Academic Year	AY22/23	**Semester**	1
Course Coordinator	Sumod Pullarkat		
Course Code	CM1001		
Course Title	Foundations of Chemistry I		
Pre-requisites	None		
Mutually Exclusive	CY1101 Molecule, BS1012 Foundations of Chemistry I, BS1022 Laboratory for Foundations of Chemistry I		
No of AUs	4		
Contact Hours	Lectures: 39, Tutorials: 5, Laboratory: 15		

Course Aims

The course covers fundamental concepts and organizing principles of chemistry that provide the foundation for many aspects of chemical science and related fields. It aims to bring Freshmen students in science and engineering to the same level of command of basic chemistry that is essential to progress to advanced courses. The concepts espoused in the course will be illustrated and connected with real world applications whenever relevant. Practical work is at the heart of chemistry. The laboratory component of this course aims to expose you to chosen experiments which will help you gain familiarity with a variety of skills, laboratory techniques and equipment and instill in you the ability to work independently as well as part of a team.

Intended Learning Outcomes (ILO)

Upon successfully completing this course, you should be able to:

1. Explain Bonding and Molecular Structure:

   (a) Analyze the formal charge, oxidation state, valency, and coordination number of atoms in molecules and ions.

   (b) Explain the concept of the Octet rule and provide examples of molecules/ions that follow/do not follow the principle by drawing the Lewis structure.

   (c) Explain the concept of resonance.

   (d) Determine the electron pair geometry and molecular geometry based on VSEPR theory

   (e) Calculate the net reaction enthalpy based on bond energy of reactants and products.

   (f) Analyze the hybridization of atoms in molecules and ions.

   (g) Explain and illustrate the orbital diagram of molecules and ions including multiple bonds.

   (h) Construct molecular orbital diagram of diatomic molecules and ions by applying the basic principles learned.

   (i) Analyze the frontier orbitals, magnetic nature, bond order of molecules and ions based on the Molecular Orbital theory.

2. Apply theoretical knowledge gained on molecular structure and properties towards the interpretation of Nuclear Magnetic Resonance (NMR) and Infra-red (IR) spectrum of simple organic molecules.

3. Kinetics: Simple Rates and Mechanisms of Chemical Reactions

(a) Determine and discuss the key factors affecting reaction rates.

(b) Express rate through a rate law and determine its components; Calculate how concentrations change as a reaction proceeds.

(c) Associate the effect of concentration and temperature on rate, and how catalysts increase reaction rates.

4. Thermochemistry: Energy Flow and Chemical Change

(a) Identify forms of energy and their interconversion.

(b) Discuss the First Law of Thermodynamics.

(c) Differentiate heat, Q, from work, W, and understand what a state function is.

(d) Analyse internal energy, E, versus enthalpy, H, and the major types of calorimetry.

(e) Apply Hess's Law to calculate an unknown change in enthalpy, ΔH.

5. Basic Thermodynamics: Entropy, Free Energy, and Reaction Direction

(a) Discuss the Second Law of Thermodynamics, and how to predict spontaneous change.

(b) Calculate the change in entropy of a reaction.

(c) Define entropy, free energy and work.

(d) Analyze the relation between free energy, equilibrium, and reaction direction.

6. Basic Quantum Theory and the Hydrogen Atom

(a) Discuss light as electromagnetic waves & photons; discuss how Einstein explained the photoelectric effect; and encountering discontinuous energy in quantized atomic spectra.

(b) Analyse the wave-particle duality for subatomic particles, the significance of the Schrödinger equation, and the interpretation of the wavefunction.

(c) Solve the Schrödinger equation for a particle in a one-dimensional box and use it to estimate quantized energy levels in various situations.

(d) Analyze the solutions of the Schrödinger equation for the hydrogen atom and construction of atomic orbitals.

6. Employ in an actual laboratory setting the various analytical and experimental techniques, methods and equipment commonly used in chemical science. Perform basic chemistry lab experiments, analyze, interpret, and present experimental data.

Course Content

1. Bonding and Molecular Structure

2. Valence Bond Theory and Molecular Orbital Theory

3. Basics of NMR and Infra-red Spectroscopy

4. Kinetics: Simple Rates and Mechanisms of Chemical Reactions.

5. Thermochemistry: Energy Flow and Chemical Change.

6. Basic Thermodynamics: Entropy, Free Energy, and Reaction Direction.

7. Basic Quantum Theory and the Hydrogen Atom.

8. Basic Laboratory Techniques for the Chemistry Laboratory

Assessment (includes both continuous and summative assessment)

Component	Course ILO Tested	Related Programme LO or Graduate Attributes	Weighting	Team/Individual	Assessment rubrics
Midterm Test I	1, 2	Competence, Creativity	15%	Individual	See Appendix 1
Midterm Test II	3,4,5	Competence, Creativity	15%	Individual	See Appendix 1
Lab component	7	Competence, Creativity	20%	Individual	See Appendix 1
Final Examination	1, 2, 3, 4, 5, 6	Competence, Creativity	50%	Individual	See Appendix 1
Total			*100%*		

Formative feedback

Formative feedback: Lecturers and TAs will be closely working with you to monitor your learning progress. They will provide you with timely feedback to improve your understanding of concepts. Furthermore, you will be given opportunities to express your ideas and discuss them with lecturers and TAs.

