reaction energy diagram for a given reaction mechanism. 9. <i>Use</i> reaction energy diagrams to <i>rationalize</i> the effect of a change in temperature or addition of a catalyst on rate and activation energy.

Big Idea: How far does a reaction proceed?

KEY CONCEPTS	ESSENTIAL SKILLS
Chemical reactions are dynamic equilibria.	10. Qualitatively <i>describe</i> chemical equilibrium.
The equilibrium state, or extent of a reaction, is described by an equilibrium constant, $K$ .	11. <i>Generate and manipulate</i> expressions for $K$ and $Q$ for reactions using concentrations or partial pressures, based on a given reaction or set of related reactions. 12. <i>Determine</i> the direction in which a reaction will proceed using values of $K$ and $Q$ . 13. <i>Determine</i> either $K$ , initial concentration, or equilibrium concentration, given the other two values.
Equilibria can be disturbed.	14. <i>Describe</i> (qualitatively and quantitatively) the effect of changes in concentration, partial pressures, and volume on equilibrium.
Equilibria can be altered.	15. <i>Describe</i> (qualitatively and quantitatively) the effect of changes in temperature on equilibrium.
Acid and base solutions are equilibrium systems.	16. <i>Identify and describe</i> the expressions for $K$ and $Q$ for: a. Acid-base reactions b. Solubility reactions c. Redox reactions.

KEY CONCEPTS	ESSENTIAL SKILLS
	17. <i>Describe</i> (quantitatively and qualitatively) the relationship between the $K_a$ of an acid, the $K_b$ of its conjugate base, and $K_w$ for the auto-ionization of water. 18. <i>Relate</i> $K_a$ and pH to the equilibrium concentrations of all species present in a monoprotic acid or base solution. 19. <i>Compare</i> the relative strengths of acids or bases using pH, $pK_a$ , $pK_b$ , and % dissociation 20. <i>Calculate</i> the pH of a weak acid or base after the addition of strong base or acid (respectively).
The key concepts of equilibria explain the solubility of salts.	21. <i>Predict</i> the relative pH of a salt solution. 22. <i>Use</i> the $K_{sp}$ and $Q_{sp}$ expressions to describe the saturation of a salt solution. 23. <i>Calculate</i> solubility from $K_{sp}$ , and vice versa. 24. Using LeChatelier's principle, <i>describe</i> how solubility is affected by a common ion, a change in pH, or formation of a complex ion.
The key concepts of equilibria explain electrochemical processes.	25. <i>Write</i> balanced reactions and half-reactions for redox reactions, and <i>identify</i> half-reactions as reduction or oxidation. (review material) 26. <i>Describe</i> voltaic and electrolytic cells, graphically or using cell notation. 27. <i>Calculate</i> $E^\circ_{cell}$ for a given reaction using tabulated half-cell data, and use it to predict reaction spontaneity. 28. <i>Calculate</i> $E_{cell}$ and $E_{electrode}$ using the Nernst equation. 29. <i>Describe</i> , qualitatively and quantitatively, the relationship between the equilibrium constant and cell potential. 30. <i>Distinguish</i> between electrolytic and voltaic/galvanic processes, and predict the products of each type of reaction. 31. <i>Identify</i> corrosion conditions and sacrificial anodes. 32. <i>Explain</i> how batteries and fuel cells use redox reactions to store electrical energy.

Big Idea: How is structure important?

KEY CONCEPTS	ESSENTIAL SKILLS
The electronic structure of atoms explains atomic properties.	<p>33. <i>Recognize</i> atomic orbital shapes (<i>s</i>, <i>p</i> and <i>d</i>) and <i>predict</i> their relative energies.</p> <p>34. <i>Write</i> electron configurations (full and condensed) and orbital diagrams for <i>s</i> &amp; <i>p</i>-block elements with <math>Z \leq 54</math>.</p> <p>35. <i>Relate</i> electron configurations to periodic trends in atomic/ionic radius, ionization energy, and electron affinity.</p>
Atomic properties can be used to predict the type and organization of bonds in a molecule.	<p>36. Use periodic trends and electronegativity to <i>predict</i> the nature of bonding in chemical species.</p> <p>37. <i>Draw</i> Lewis structures for atoms, molecules and ions that minimize formal charges and/or follow the octet rule</p> <p>38. <i>Draw</i> VSEPR structures for molecules and polyatomic ions and <i>name</i> each electron-group and molecular geometry.</p> <p>39. <i>Assign</i> bond polarity and overall molecular polarity.</p>
Chemical properties are determined by both the bonding within AND between chemical species.	<p>40. <i>Explain</i> how the type of bonding that characterizes a substance affects its physical and chemical properties.</p> <p>41. <i>Explain</i> how overlapping atomic orbitals result in covalent bond formation; and <i>identify</i> trends in covalent bond strength.</p> <p>42. <i>Identify</i> the hybridization of atoms in molecules and polyatomic ions. (<i>s</i>, <i>sp</i>, <i>sp</i><sup>2</sup>, <i>sp</i><sup>3</sup> only)</p>

Big Idea: How is laboratory work an important component of chemistry?

