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

Course Overview

Expected Implementation in Academic Year	AY2025-2026
Semester/Trimester/Others (specify approx. Start/End date)	Semester 2
Course Author * Faculty proposing/revising the course	Richard D. Webster, Zhang Zhengyang
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Course Title	Advanced Analytical Chemistry
Course Code	CM4011
Academic Units	3
Contact Hours	39
Research Experience Components	Not Applicable

Course Requisites (if applicable)

Pre-requisites	(CM2011 and CM2062 and CM3062)
Co-requisites	
Pre-requisite to	
Mutually exclusive to	
Replacement course to	
Remarks (if any)	

Course Aims

The lectures provide an advanced account of modern analytical methods and instruments that are used to quantify chemical and biological samples and to monitor the progress of reactions. Students will understand the principles of advanced electrochemical, spectroscopic and chromatographic techniques applied to chemical analysis. The students will be able to use their in-depth knowledge of analytical chemistry to devise experiments that can quantify a range of diverse chemical components. The students will learn problem solving skills where they apply their theoretical knowledge to real life problems in the environment.

Course's Intended Learning Outcomes (ILOs)

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

ILO 1	Quality Assurance and Calibration Methods a. Explain the steps in Quality Assurance (Use objectives, Specifications and Assessment). b. Describe how method validation is performed. c. Calculate the limit of detection (LOD) and limit of quantification (LOQ) and understand how they differ. d. Explain how and why standard additions are performed and how to calculate the concentration. e. Describe the principles of internal standards.
ILO 2	Automated Measurements of Priority Pollutants a. Explain how PM2.5/10 levels are determined, first by separation into their respective sizes (by impactors or cyclones), and then their quantification by (direct weighing, beta attenuation monitoring, or with a tapered element oscillating microbalance). b. Describe how the gases SO2 (fluorescence), O3 (absorbance or chemiluminescence) and CO (infrared) are measured. c. Explain the equilibria between the major nitrogen/oxygen containing gaseous pollutants. d. Explain how NO, NOX (fluorescence) and NO2 (chemiluminescence) are measured.
ILO 3	Electrolytic Methods a. Describe why flowing current affects the cell potentials. b, Explain IR drop and polarisation (concentration and kinetic). c. Calculate “charge” and describe how it relates to electron count and mols of compounds (Faraday’s law). d. Explain how electrochemical electrolysis cells are constructed. e. Describe how the Karl Fischer (KF) titration works and how to calculate the water content from the measurements. f. Explain the principles of ion chromatography. g. Describe the pros and cons of ion chromatography (IC) and ion-selective electrodes (ISE) measurements and when you would use the techniques.

ILO 4	Voltammetric Analysis a. Describe the concepts of voltammetry. b. Explain the different ways that voltammetric excitation signals can be applied and the advantages and disadvantages of the different voltammetric techniques. c. Explain how a potentiostat functions and what is the purpose of having 3 electrodes. d. Explain the difference between hydrodynamic and stationary electrode voltammetry. e. Describe why current-voltage curves have a specific shape in hydrodynamic voltammetry. f. Explain how pH effects voltammograms for reactions that involve protons. g. Explain the differences and similarities in pulsed voltammetric methods. h. Describe how the oxygen and glucose voltammetric sensors function.
ILO 5	Cyclic voltammetry a. Explain how cyclic voltammetry is performed. b. Explain why comproportionation reactions occur. c. Explain the use of cyclic voltammetry to determine electrochemical mechanisms.
ILO 6	EPR spectroscopy a. Describe the Zeeman effect. b. Explain what hyperfine interactions are and why they occur in a magnetic field. c. Describe how the nuclear spin quantum number affects the hyperfine pattern. d. Explain the important rules for predicting hyperfine coupling patterns for all nuclei (2nI + 1) and the binomial expansion (Pascal's triangle) for I = 1/2 nuclei. e. Describe why isotopes affect the line intensities. f. Explain the methods of preparing radicals. g. Describe the difference between spin traps and spin labels
ILO 7	Optical Sensors a. Describe the scientific concepts of absorbance and fluorescence. b. Explain how optical fibres transmit light and the importance of the “cone of acceptance” and “critical angle”. c. Explain the different ways that optodes can function in sensing, including through absorbance (transmission and reflectance) and fluorescence and be able to draw simple schematic diagrams.

