

## Annexe A: New/Revised Course Content in OBTL+ Format

### Course Overview

|                                                            |                                                                          |
|------------------------------------------------------------|--------------------------------------------------------------------------|
| Expected Implementation in Academic Year (New format)      | AY2026-2027                                                              |
| Semester/Trimester/Others (specify approx. Start/End date) | Semester 1                                                               |
| Course Author<br>* Faculty proposing/revising the course   | Pullarkat Appukuttan Sumod (Dr), Dr Zhang Zhengyang, Asst Prof Qiao Yuan |
| Course Author Email                                        | Sumod@ntu.edu.sg, zhang.zy@ntu.edu.sg, yuan.qiao@ntu.edu.sg              |
| Course Title                                               | Molecule                                                                 |
| Course Code                                                | CY1101                                                                   |
| Academic Units                                             | 4                                                                        |
| Contact Hours                                              | 69                                                                       |
| Research Experience Components                             | Not Applicable                                                           |

### Course Requisites (if applicable)

|                       |                                                                    |
|-----------------------|--------------------------------------------------------------------|
| Pre-requisites        | By permission                                                      |
| Co-requisites         |                                                                    |
| Pre-requisite to      |                                                                    |
| Mutually exclusive to | BS1003 or BS1012 or BS1013 or BS1022 or BS1033 or CM1001 or CM1002 |
| Replacement course to |                                                                    |
| Remarks (if any)      |                                                                    |

## Course Aims

The course provides an introduction to modern chemistry with the focus on molecules that are used to build key fundamental understandings of inorganic, organic, biological and physical chemistry. You will understand the nature of chemical bonds in structures of compounds, reaction mechanisms, kinetics and thermodynamics, and basic spectroscopic methods used to monitor the progress of reactions. The course comprises basic laboratory skills, and virtual laboratory simulations, linked to the course syllabus to provide you with hands on application of the key concepts and principles learned during the duration of the course thus further enhancing their understanding. You will understand the role that chemistry plays in other sciences, such as physics, biology, or earth science, and apply chemistry knowledge to solve real life problem in science or engineering related problems.

## Course's Intended Learning Outcomes (ILOs)

Upon the successful completion of this course, you (student) would be able to:

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| ILO 1 | <p>Chemical Kinetics</p> <p>a) Determine the average reaction rate over a specified period of time and estimate instantaneous reaction rate from a graph of concentration versus time.</p> <p>b) Relate the rate of consumption of any reactant to the rate of formation of any product using reaction stoichiometry.</p> <p>c) Find the reaction order with respect to each reactant, the overall reaction order, and the units of the rate constant from a given rate law.</p> <p>d) Predict the change in reaction rate when the concentration of a reactant changes by a specified amount.</p> <p>e) Determine the rate law and rate constant using initial rate and concentration data.</p> <p>f) Use the integrated rate law to determine the half-life and the concentrations remaining at various times for a zeroth order, first order and second order reactions.</p> <p>g) Interpret potential energy diagrams and suggest geometries for successful collisions and transition states using collision theory.</p> <p>h) Calculate rate constants, temperatures, and activation energy using the Arrhenius equation.</p> <p>i) Given a reaction mechanism, write the overall reaction, identify intermediates, and determine the molecularity for each elementary step.</p> <p>j) Illustrate and interpret Gibbs energy profiles for reactions.</p> <p>k) Explain how a catalyst speeds up a reaction and the difference between heterogeneous and homogeneous catalysis.</p> |
| ILO 2 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |

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|       | <p>Thermochemistry</p> <p>a) Explain the terms system and surroundings.</p> <p>b) Calculate the heat and work involved.</p> <p>c) Describe the difference between heat capacity, specific heat capacity, molar heat capacity, and perform calculations using these properties.</p> <p>d) Describe the characteristics of a state function.</p> <p>e) Describe enthalpy change and calculate changes of enthalpy during phase changes and chemical reactions.</p> <p>f) Apply Hess's law to calculate enthalpy changes (<math>\Delta H</math>).</p> <p>g) Describe enthalpy changes of formation (<math>\Delta H_f</math>) and use them to calculate enthalpy changes during reactions.</p> <p>h) Describe and use enthalpy changes of combustion (<math>\Delta H_c</math>) and enthalpy changes of solution.</p>                                                                                                                                 |
| ILO 3 | <p>Thermodynamics</p> <p>a) Explain and calculate expansion work.</p> <p>b) Describe the First, Second and Third Laws of thermodynamics.</p> <p>c) Calculate internal energy change from enthalpy change and vice versa.</p> <p>d) Describe how to use a bomb calorimeter to measure energy changes of combustion.</p> <p>e) Describe spontaneous changes.</p> <p>f) Apply changes in entropy and Gibbs energy to assess the spontaneity of processes or reactions.</p> <p>g) Predict the sign of the entropy change (<math>\Delta S</math>) given the chemical equation or a molecular diagram.</p> <p>h) Using the relationship between the Gibbs free energy (<math>\Delta G</math>) and spontaneity, predict the sign of <math>\Delta G</math>, <math>\Delta H</math>, <math>\Delta S</math>.</p> <p>i) Use <math>\Delta H</math> and <math>\Delta S</math> to determine the temperature at which a reversible system is at equilibrium.</p> |
| ILO 4 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |

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|       | <p>3H NMR Spectroscopy</p> <p>a) Describe typical requirements for reference compounds for <math>^4\text{H}</math>.</p> <p>b) Explain what leads to signal multiplicity in <math>^1\text{H}</math> NMR.</p> <p>c) Describe typical requirements for reference compounds for <math>^1\text{H}</math> NMR.</p> <p>d) Correlate the number of peaks to the number of nuclei environments in <math>^1\text{H}</math> NMR.</p> <p>e) List and explain the different regions of <math>^1\text{H}</math> NMR spectrum.</p> <p>f) State the factors that local magnetic field depends on.</p> <p>g) Explain shielding and deshielding in <math>^1\text{H}</math> NMR</p> <p>h) Illustrate the formation of doublet, triplet, quartet, quintets, etc. in <math>^1\text{H}</math> NMR</p> <p>i) Explain and depict coupling pattern in <math>^1\text{H}</math> NMR.</p> <p>j) Predict the intensity ratios using Pascal's triangle and tree diagrams in <math>^1\text{H}</math> NMR</p> |
| ILO 5 | <p>Molecular orbital theory</p> <p>a) Interpret the different energies of bonding and antibonding orbitals</p> <p>b) Sketch graphical addition of AOs to form MOs</p> <p>c) Define Molecular orbital</p> <p>d) Sketch qualitative MO diagrams for <math>\text{H}_2^+</math> ion</p> <p>e) Fill in the electrons in MO diagrams</p> <p>f) Construct simple MO diagrams for diatomic molecules (involving s orbitals)</p> <p>g) Calculate bond order for simple diatomic molecules</p> <p>h) Relate bond orders to bond strengths and stability in diatomic molecules</p> <p>i) Compose MO diagrams for heteronuclear diatomic molecules</p> <p>j) Estimate validity of MO diagrams for heteronuclear diatomic molecules</p>                                                                                                                                                                                                                                                    |
| ILO 6 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |

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|       | <p>Molecule structures: bonding and stereochemistry</p> <p>a) Explain electronegativity, polarity and inductive effects.</p> <p>b) Recognize the differences among types of bonds: nonpolar covalent bond, polar covalent bond, ionic bond, H-bond.</p> <p>c) Be able to convert the resonance structures of molecules by applying the 5 rules of resonance forms.</p> <p>d) Explain the difference between structural isomers and stereoisomers.</p> <p>e) Recognize both types of configurational isomers - E/Z isomers and isomers with chiral centres.</p> <p>f) Recognize enantiomers and assign the configuration of chiral centres as R or S using the Cahn-Ingold-Prelog sequence rules.</p> <p>g) Convert a hashed-wedged line structure into a Fischer projection (and vice versa).</p> <p>h) Recognize diastereomers and the difference between diastereomers and enantiomers.</p> |
| ILO 7 | <p>Molecule reactions: survey of reactions with alkyl halide:</p> <p>a) Recognize the difference in curved arrows in drawing mechanisms.</p> <p>b) Recognize the basic types of organic reactions: Addition, elimination, substitution, rearrangement.</p> <p>c) Explain why different carbon-halogen bonds in alkyl halide react differently from one another.</p> <p>d) Explain how alkyl halide react in SN2 and SN1 reactions</p> <p>e) Explain how alkyl halide react in E2 and E1 reactions.</p> <p>f) Describe the factors that affect SN2 versus SN1 reactions.</p> <p>g) Describe the factors that affect E2 versus E1 reactions.</p> <p>h) Describe the factors that influence substitution versus elimination reactions.</p>                                                                                                                                                       |
| ILO 8 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |

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|        | <p>Sweet molecules: carbonyl chemistry in biological systems:</p> <p>a) Recognize structures of hemiacetal, hemiketal, acetal, ketal.</p> <p>b) Recognize the <math>\alpha</math>- and <math>\beta</math>- anomers of carbohydrate.</p> <p>c) Recognize the nucleophilic addition to carbonyl compounds to obtain hemiacetal or hemiketal.</p> <p>d) Recognize enolization of carbonyl under acidic and basic conditions.</p> <p>e) Explain the interconversion between cyclic <math>\alpha</math> and <math>\beta</math>-anomers and open-chain carbonyl.</p> <p>f) Recognize the difference in retaining glycosidase and inverting glycosidases.</p> |
| ILO 9  | <p>Introduction to Amino acids and protein structure:</p> <p>a) Recognize the structure and property of 20 amino acids</p> <p>b) Explain the acid-base titration property of amino acids.</p> <p>c) Explain the protein structures (primary, secondary, tertiary and quaternary</p>                                                                                                                                                                                                                                                                                                                                                                    |
| ILO 10 | <p>Nature's catalysts: Enzymes:</p> <p>a) Explain basic enzyme kinetic terms: <math>V_{max}</math>, <math>K_m</math>, <math>K_d</math>, <math>K_i</math>.</p> <p>b) Explain the difference between competitive inhibitor and non-competitive inhibitor</p> <p>c) Perform Lineweaver-Burk Plot.</p>                                                                                                                                                                                                                                                                                                                                                     |

## Course Content

1. Chemical Kinetics
2. Thermochemistry
3. Thermodynamics
4.  $^1\text{H}$  NMR Spectroscopy
5. Molecular orbital theory
6. Molecule structures: bonding and stereochemistry
7. Molecule reactions: survey of reactions with alkyl halide
8. Sweet molecules: carbonyl chemistry in biological systems
9. Introduction to amino acids and proteins
10. Nature's catalysts: Enzymes

## Reading and References (if applicable)

A. Burrows, J. Holman, A. Parsons, G. Pilling, and G. Price "Chemistry<sup>3</sup> (3rd Edition)", Oxford University Press, 2017. ISBN: 978-0-19-969185-2.

J.E. McMurry, R.C. Fay, J.K. Robinson "Chemistry (7th Edition)", Pearson Education, 2015. ISBN: 978-1-292-09275-1.

## Planned Schedule

| Week or Session | Topics or Themes                                          | ILO | Delivery Mode | Activities                    | Readings                      |
|-----------------|-----------------------------------------------------------|-----|---------------|-------------------------------|-------------------------------|
| 1               | Chemical Kinetics                                         | 1   | In-person     | Online lectures and materials | Online lectures and materials |
| 2               | Thermochemistry                                           | 2   | In-person     | Online lectures and materials | Online lectures and materials |
| 3               | Thermodynamics                                            | 3   | In-person     | Online lectures and materials | Online lectures and materials |
| 4               | <sup>1</sup> H NMR Spectroscopy                           | 4   | In-person     | Online lectures and materials | Online lectures and materials |
| 5               | Mid-term Test 1                                           | 1-4 | In-person     | Mid-term Test 1               | Online lectures and materials |
| 6               | Molecular orbital theory                                  | 5   | In-person     | Online lectures and materials | Online lectures and materials |
| 7               | Molecule structures: bonding and stereochemistry          | 6   | In-person     | Online lectures and materials | Online lectures and materials |
| 8               | Molecule reactions: survey of reactions with alkyl halide | 7   | In-person     | Online lectures and materials | Online lectures and materials |
| 9               | Sweet molecules: carbonyl chemistry in biological systems | 8   | In-person     | Online lectures and materials | Online lectures and materials |
| 10              | Introduction to amino acids and proteins                  | 9   | In-person     | Online lectures and materials | Online lectures and materials |
| 11              | Mid-term Test 2                                           | 6-8 | In-person     | Mid-term Test 2               | Online lectures and materials |
| 12              | Nature's catalysts: Enzymes                               | 10  | In-person     | Online lectures and materials | Online lectures and materials |

## Learning and Teaching Approach

| Approach                            | How does this approach support you in achieving the learning outcomes?                                                                                                                                                        |
|-------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Online material and online lectures | The bulk of the content will be delivered through online lectures and online material. This allows (a) extensive use of animations and (b) use of interactive questions so that students may immediately test their learning. |