KEY CONCEPTS	ESSENTIAL SKILLS
While in the lab, one collects data and observations.	<p>43. <i>Collect</i> and <i>record</i> data and observations using appropriate graphical elements (tables, figures, structures, sketches, graphs, etc).</p> <p>44. <i>Evaluate</i> the accuracy and precision of data and observations.</p>
Data and observations are analyzed by making links to theoretical concepts.	45. <i>Relate</i> experimental procedures and results to the remaining three BIG IDEAS in the course.
The analysis of data and observations leads to predictions.	46. <i>Explain</i> data and observations at the molecular level.

## 7. Lecture, Laboratory, Workshop &amp; Exam Schedule

Week Starting:	Workshop #	Tentative Schedule for Workshop Topics:	Lab Schedule:	
			Odd sections (B01, B03, ..., B23)	Even sections (B02, B04, ..., B24)
September 6*	<b>Workshop 1</b> <i>(no assessment)</i>	Introduction <i>How fast are reactions?</i> Chemical Kinetics	No lab	No lab
September 13	<b>Workshop 2</b> <i>Group assessment</i>	<i>How fast are reactions?</i> Chemical Kinetics	No lab	<b>Experiment 1</b>
September 20	<b>Workshop 3</b> <i>Individual assessment</i>	<i>How fast are reactions?</i> Chemical Kinetics	<b>Experiment 1</b>	No lab
September 27*	<b>Workshop 4*</b> <i>Online, Asynchronous (no assessment)</i>	<i>How far does a reaction proceed?</i> Equilibrium	No lab	No lab
October 4	<b>Workshop 5</b> <i>Individual assessment</i>	<i>How far does a reaction proceed?</i> Acids & Bases	<b>Experiment 2</b>	No lab
October 11*	<b>Workshop 6</b> <i>(no assessment)</i>	<i>How far does a reaction proceed?</i> Acids & Bases	No lab	<b>Experiment 2*</b> <i>B02 to be rescheduled</i>
October 18	<b>Workshop 7</b> <i>Group assessment</i>	<i>How far does a reaction proceed?</i> Electrochemistry <b>*Midterm Tuesday Oct 19</b>	<b>Experiment 3</b>	No lab
October 25	<b>Workshop 8</b> <i>Individual assessment</i>	<i>How far does a reaction proceed?</i> Electrochemistry	No lab	<b>Experiment 3</b>
November 1	<b>Workshop 9</b> <i>Individual assessment</i>	<i>How far does a reaction proceed?</i> Solubility	<b>Experiment 4</b>	No lab
November 8	<b>Term break: no labs or workshops</b>			
November 15	<b>Workshop 10</b> <i>Group assessment</i>	<i>How is structure important?</i> Electron Configuration	No lab	<b>Experiment 4</b>
November 22	<b>Workshop 11</b> <i>Group assessment</i>	<i>How is structure important?</i> Atoms & Bonding	<b>Experiment 5</b>	No lab
November 29	<b>Workshop 12</b> <i>(no assessment)</i>	<i>How is structure important?</i> Intermolecular Forces	No lab	<b>Experiment 5</b>
December 6	<i>Optional Review Session – Q&amp;A</i>	<i>Note: L03 students are invited to attend any of the Thursday sections.</i>	No lab	No lab

**Last day of classes: Thursday December 9. Final exam period: Dec 13 – 22.**

\*Monday sections that fall on the holidays will have a make-up scheduled. Details will be announced via email (check your @ucalgary account) and on D2L.

\* In-person workshops will be canceled for the week of Sept. 27<sup>th</sup>. An online asynchronous workshop (ungraded) will be posted on D2L.

\* University closed: September 6 – Labor Day, September 30<sup>th</sup> – Truth & Reconciliation Day, October 11 – Thanksgiving Day, November 11 – Remembrance Day. No classes or labs.