ILO 8	Capillary Electrophoresis a. Explain how ions are separated in capillary zone electrophoresis. b. Describe how charge is related to electrophoretic mobility. c. Explain how the solution is transported from anode to cathode. d. Describe the arrival of species in the detector. e. Describe what is apparent mobility. f. Explain how zone dispersion arises in capillary zone electrophoresis. g. Describe how stacking of solute ions in the capillary occurs. h. Describe electroosmotic flow under low pH. i. Explain how covalent coatings reduces electroosmosis and wall adsorption. j. Describe hydrodynamic and electrokinetic sample injection. k. Describe common detection methods in capillary electrophoresis. l. Explain how micellar electrophoretic chromatography separates neutral molecules and ions. m. Explain how capillary gel electrophoresis separates macromolecules and discuss the speed of separation with molecular exclusion chromatography. n. Discuss how microfluidic devices function.
ILO 9	

	Mass spectrometry a. Explain how ions are created in mass spectrometer. b. Describe how magnetic sector mass spectrometer separates gaseous ions. c. Describe how ions are detected. d. Explain the high resolution obtained by double-focusing mass spectrometer. e. Explain the operations of transmission quadrupole and time-of-flight mass spectrometer. f. Describe how resolving power is defined. g. Describe how to determine molecular ion from the mass spectrum. h. Explain how to predict the relative intensities of isotopic peaks for a given composition. i. Interpret the fragment ions arising from bond cleavage to determine the molecular structure. j. Calculate the molecular composition from the rings + double bonds equation. k. Explain how electrospray ionization creates ions in liquid chromatography. l. Describe how atmospheric pressure chemical ionization crate gaseous ions. m. Explain how collisionally activated dissociation produce fragmented ions. n. Describe the working principle of matrix-assisted laser desorption/ionization. o. Describe the peaks obtained in reconstructed total ion chromatogram and extracted ion chromatogram. p. Describe the working principle in selected ion monitoring. q. Explain how molecules can be ionized from the surface of an object in ambient atmosphere. r. Explain how ion mobility spectrometer separates gas-phase ions.

Course Content

S/N	Topic	Approx. Lecture Hours
1	Quality Assurance and Calibration Methods: Method blanks, standard operating procedures, method validation, limits of detection and quantification, calibration curves, standard additions and internal standards.	3
2	Automated Measurements of Priority Pollutants: Air quality index and pollutant standards index, PM2.5 and PM10 and methods of separation and quantification, inorganic gases including SO2, NOX, O3, CO and their methods of detection and quantification though absorbance, luminescence and infrared measurements.	2
3	Electrolytic Methods: The effect of current on cell potentials, concentration and kinetic polarisation, controlled potential electrolysis, coulometry, Karl Fischer (KF) titrations and ion chromatography.	3
4A	Voltammetric Analysis: Linear sweep voltammetry, electrode materials, microelectrodes, hydrodynamic effects, differential pulse voltammetry, square-wave voltammetry, stripping methods and voltammetric sensors.	3
4B	Cyclic voltammetry: Diagnostic features, scan rate dependence, electrochemical mechanisms, comproportionation, reduction of aromatic halides, hydroquinones, quinones, phenols, disproprtionation, reversible dimerization and the square scheme mechanism.	3
5	EPR spectroscopy: Basic theory, rules for interpreting spectra of organic radicals, examples of spectra, methods or preparing paramagnetic compounds and spin traps.	3
6	Optical Sensors: Beer-Lambert law, optodes, total internal reflection, absorbance (transmission, reflectance) and fluorescence	2
6	Capillary Electrophoresis: Principles of capillary electrophoresis, electrophoresis, electroosmosis, mobility, theoretical plates and resolution, conducting capillary electrophoresis, controlling the environment inside the capillary, sample injection and composition, conductivity effects (stacking and skewed peaks), detectors, micellar electrokinetic chromatography, capillary gel electrophoresis, method development, lab-on-a-chip.	8
7	Mass spectrometry: Molecular mass and nominal mass, separation of masses by magnetic field, electron ionization, resolving power, molecular ion and isotope patterns, high-resolution mass spectrometry, rings and double bonds, identifying molecular ion peak, interpreting fragmentation patterns, types of mass spectrometers, transmission quadrupole mass spectrometer, time-of-flight mass spectrometer, orbitrap mass spectrometer, chromatography-mass spectrometry interfaces, electrospray ionization, atmospheric pressure chemical ionization, direct electron ionization, photoionization, chromatography-mass spectrometry techniques, selected ion monitoring and extracted ion monitoring, selected reaction monitoring, electrospray of proteins, electron-transfer dissociation for protein sequencing, open-air sampling for mass spectrometry, direct analysis in real time, desorption electrospray ionization, ion mobility spectrometry.	8

