CHEMISTRY MODULES OBJECTIVE AND SYLLABUS

LEVEL 1 MODULES

CM1111: Inorganic Chemistry 1 (Essential Module)
Workload: 4-1-0-2-3

Aims & Objectives
This module introduces some basic concepts of modern inorganic chemistry. In the first part, the atomic structure, the bonding models (Lewis structure, valence bond theory, basic molecular theory), basic concepts of acids and bases, redox reactions will be covered. In the part 2, the periodicity and chemistry of most main group elements will be included.

Syllabus
Part One: Basic Concepts
1. Atomic Structure
   1) Atomic Quantization
   2) Schrödinger Equation for hydrogen atom
   3) Many-electron systems
2. Chemical periodicity and the periodic Table
3. Molecular structure and bonding
   1) Lewis structure
   2) Valence bond theory
   3) Basic molecular orbital theory
4. Acid - Base and donor – acceptor chemistry
   1) Brønsted-Lowry concept
   2) Lewis concept
5. Reduction and Oxidation

Part Two: Chemistry of Selected Main Group Elements
1. Hydrogen and Group 1
2. Group 2
3. Group 13
4. Group 14
5. Group 15
6. Group 16
7. Group 17
8. Group 18

CM1121: Organic Chemistry 1 (Essential Module)
Workload: 4-2-0-2-2

Aims & Objectives
The module deals primarily with the basic principles to understand the structure and reactivity of organic molecules. Emphasis is on substitution and elimination reactions and chemistry of various functional groups. You will be taught the basic concepts on how simple molecules can be constructed. Reactions mechanism, organic transformations and stereochemistry will also be discussed.

By reading this modules, students should be able to:

i. Understand and be able to apply and evaluate simple organic reaction transformations, functional group interconversion and C-C bond formation reactions.
ii. Understand the scope and limitations as well as the mechanisms of organic reactions.
iii. Understand the importance of stereochemistry and be able to view three-dimensional structures with ease.
iv. Describe and explain currently held views of chemical bonding, and account for the chemical reactivity of reactions.
**Syllabus**

(i) Organic Structures - hydrocarbon framework and functional groups, systematic nomenclature
(ii) Structure of Molecules - atomic structure, atomic orbitals, hybridization
(iii) Organic Reactions - chemical reactions, using curly arrows to represent reaction mechanisms
(iv) Nucleophilic Addition to Carbonyl Group - nucleophilic attack by hydrides, organometallic reagents, water and alcohol
(v) Delocalization and Conjugation - structure of alkene, benzene; conjugation, the allyl system, aromaticity
(vi) Acidity, Basicity and pKa - definition of pKa, nitrogen and oxygen bases
(vii) Using Organometallic Reagents to Make C-C Bonds
(viii) Conjugate Addition - effects of conjugation, polarization, conjugate addition of alcohols, conjugate addition or direct addition to the carbonyl group, copper (I) salt and organometallic reagents
(ix) Nucleophilic Substitution at the Carbonyl Group - carboxylic acid derivatives and their substitution reactions
(x) Equilibria, Rates and Mechanisms - effects of reactants, temperature and products on the equilibrium constant, kinetic versus thermodynamic products
(xi) Nucleophilic Substitution at C=O with Loss of Carboxyl Oxygen - hemiacetal and acetal formation, reductive amination, Wittig reaction
(xii) Stereochemistry - enantiomers, optical activity, diastereoisomers, resolution
(xiii) Nucleophilic Substitution at Saturated Carbon - leaving group, nucleophiles, S_N1 and S_N2 reactions, elimination and rearrangement reactions
(xiv) Conformational Analysis - bond rotation, barriers to rotation, conformation of alkanes and cycloalkanes, ring strain
(xv) Elimination Reactions - E1 and E2 reactions and mechanisms
(xvi) Electrophilic Addition to Alkenes - bromination, oxidation, regioselectivity, Iodolactonization and bromolactonization
(xvii) Electrophilic Aromatic Substitution - reaction of benzene, phenols and substituted benzenes with electrophiles

**CM1131: Physical Chemistry 1 (Essential Module)**

**Workload: 4-1-0-2-3**

**Aims & Objectives**

Physical chemistry is the study of phenomena in chemical systems in terms of physical concepts and laws. In CM1131, two of the pillars of physical chemistry will be explored. *Thermodynamics* gives us information on the energetics of chemical reactions whether the reaction can proceed in the forward or backwards direction. If the rate of reaction is required, the field of *chemical kinetics* will help us understand the process in detail down to the atomic or molecular level.

