

Academic Year	2019	Semester	2
Course Coordinator	Soo Han Sen		
Course Code	CM9091		
Course Title	Industrial and Environmental Chemistry		
Pre-requisites	(CM1021 and CM1031) or CM9001 or CY1101 or by permission		
No of AUs	3 AU		
Contact Hours	39 lecture hours		
Proposal Date	8 Oct 2019		

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) Differentiate between thermodynamic and kinetic effects on catalytic processes
- 2) Critically analyse the costs and benefits of industrial processes, including technological, economic, social, and environmental aspects.
- 3) 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
- 4) Use energy level diagrams and band levels of materials to predict their chemical behaviour
- 5) Apply periodic trends to explain the properties of nanomaterials and chemical compounds
- 6) Interpret provided experimental data and predict the properties and reactivity of known nanomaterials to speculate on the identity of unknown materials
- 7) Use different water treatment methods to purify water
- 8) Apply sustainable concepts in daily life by evaluating their family's energy water use and analysing consumer products

Course Content

- 1) Economics, engineering, and cost-benefit analysis
- 2) Environmental impact and inherently safer design
- 3) Process intensification
- 4) Waste reduction and treatment
- 5) Kinetics and catalysis
- 6) Bioinspired catalysis
- 7) Heterogeneous catalysis
- 8) Surface chemistry and nanomaterials
- 9) Environmental impact of nanomaterials
- 10) Heterogeneous catalysis in petrochemical industry
- 11) Plastics
- 12) Petrochemicals and the energy industry
- 13) Biofuels
- 14) Renewable energy and artificial photosynthesis

- 15) Trends for sustainability and platform chemicals in the petrochemical industry
- 16) Thermodynamics and gas equilibria
- 17) Haber-Bosch process and small molecule activation
- 18) Recent developments in gas separation
- 19) Conventional water treatment technology
- 20) Membrane and heterogeneous water purification
- 21) Water treatment with green chemistry
- 22) Pharmaceutical chemistry

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 a-c), creativity (a,b), communication (a), character (a,b), and civic-mindedness (a-c)	35%	Individual	
2. Continuous Assessment 1 (CA): 2 x Mid-terms	1-7	Competence a-c), creativity (a,b), communication (a), character (a,b), and civic-mindedness (a-c)	40%	Individual	
3. CA2: 2 x online quizzes	1-7	Competence a-c), creativity (a,b), character (a,b), and civic-mindedness (a-c)	10%	Individual	
4. CA3: 3 x problem sets	1-8	Competence a-c), creativity (a,b), communication (a,b), character (a,b), and civic-mindedness (a-c)	15%	Individual	
5. In-lecture tutorial	1-8	Competence a-c), creativity (a,b), communication (a,b), and civic-mindedness (a-c)	0	Both	

Total	100%		
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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 public 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
Clickers	Clickers 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

Planned Weekly Schedule

Week	Topic	Course ILO	Readings/ Activities
1	Economics, engineering, cost-benefit analysis, environmental impact, and inherently safer design	2,8	
2	Process intensification, waste reduction, and treatment	2,8	
3	Kinetics, catalysis, and bioinspired catalysis	1-6,8	Open-book, open-notes Quiz 1 on NTULearn
4	Heterogeneous catalysis, surface chemistry, and nanomaterials; revision	1-6,8	Problem Set 1 due

5	Environmental impact of nanomaterials, review of Midterm 1	1-6,8	Midterm 1
6	Platform chemicals in the petrochemical industry and heterogeneous catalysis in the petrochemical industry	1-6,8	
7	Plastics and trends for sustainability in the petrochemical industry	1-6,8	
8	Petrochemicals and the energy industry	1-6,8	E-learning lecture
9	Biofuels, renewable energy, and artificial photosynthesis; revision	1-6,8	Problem Set 2 due
10	Pharmaceutical chemistry	1-8	Midterm 2; E-learning lecture
11	Thermodynamics, gas equilibria, Haber-Bosch Process, and small molecule activation; review of midterm 2	1-8	
12	Recent developments in gas separation, membranes, and heterogeneous water purification	1-8	Problem Set 3 due
13	Conventional water treatment technology	1-8	Open-book, open-notes Quiz 2 on NTULearn

Appendix 1: CBC Programme Learning Outcomes

1. Competence

- a. Be well-versed in the foundational and advanced concepts of chemical science
- b. Evaluate chemistry-related information critically and independently
- c. Use complex reasoning to solve emergent chemical problems

2. Creativity

- a. Synthesize and integrate multiple ideas across the curriculum
- b. Propose innovative solutions to emergent chemistry-related problems based on their training in chemistry

3. Communication

- a. Demonstrate clarity of thought, independent thinking, and sound scientific analysis and reasoning through written and oral reports to audiences with varying technical backgrounds
- b. Effectively engage other professional chemists in collaborative endeavours

4. Character

- a. Act in responsible ways
- b. Uphold the high ethical standards that the society expects of professional chemists

5. Civic-mindedness

- a. Be aware of the impact of chemistry on society
- b. Apply chemistry to benefit mankind
- c. Uphold the best chemical safety practices