## Assessment Structure

Assessment Components (includes both continuous and summative assessment)

| No. | Component                                                  | ILO  | Related PLO or Accreditation | Weightage | Description of Assessment Component | Team/Individual | Rubrics  | Level of Understanding |
|-----|------------------------------------------------------------|------|------------------------------|-----------|-------------------------------------|-----------------|----------|------------------------|
| 1   | Continuous Assessment (CA): Test/Quiz(Mid-term Test 1)     | 1-4  | Competence                   | 15        |                                     | Individual      | Analytic | Relational             |
| 2   | Continuous Assessment (CA): Others(Laboratory)             | 1-10 | Competence                   | 20        |                                     | Individual      | Analytic | Multistructural        |
| 3   | Summative Assessment (EXAM): Final exam(Final examination) | All  | Competence                   | 50        |                                     | Individual      | Analytic | Relational             |
| 4   | Continuous Assessment (CA): Test/Quiz(Mid Term 2)          | 6-8  | Competence                   | 15        |                                     | Individual      | Analytic | Relational             |

Description of Assessment Components (if applicable)

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### Formative Feedback

You will be given feedback in four ways:

1. By response to postings on the course discussion board.
2. Through the marking of the mid-terms.
3. Through tutorial sessions and/or 1-on-1 discussions with the course instructor (pre-scheduling required)
4. General feedback will be provided to the students following the final exam.

## NTU Graduate Attributes/Competency Mapping

This course intends to develop the following graduate attributes and competencies (maximum 5 most relevant)

| Attributes/Competency | Level |
|-----------------------|-------|
| Collaboration         | Basic |
| Curiosity             | Basic |
| Learning Agility      | Basic |
| Problem Solving       | Basic |
| Critical Thinking     | Basic |

# Course Policy

## Policy (Academic Integrity)

Good academic work depends on honesty and ethical behaviour. The quality of your work as a student relies on adhering to the principles of academic integrity and to the NTU Honour 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 academic integrity website for more information. On the use of technological tools (such as Generative AI tools), different courses / assignments have different intended learning outcomes. Students should refer to the specific assignment instructions on their use and requirements and/or consult your instructors on how you can use these tools to help your learning. Consult your instructor(s) if you need any clarification about the requirements of academic integrity in the course.

## Policy (General)

You are expected to complete all online activities in good time.

## Policy (Absenteeism)

If you are unable to attend any of the continuous assessments (CAs) or assigned lab sessions, you must provide the original supporting document (e.g. medical certificate from a medical doctor, order for court appearance) to the CCEB UG Office within 7 days of the missed session. In addition, for missed sessions you must email the Course Coordinator (for CAs) or Teaching Lab staff (for Labs) a copy of the supporting document within 2 days after your excuse has expired.

If you need to obtain a Leave of Absence (LOA) for any of the assessments or labs, please file a formal application through the CCEB UG Office. Only official approvals from the CCEB UG Office will be accepted. Failure to do so will result in a zero grade for the assessments or labs from which the student is absent.

You must attend and complete all 9 in-lab experiments for this lab course.

Make-up laboratory experiments will only be arranged for students with an approved LOA from the CCEB UG office. Students who are absent without an approved LOA will not be allowed to do any make-up session and will receive a zero grade for that lab.

## Policy (Others, if applicable)

### Diversity and Inclusion Policy

Integrating a diverse set of experiences is important for a more comprehensive understanding of science and engineering. It is our goal to create an inclusive and collaborative learning environment that supports a diversity of perspectives and learning experiences. That honours your identities, including ethnicity, gender, socioeconomic status, sexual orientation, religion, or ability.

To help accomplish this:

- If you are neuroatypical or neurodiverse, have dyslexia or ADHD (for example), or have a social anxiety disorder or social phobia
- If you feel your performance in the course is being impacted by your experiences outside of class
- If something was said in the course (by anyone, including instructor/supervisor) that made you uncomfortable.

Please e-mail our Associate Chair (Students & Continuing Education) at [ac-cceb-stud@ntu.edu.sg](mailto:ac-cceb-stud@ntu.edu.sg) about how we can help facilitate your learning experience.

As a participant in course discussions, you should also strive to honour the diversity of your classmates.

You can do this by using preferred pronouns and names, being respectful of others' opinions, actively making sure all voices are being heard, and refraining from the use of derogatory or demeaning speech or actions.

All members of the course are expected to strictly adhere to the student code of conduct

(<https://www.ntu.edu.sg/life-at-ntu/student-life/student-conduct>). If you witness something that goes against this or has any other concerns, please speak to your instructors or a faculty member.

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