Summative Feedback: Summative feedback on laboratory reports and mid-term tests will be given. For laboratory reports, you will be provided with comments on mistakes, areas of improvement and examples of good practice in scientific writing etc.

This will help you to achieve the intended learning outcomes listed above.

Learning and Teaching Approach

Lectures (39 hours)	The lectures will convey key concepts in organic, inorganic, selected topics in spectroscopy and physical chemistry thus providing critical information and background on how the concepts come about, with relevant theories and illustrative examples. The concepts will also be further illustrated with worked examples and with real world applications to show the relevance and importance of learning chemistry and its links to other disciplines.
Tutorials (5 hours)	You will be assigned to a small group for interactive discussions toward some representative questions, which will help you develop your own critical thinking capability and problem-solving skills. A group member will be randomly selected to present the answers. TAS will assist in clarifying key concepts if necessary and rectifying errors when answers are presented.
Laboratory (15 hours)	Laboratory session will consist of three main parts. Pre-laboratory exercises will involve online pre-lab quiz to be attempted prior to a lab session and consists of risk assessment and questions based on the lab manual to ensure that students have read and understood the respective experimental description before starting the actual lab session. During the actual lab session, you will typically work in pairs and conduct the assigned experiment under the supervision of laboratory TAs following the instructions provided in the lab manual. This will train you in applying concepts learned to real life situations. Subsequent to the lab session you are to submit an individual post-lab report in the prescribed format which will help to develop your critical thinking ability, ability to assimilate, evaluate and present the data gathered during a lab experiment.

Reading and References

Recommended textbook:

For General Chemistry:

Chemistry & Chemical Reactivity, 10th Ed (2019), Kotz/Treichel (KT), Cengage Learning Asia Pte. Ltd., ISBN 978-1-337-39907-4.

Chemistry: The Molecular Nature of Matter and Change, 8th Ed (2018), Silberberg/Amateis (SA); McGraw-Hill Education; ISBN 978-I-259-92175-9

For NMR and IR spectroscopy:

Organic Chemistry, 8th Ed (2014), Wade (WD), Pearson Education Ltd, ISBN 978-1-29202-165-2.

For Physical Chemistry:

Elements of Physical Chemistry, 7th Ed (2016), Atkins / de Paula (AdP); Oxford University Press; ISBN: 9780198727873

Course Policies and Student Responsibilities

You are expected to read the lecture/pre-tutorial/laboratory materials prior to the respective

lecture/tutorial/laboratory session. This will help you to learn much more efficiently as you will already have an impression on the topics to be covered. For laboratory sessions, besides reading the laboratory manual and understanding the experimental procedure, you should also complete the pre-lab quiz (online) and risk assessment component of the lab report in which you should list possible hazards and their prevention steps. You should also read through the recommended textbooks as outlined in the references. Where relevant students are expected to go through the preparatory course and course materials provided which will help to refresh your memory on concepts learned previously or basic concepts that you are expected to know coming into this Freshman year course.

Academic Integrity

Good academic work depends on honesty and ethical behavior. The quality of your work as a student relies on adhering to the principles of academic integrity and to the NTU Honor Code, a set of values shared by the whole university community. Truth, Trust and Justice are at the core of NTU's shared values.

As a student, it is important that you recognize your responsibilities in understanding and applying the principles of academic integrity in all the work you do at NTU. Not knowing what is involved in maintaining academic integrity does not excuse academic dishonesty. You need to actively equip yourself with strategies to avoid all forms of academic dishonesty, including plagiarism, academic fraud, collusion, and cheating. If you are uncertain of the definitions of any of these terms, you should go to the university academic integrity website for more information. Consult your instructor(s) if you need any clarification about the requirements of academic integrity in the course.