Reading and References (if applicable)

D. A. Skoog, D. M. West, F. J. Holler and S. R. Crouch "Fundamentals of Analytical Chemistry (9th Edition)", Brooks/Cole, Cengage Learning, 2014.

Reference textbook: D. C. Harris and C. A. Lucy “Quantitative Chemical Analysis (9th Edition)", W. H. Freeman and Company, 2016.

Planned Schedule

Week or Session	Topics or Themes	ILO	Readings	Delivery Mode	Activities
1	Quality Assurance / Air Quality Measurements	1			Lecture and online
2	Air Quality Measurements / Electrolysis	2			Online content
3	Electrolysis	3			Online content
4	Voltammetry	4			Online content
5	Voltammetry	5			Online content
6	Mid-term Test 1 / EPR Spectroscopy	6a-6d	Online content		Lecture and online content
7	EPR Spectroscopy / Optical Sensors	6e-6g, 7			Online content
8	Capillary Electrophoresis	8a-8f			Lecture and online
9	Capillary Electrophoresis	8g-8l			Lecture and online
10	Capillary Electrophoresis / Mass spectrometry	8n to 8n, 9a-9d			Lecture and online
11	Mass spectrometry	9e-9h			Lecture and online
12	Mid-term Test 2 / Mass spectrometry	9i-9l			Lecture and online
13	Mass spectrometry	9m-9r			Lecture and online

Learning and Teaching Approach

Approach	How does this approach support you in achieving the learning outcomes?
Blend of online and face-to- face lectures.	The bulk of the content will be delivered online. This allows (a) extensive use of animations and laboratory videos and (b) use of interactive questions so that students may immediately test their learning. Face to face lectures and experimental demonstrations will be employed for selected topics.

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 1)	1-7	Competence and Creativity	20	Tests under exam conditions. MCQ or short answer questions.	Individual	Analytic	Multistructural
2	Continuous Assessment (CA): Test/Quiz(Mid-term 2)	8,9	Competence and Creativity	15	Test under exam conditions. MCQ or short answer questions.	Individual	Analytic	Multistructural
3	Continuous Assessment (CA): Class Participation()	1-9 (depending on week)	Competence and creativity	5	One or two online questions during each class to test understanding of current topic. Must attend class in person and full marks will be given for participation.	Individual	Holistic	Multistructural
4	Summative Assessment (EXAM): Final exam()	1-9	Competence and creativity	60	Closed book exam consisting of short answer questions and calculations (see past year's examinations for format).	Individual	Analytic	Multistructural

Description of Assessment Components (if applicable)

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 one-on-one discussions via appointment with the course instructor

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
Communication	Basic
Learning Agility	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 miss a lecture, you are expected to make up for the lost learning activities. If you miss one of the mid-term tests with a valid reason and approval (such as a medical certificate), then the total CA will come from the other mid-term test. If you miss both mid-term tests with a valid reason then an additional make-up test will be set to obtain the total CA mark.

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 to your Associate Chair (Students & Continuing Education) at 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 and 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 have any other concerns, please speak to your instructors or a faculty member.

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Last Updated By: Natasha Bhatia (Dr)