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

Contents:

1. Course Contacts

LEC	DAY	TIME	INSTRUCTOR	EMAIL	OFFICE HOURS
L01	TR	12:30-1:45	Dr. Roxanne Jackson	rjjackso@ucalgary.ca	All instructors: by appointment. See D2L for a direct booking link.
L02	TR	8:00-9:15	Dr. Amanda Musgrove	amanda.musgrove@ucalgary.ca	
L03	MWF	12:00 – 12:50	Dr. Jing Li	li22@ucalgary.ca	
Course Coordinator:			Dr. Amanda Musgrove	amanda.musgrove@ucalgary.ca	
Lab Coordinator:			Dr. Roxanne Jackson	rjjackso@ucalgary.ca	

Course website can be reached via the course management system, D2L (https://d2l.ucalgary.ca).
Course Q&A Piazza site: https://piazza.com/ucalgary.ca/winter2021/chem209/home
Departmental Office: SA 229, Tel: 403- 220-5341, email: 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

Paul Flowers, Klaus Theopold, Richard Langley, William R. Robinson: *Chemistry 2e.* OpenStax (2020).
Free access via this link: https://openstax.org/details/books/chemistry-2e

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 lectures, laboratories, and workshops (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.

Since this is the first semester using the OpenStax textbook, 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 **Ignore any usage of non-SI units.*

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?

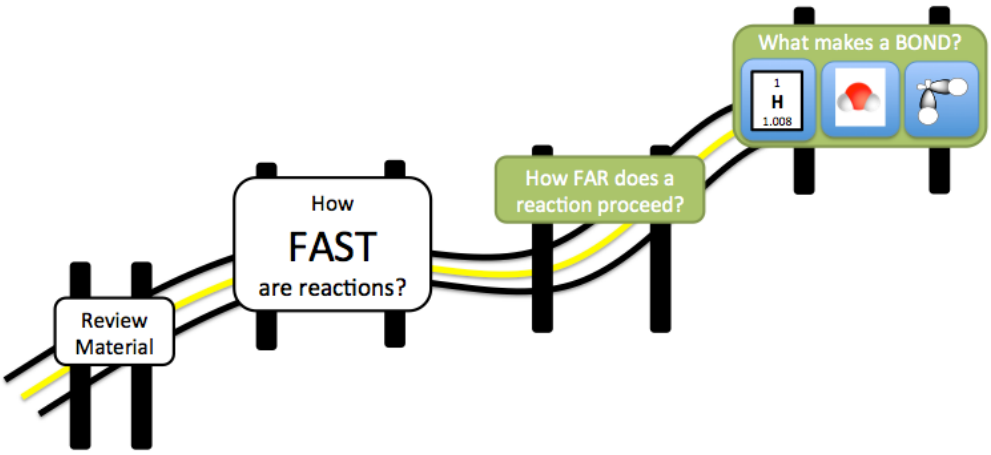
1. Kinetics of the Fading of Phenolphthalein
   Topic: *How fast is a reaction?* (Essential Skills 1,3,5)
   Skills: Making solutions / handling glassware, determining rate of reaction, making observations
2. Investigation into Equilibrium
   Topic: *How far does a reaction proceed?* (Essential Skills 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 *describe* 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. *Use* concentration versus time data to *determine* the instantaneous and average rate of reaction. 3. *Generate* a rate law for a reaction. 4. *Explain* the effect that each component of a rate law (concentration, *k*, and order) has on the rate of a reaction. 5. Given experimental data, *determine* the components of a rate law (*k* and order), using the method of initial rates. 6. *Use* integrated rate laws to *determine* the amount of product produced (or reactant remaining) at any given point within a reaction and *determine* 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. *Determine* the rate law given the mechanism of a reaction, and vice versa - for reactions with a slow first step only. 8. *Draw* and *interpret* a reaction energy diagram for a given reaction mechanism.
	9. *Use* reaction energy diagrams to *rationalize* 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 *describe* chemical equilibrium.
The equilibrium state, or extent of a reaction, is described by an equilibrium constant, K.	11. *Generate* and *manipulate* expressions for K and Q for reactions using concentrations or partial pressures, based on a given reaction or set of related reactions. 12. *Determine* the direction in which a reaction will proceed using values of K and Q. 13. *Determine* either K, initial concentration, or equilibrium concentration, given the other two values.
Equilibria can be disturbed.	14. *Describe* (qualitatively and quantitatively) the effect of changes in concentration, partial pressures, and volume on equilibrium.
Equilibria can be altered.	15. *Describe* (qualitatively and quantitatively) the effect of changes in temperature on equilibrium.
Acid and base solutions are equilibrium systems.	16. *Identify* and *describe* how the expressions for K and Q are modified for: a. Acid-base reactions b. Solubility reactions c. Redox reactions.