**Syllabus**

This module introduces chemical thermodynamics and kinetics. Among the topics covered in thermodynamics are properties of ideal and real gases, kinetic theory of gases, first law of thermodynamics, enthalpy, thermochemistry, the second law; entropy, the third law; Gibbs free energy, mixtures and phase diagrams. The topics in kinetics are rates and rate laws of chemical reactions, elementary and complex reactions, effect of temperature on reaction rate, reaction mechanisms and basic theories of reaction rates.

*Thermodynamics*

Properties of gases - Gas laws, deviation from ideal behavior : Intermolecular interactions ; van der Waals equation;

The first law of thermodynamics - Internal energy, enthalpy, heat capacity, reversible and irreversible processes (isothermal, isobaric, isochoric, adiabatic).

Thermochemistry - Enthalpy change of a reaction; the Hess' law; standard enthalpy of formation; standard enthalpy of combustion; group additivity method of determining enthalpy of formation
and heat capacity; temperature dependence of reaction enthalpy, the Joule-Thomson effect and Joule-Thomson coefficient.
The second and third laws of thermodynamics - Thermodynamics and spontaneity; the second law; the Carnot cycle; entropy and entropy change; measurements of entropy; how to achieve low temperature; criteria for spontaneous process; Clausius inequality
Equilibria and Gibbs free energy - Relationship between dG and equilibrium constant K, effect of temperature and pressure on K; Le Chatelier's principle
Phase changes - Phase changes, Phase equilibrium - phase diagram of single/multicomponent, response of melting to applied pressure, phase boundaries and the Clausius-Clapeyron equation.
Mixtures - Ideal solutions, Liquid mixtures -partial molar volume, mixing, osmotic pressure, partial molar Gibbs energy, Raoult's and Henry's laws, colligative properties
Kinetics
Rate Laws – 1st and 2nd order reactions; Elementary and Complex reactions; Steady state approximation, Arrhenius law, various types of rate laws, measurements using differential and integration methods
Mechanisms and theory - Accounting for the rate laws; Proposal of reaction mechanisms; the collision theory.

CM1191: Experiments in Chemistry 1 (Essential Module)
Workload: 2-0-6-0-2

Aims & Objectives
This is a module designed for chemistry majors and deals with laboratory experiments on selected topics of basic chemistry principles and theoretical contents primarily selected from the modules CM1111, CM1121 and CM1131.
In CM1191, by conducting a selected series of experiments, students could strengthen their understanding of the related theoretical aspects. The most important learning outcome is, however, the training in fundamental but essential laboratory skills and treatment and applications of experimental data in chemical analysis and synthesis.
In a series of integrated experiments, students could also correlate the common laboratory procedure and practices among different areas in physical, analytical, inorganic and organic chemistry. Students can also see the cross-linkage among different areas in chemistry, namely physical chemistry, analytical chemistry, inorganic chemistry and organic chemistry. Furthermore, they are also trained with essential chemistry laboratory skills, as a key to their success in their higher year education and future work.
The overall training in CM1191 should provide students with a good foundation to do experiments at Levels 2000 and 3000 and basic research initiatives such as in UROPS.

Syllabus
In Experiment 1(Isolation of Chlorophyll and β-Carotene from Plant Leaves), column chromatography is used to isolate an inorganic complex chlorophyll and an organic molecule β-carotene. The physical chemistry background of chromatography is discussed, together with its wide application in analytical chemistry and synthetic chemistry. Students are trained with the following experimental skills: choosing proper elution solvent, packing a column, running a column and proper disposal of silica gel. Both good understanding of the principle and hand-on practice of column chromatography will build a strong foundation for higher level experiments.
In Experiment 2 (Separation of the Components of an Analgesic Tablet), TLC and melting point analysis are used to identify the compounds present in Aspirin. Compounds A-D are separated and isolated via gravity filtration, extraction and suction filtration techniques.
In Experiment 3 (Preparation and Reactivity Study of Tetraiodotin (IV), SnI4 by refluxing tin and iodine in toluene. The product was purified via recrystallization and dried under partial vacuum. The SnI4 was used in further reactions such as hydrolysis, reaction with PPh3 and NaI to form other tin (IV) complexes.
In Experiment 4 (Preparation and Spectrophotometric Analysis of Copper (I) Iodide), inorganic synthesis of an interesting copper (I) iodide is conducted and physical/analytical characterization is used to determine its component. The relative stability of copper (I) and copper (II) will be compared and the principle of redox reaction will be discussed. Experimental skill of sample weighing, sample transfer, standard solution preparation and suction filtration will be taught and
practiced by the students. UV-visible spectroscopy is used for quantitative determination of copper in the synthesized salt. Standard curve is used for calibration, with a proper data treatment. The spectroscopic method used in Experiment 3 is compared with titration method in Experiment 1 and 2.

