Academic Year	2022/23	**Semester**	2
Course Coordinator	Soo Han Sen, Valerio Isoni		
Course Code	CM5091[1]		
Course Title	Industrial and Environmental Chemistry		
Pre-requisites	(CM1021 and CM1031) or CM9001/CM5000 or CY1101 (CM1001 and CM1002) or by permission		
No of AUs	3 AU		
Contact Hours	39 lecture hours		
Proposal Date	21 October 2021		

Course Aims

This course aims to provide an overview of industrial and environmental chemistry, with a focus on industries relevant to Singapore's current and future chemical industry. You will be given opportunities to critically analyse and evaluate the many, often conflicting, parameters to consider for commercially viable chemical processes. Extra emphasis will be placed on trends in sustainable development. You will also develop and gain confidence of your presentation skills to a public audience.

Intended Learning Outcomes (ILO)

By the end of this course, you should be able to:

1) Critically analyse the costs and benefits of industrial processes, including technological, economic, social, and environmental aspects.
2) Differentiate between batch and continuous operations
3) Analyse the critical process parameters during the process development stage for a smoother scale-up
4) Differentiate between scalable and not readily scalable operations in batch and continuous chemical processing
5) Differentiate between thermodynamic and kinetic effects on catalytic processes
6) Use energy level diagrams and band levels of materials to predict their chemical behaviour
7) Use spectroscopic and analytical methods, including NMR, FT-IR, Raman, UV-visible, X-ray absorption, and X-ray photoelectron spectroscopy, as well as cyclic voltammetry and various mass spectrometries to characterize nanomaterials
8) Interpret provided experimental data and predict the properties and reactivity of known nanomaterials to speculate on the identity of unknown materials
9) Apply sustainable concepts in daily life by evaluating their family's energy water use and analysing consumer products

Course Content

1) Economics, engineering, and general introduction to industrial chemistry
2) Process development and Process understanding
3) Solvent selection
4) Route and reagent selection, metrics
5) Work-up and purification
6) Introduction to calorimetry

[1] Previously listed as CM9091

7) When scale up goes wrong (and how to avoid it)
8) Batch vs continuous and anything in between
9) Trends in industrial chemistry and emerging technologies
10) Kinetics and catalysis
11) Bioinspired catalysis
12) Heterogeneous catalysis
13) Surface chemistry and nanomaterials
14) Plastics
15) Environmental impact of nanomaterials
16) Platform chemicals in the petrochemical industry
17) Petrochemicals and the energy industry
18) Biofuels
19) Renewable energy and artificial photosynthesis

Assessment (includes both continuous and summative assessment)

Component	Course LO Tested	Related Programme LO or Graduate Attributes	Weighting	Team/Individual	Assessment rubrics
1. Final Examination	1-7	Competence, creativity, communication, character, and civic-mindedness	40%	Individual	
2. Continuous Assessment 1 (CA): 2 x Mid-terms	1-7	Competence, creativity, communication, character, and civic-mindedness	40%	Individual	
3. CA2: 2 x online quizzes	1-7	Competence, creativity, character, and civic-mindedness	10%	Individual	
4. CA3: 2 x problem sets	1-8	Competence, creativity, communication, character, and civic-mindedness	10%	Individual	
Total			100%		

Formative feedback

Describe how you would be giving feedback to students on how they are learning in this course.

We have regular consultation hours weekly. In addition, we provide feedback after quizzes and mid-term examinations when we return the assessments. Each student is given some guidance based on their performance in the assessment if they come to collect their quizzes and examinations.

Learning and Teaching approach

Approach	How does this approach support students in achieving the learning outcomes?
Lecture with incomplete notes and hand-written examples	This encourages students to remain engaged by taking notes and working on problems at the pace they should try to achieve. This gives them practice and a better idea about how long it takes to draw chemical structures and answer questions. They are also less likely to sit back, relax, and watch a performance while understanding nothing.
Video clips of (potentially dangerous) experiments relevant to the class or applications of the chemistry	Helps to break the monotony and keep them engaged. Some of the experiments are visually more impactful so they can understand the chemistry without being exposed to potential hazards. The applications also expose them to the practical aspects of the chemistry that they learn, and hopefully will help students become more aware of chemistry in their daily lives
In-lecture tutorials	To provide students a familiar, stress-free environment to acquire confidence in public speaking and presentations. Chemistry students do not have sufficient opportunities at publics speaking and need to build up confidence for their future careers
Open-book, open notes assessments	Helps them to think and explain concepts critically. The questions are designed so that they apply concepts instead of just regurgitating information. Information is freely available online nowadays. But our students need to be able to critically analyse information and explain things in their own words instead of reproducing information
Online quizzes	Partly the same as above. In addition, online quizzes give students the flexibility to take the assessment under a stress-free environment at a convenient time that they choose
TurningPoint Cloud or some form of in-class feedback	TurningPoint Cloud provide me with instant feedback about the level of understanding. I can gauge whether the concept is easy or difficult and adjust my pace. It also gives students the opportunity to compare themselves with their peers anonymously. I hope that weaker students can recognise their lack of understanding and approach me separately for consultation.
Problem sets	The students are encouraged to work in teams to arrive at answers for the problem sets. In addition, some of the questions require students to look at consumer products and their labels to bring more awareness to chemistry in their daily lives. Students are also asked to look for recycling bins and learn about water conservation in Singapore to raise awareness about environmental chemistry. Students also have to look at their family's utilities bills and assess how they can do their part for the environment and conservation in Singapore