KEY CONCEPTS	ESSENTIAL SKILLS
	17. *Describe* (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. *Relate* K_a and pH to the equilibrium concentrations of all species present in a monoprotic acid or base solution.
	19. *Compare* the relative strengths of acids or bases using pH, pK_a, pK_b, and % dissociation
	20. *Calculate* 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. *Predict* the relative pH of a salt solution.
	22. *Generate* expressions for K_{sp} and Q_{sp}, and use them to describe the saturation of a salt solution.
	23. C*alculate* solubility from K_{sp}, and vice versa.
	24. *Describe* 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. *Write* balanced reactions and half-reactions for redox reactions, and *identify* half-reactions as reduction or oxidation. (review material)
	26. *Describe* voltaic and electrolytic cells, graphically or using cell notation.
	27. *Calculate* E^o_{cell} for a given reaction using tabulated half-cell data, and use it to predict reaction spontaneity.
	28. *Calculate* E_{cell} and $E_{electrode}$ using the Nernst equation.
	29. *Describe*, qualitatively and quantitatively, the relationship between the equilibrium constant and cell potential.
	30. *Distinguish* between electrolytic and voltaic/galvanic processes, and predict the products of each type of reaction.
	31. *Identify* corrosion conditions and sacrificial anodes.
	32. *Explain* 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.	33. *Recognize* atomic orbital shapes (*s, p* and *d*) and *predict* their relative energies. 34. *Write* electron configurations (full and condensed) and orbital diagrams for *s* & *p*-block elements with $Z \leq 54$. 35. *Relate* electron configurations to periodic trends in atomic/ionic radius, ionization energy, and electron affinity.
Atomic properties can be used to predict the type and organization of bonds in a molecule.	36. Use periodic trends and electronegativity to *predict* the nature of bonding in chemical species. 37. *Draw* Lewis structures for atoms, molecules and ions that minimize formal charges and/or follow the octet rule 38. *Draw* VSEPR structures for molecules and polyatomic ions and *name* each electron-group and molecular geometry. 39. *Assign* bond polarity and overall molecular polarity.
Chemical properties are determined by both the bonding within AND between chemical species.	40. *Explain* how the type of bonding that characterizes a substance affects its physical and chemical properties. 41. *Explain* how overlapping atomic orbitals result in covalent bond formation; and i*dentify* trends in covalent bond strength. 42. *Identify* the hybridization of atoms in molecules and polyatomic ions. (s, sp, sp^2, sp^3 only)

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

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

7. Lecture, Laboratory, Workshop & Exam Schedule

Week Starting:	Tentative Schedule for Lecture Topics:	Lab Schedule: Odd sections (B01, B03, …, B23)	Lab Schedule: Even sections (B02, B04, …, B24)	Workshop Schedule: (During 'tutorial')
January 11	Introduction *How fast are reactions?* Chemical Kinetics	*No lab*	*No lab*	*No Workshops*
January 18	*How fast are reactions?* Chemical Kinetics	*No lab*	**Experiment 1**	**Workshop 1**
January 25	*How fast are reactions?* Chemical Kinetics	**Experiment 1**	*No lab*	**Workshop 2**
February 1	*How far does a reaction proceed?* Equilibrium	*No lab*	**Experiment 2**	**Workshop 3**
February 8	*How far does a reaction proceed?* Acids & Bases ***Midterm 1 Wednesday Feb 10 7-8:30**	**Experiment 2**	*No lab*	*No Workshops*
February 15	**Term break: no classes, labs, or workshops**			
February 22	*How far does a reaction proceed?* Acids & Bases	*No lab*	**Experiment 3**	**Workshop 4**
March 1	*How far does a reaction proceed?* Solubility	**Experiment 3**	*No lab*	**Workshop 5**
March 8	*How far does a reaction proceed?* Electrochemistry	*No lab*	**Experiment 4**	**Workshop 6**
March 15	*How far does a reaction proceed?* Electrochemistry	**Experiment 4**	*No lab*	**Workshop 7**
March 22	*How is structure important?* Electron Configuration ***Midterm 2 Wednesday Mar 24 7-8:30**	*No lab*	**Experiment 5**	*No Workshops*
March 29*	*How is structure important?* Atoms & Bonding	**Experiment 5****	*No lab*	**Workshop 8**
April 6*	*How is structure important?* Covalent Bonding	*No lab*	*No lab*	*No workshops*
April 12	*How is structure important?* Intermolecular Forces	*No lab*	*No lab*	**Workshop 9**

Last day of classes: April 15. Final exam period: April 19 – 29.

**Monday and Friday 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.

*April 2: Good Friday holiday: University closed. April 5: Easter Monday holiday. No classes or labs.