Course Instructors

Instructor	Office Location	Phone	Email
Rei Kinjo	SPMS CBC-06-22	65922625	rkinjo@ntu.edu.sg
Sumod Pullarkat	CBC-06-02	63168906	sumod@ntu.edu.sg
Zhang Zhengyang	CBC-03-02	65136059	zhang.zy@ntu.edu.sg

Planned Weekly Schedule

Week	Topic	Course ILO	Readings/Activities
1,2	Bonding and Molecular Structure	1	Lecture, pre-recorded lectures, recommended text (see readings and references), other relevant materials and exercises posted on NTULearn

3,4,5	Valence Bond Theory and Molecular Orbital Theory	1	Lecture, pre-recorded lectures, recommended text (see readings and references), other relevant materials and exercises posted on NTULearn
6,7	Basics of NMR and Infra-red Spectroscopy	2	Lecture, pre-recorded lectures, recommended text (see readings and references), other relevant materials and exercises posted on NTULearn
8	Kinetics: Simple Rates and Mechanisms of Chemical Reactions.	3	SA Ch 16
9,10	Thermochemistry: Energy Flow and Chemical Change.	4	SA Ch 6
11,12	Basic Thermodynamics: Entropy, Free Energy, and Reaction Direction.	5	SA Ch 20
13	Basic Quantum Theory and the Hydrogen Atom.	6	AdP Ch 12 & 13

Note: Lecture schedule, Midterm test dates and topics tested may vary based on course progress. Please always refer to announcements made via NTULearn which will supersede the above information.

Appendix 1: Assessment Rubrics

Rubric for Midterm and Final Examination

For the questions in the midterm and final exam, you will be expected to show your competency to understand basic general chemistry principles and having critical thinking and practical skills to solve scientific problems. Questions posed will be mix of Short answer, calculation based and Multi-choice questions.

0-3 marks	4-7 marks	8-10 marks
Shows little to no understanding of the theoretical and practical principles covered in the lectures	Shows moderate to good understanding of the theoretical and practical principles covered in the lectures	Shows a comprehensive or near comprehensive understanding of the theoretical and practical principles covered in the lectures

Assessment Rubric for Laboratory

Overall presentation	Appropriate as a piece of scientific writing. Words were chosen carefully and appropriately. Sentence structure was clear and easy to follow. The report is free of spelling, punctuation, calculation and grammatical errors.	Minimal awkward phrasing or word choices. Minimal mistakes in calculations and explanations	Many passages are phrased poorly, contained awkward word choices, or many long sentences. Narrative is disorganized in many places. Multiple grammatical and/or spelling errors.	Poorly organized report with frequent awkward phrases, poor word choices and wrong inferences/calculations. Lacks cohesion, style and fluidity.
Answers to Proforma questions	Relevant experimental data/calculation steps are presented which are used for answering proforma questions. Demonstrates a logical, coherent working knowledge and understanding of important experimental concepts, forms appropriate conclusions based on interpretations of results, includes applications of and improvements in the experiment, collected data and analysis and demonstrates accountability by providing justification for any errors. Address all specific questions posed in the proforma.	All data and associated figures, calculations etc. are presented. Demonstrates an understanding of most important experimental concepts, forms conclusions based on results and/or analysis but either lacks proper interpretation, suggests inappropriate improvements in the experiment or lacks overall justification of error. Address most of the specific points for questions posed in the proforma.	Most figures, graphs, and tables are included, but some important or required features are missing. Certain data reported are not mentioned in the text or are missing. Captions are not descriptive or incomplete. While some of the results have been correctly interpreted and discussed, partial but incomplete understanding of results is still evident. Student fails to make one or two connections to underlying theory. Address some of the specific points or questions posed in the proforma.	Figures, graphs, and tables are poorly constructed; have missing titles, captions or numbers. Certain data reported are not mentioned in the text. Important data missing. Does not demonstrate an understanding of the important experimental concepts, forms inaccurate conclusions, suggests inappropriate improvements in the experiment and lacks overall justification of error. Address none of the specific points or questions posed in the proforma.

CBC Programme Learning Outcome

The Division of Chemistry and Biological Chemistry (CBC) offers an undergraduate degree major in Chemistry that satisfies the American Chemical Society (ACS) curricular guidelines and equips students with knowledge relevant to the industry. Graduates of the Division of Chemistry and Biological Chemistry should have the following key attributes:

1. Competence

Graduates should be well-versed in the foundational and advanced concepts of chemical science, be able to evaluate chemistry-related information critically and independently, and be able to use complex reasoning to solve emergent chemical problems.

2. Creativity

Graduates should be able to synthesize and integrate multiple ideas across the curriculum, and propose innovative solutions to emergent chemistry-related problems based on their training in chemistry.

3. Communication

Graduates should be able to demonstrate clarity of thought, independent thinking, and sound scientific analysis and reasoning through written and oral reports to audiences with varying technical backgrounds. They should also be able to effectively engage other professional chemists in collaborative endeavours.

4. Character

Graduates should be able to act in responsible ways and uphold the high ethical standards that the society expects of professional chemists.

5. Civic-mindedness

Graduates should be aware of the impact of chemistry on society, and how chemistry can be applied to benefit mankind. They should also be aware of and uphold the best chemical safety practices.