Reading and References

(1) Cavani, F.; Centi, G.; Perathoner, S.; Trifiro, F. eds. "*Sustainable Industrial Chemistry*" **2009**, Wiley-VCH Verlag GmbH & Co. KGaA, ISBN: 978-3-527-31552-9.

(2) Heaton, A. ed. "*An Introduction to Industrial Chemistry*" **1996**, Chapman & Hall, ISBN 978-94-011-0613-9.

(3) Sawyer, D. T.; Martell, A. E. eds. "*Industrial Environmental Chemistry*" **1992**, Plenum Publishing Corporation, ISBN: 978-1-4899-2320-2.

(4) Jimenez-Gonzalez, C.; Constable, D. J. C. "*Green Chemistry and Engineering*" **2011**, John Wiley & Sons, ISBN: 978-1-118-10197-1.

(5) Towler, G.; Sinnott, R. "*Chemical Engineering Design*" **2008**, Butterworth-Heinemann, Elsevier, ISBN**:** 9780080966601.

(6) Swaddle, T. W. "*Inorganic Chemistry: An Industrial and Environmental Perspective*" **1997**, Academic Press, ISBN 0-12-678550-3.

(7) Anslyn, E. V.; Dougherty, D. A. "*Modern Physical Organic Chemistry*" **2006**, University Science Books, ISBN-13: 978-1891389313.

(8) Dunn, P. J.; Wells, A. S.; Williams, M. T. eds. "*Green Chemistry in the Pharmaceutical Industry*" **2010**, Wiley-VCH Verlag GmbH & Co. KGaA, ISBN: 978-3-527-62969-5.

(9) Select journal articles.

(10) The internet.

Course Policies and Student Responsibilities

(1) General

Students are expected to complete all assigned pre-class readings and activities, attend all seminar classes punctually and take all scheduled assignments and tests by due dates. Students are expected to take responsibility to follow up with course notes, assignments and course related announcements for seminar sessions they have missed. Students are expected to participate in all seminar discussions and activities.

(2) Absenteeism

Absence from class without a valid reason will affect your overall course grade. Valid reasons include falling sick supported by a medical certificate and participation in NTU's approved activities supported by an excuse letter from the relevant bodies. There will be no make-up opportunities for in-class activities.

(3) Online Compulsory Assignments

You are required to submit online compulsory assignments on due dates.

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. 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
Soo Han Sen	SPMS-CBC-05-03	65923182	Hansen@ntu.edu.sg
Valerio Isoni			isoniva@ices.a-star.edu.sg

Planned Weekly Schedule

Week	Topic	Course ILO	Readings/ Activities
1	Economics, engineering, and general introduction to industrial chemistry	2,8	
2	Process development and process understanding	2,8	
3	Solvent selection	1-6,8	Open-book, open-notes Quiz 1 on NTULearn
4	Route and reagent selection, metrics Work-up and purification	1-6,8	Problem Set 1 due
5	Introduction to calorimetry When scale up goes wrong (and how to avoid it)	1-6,8	Midterm 1
6	Batch vs continuous and anything in between	1-6,8	
7	Trends in industrial chemistry and emerging technologies	1-6,8	
8	Kinetics, catalysis, and bioinspired catalysis	1-6,8	

9	Heterogeneous catalysis, surface chemistry, and nanomaterials	1-6,8	Open-book, open-notes Quiz 2 on NTULearn
10	Environmental impact of nanomaterials and petrochemicals and the energy industry	1-6,8	
11	Biofuels, renewable energy, and artificial photosynthesis	1-6,8	Problem Set 2 due
12	Trends for sustainability in the petrochemical industry; review of Midterm 2	1-6,8	Midterm 2
13	Plastics and revision	1-6,8	

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.