In Experiment 5 (Kinetic Studies on the Decomposition of Aspirin) the kinetic studies of a decomposition reaction is conducted. With the background knowledge of nucleophilic substitution reaction, the kinetics of the decomposition of aspirin in water to salicylic acid and acetic acid is studied. The concentration of salicylic acid formed is determined by measuring the visible absorbance of the salicylic-iron complex. The basic concept of kinetic study is integrated in this experiment, especially during treatment of experimental data. The concept of data record and treatment is emphasized again in this experiment.

In Experiment 6 (Heat of Neutralization by Calorimetry) the heat capacity of a calorimeter is first determined by making use of the known heat of neutralization of a strong acid and a strong base. The heat capacity of the calorimeter is used to find the heat of neutralization of acetic acid with sodium hydroxide. Finally, the heat of neutralization of an unknown acid (monoprotic, diprotic or triprotic) is deduced by measuring the temperature change associated with the neutralization of the acid and a strong base.

In Experiment 7 (Study of Solubility Equilibrium) the thermodynamic property $K_{sp}$ of an organic salt is measured at different temperatures and the enthalpy and entropy change of the process is also determined. Titration technique is used to determine the concentration of hydrogen tartrate ion, with acid-base equilibrium as its background theory. Students will be trained on proper data recording and treatment, especially on significant figures and linear regression.

In Experiments 1-3, some basic synthetic chemistry skills are taught and practiced. In Experiments 4-7, physical chemistry and analytical chemistry skills are taught and practiced, as well as the concept and application of data record and treatment. All the basic skills in CM1191 module serves as important foundation for higher year experiments.

**LEVEL 2 MODULES**

**CM2101: Physical Chemistry 2 (Essential Module)**

*Workload: 4-1-0-2-3*

**Aims & Objectives**

In this module, the basic idea of how light interacts with matter, in particular atoms and molecules will be discussed. The topics discussed are energy quantization, particle-in-a-box, rigid rotors and harmonic oscillators and molecular symmetry. Microwave, infrared, Raman, electronic and nuclear magnetic resonance spectroscopic techniques will be discussed. Chemical examples relating to these techniques will be highlighted.

**Syllabus**

General Features - EM radiation, absorption and emission, Transition dipole moments and selection rules, Boltzmann distribution and population of states, Beer’s law

Rotational Spectroscopy - Diatomic molecules – rigid and non-rigid rotor models, Dipole moment, rotational constant, isotopic substitution and centrifugal distortion

Vibrational Spectroscopy - Diatomic molecules – harmonic and anharmonic oscillator models, Dynamic dipole moment, equilibrium vibrational frequency and anharmonicity constant, Rotational-vibrational transitions for linear molecules

Electronic Spectroscopy - Potential energy curves, Born-Oppenheimer approximation, Franck-Condon principle, Dissociation energies and Birge-Sponer extrapolation, Diatomic molecules – molecular orbitals, electronic configurations, term symbols and selection rules, Structural analysis by UV-visible spectroscopy – chromophores

Raman Spectroscopy - Molecular polarizability, Diatomic molecules – rotational and vibrational Raman spectra, Rule of mutual exclusion.

Polyatomic molecules - Normal modes of vibration, Structural analysis by infrared spectroscopy – group and skeletal frequencies, Types of polyatomics linear molecules - Symmetric top, Spherical top, Asymmetric top.

Symmetry - Character tables, Irreducible representations of AO in point groups, Molecular orbital, Stretching mode analysis, Projection operators.
NMR spectroscopy - Interaction of nuclei with magnetic field, Gyromagnetic ratio, Energy level splitting, coupling, interpretation of spectrum of simple organic molecules

CM2111: Inorganic Chemistry 2 (Essential Module)
Workload: 4-1-0-2-3

Aims & Objectives
This is a chemistry module designed for chemistry majors and covers fundamental solid-state chemistry, coordination chemistry of transition metal elements, molecular symmetry and applications in molecular orbitals analysis and vibrational spectroscopy, electronic spectra of transition metal complexes and origin, selection rule of electronic transition, Orgel diagram.

Syllabus
This module covers three parts: 1) solid state chemistry, 2) coordination chemistry, 3) molecular symmetry and applications in spectroscopy of transition metal complexes. Part 1 includes properties of solids, crystal structures of inorganic solids, energetic of ionic solids and defects. Part 2 describes several important aspects of coordination chemistry of transition metal elements, such as nomenclature, coordination number and geometry, types of ligands, isomerism, bonding, Jahn-Teller theorem, crystal field/ligand field theories, 18 electron rule, stability and reactivity of metal complexes. Part 3 primarily focuses on the local or point symmetry of a molecule, symmetry elements and operations, determination of point group as well as character tables. Application is mainly limiting to proper assignment of the symmetry labels for atomic/molecular orbitals and vibrational analysis of metal complexes. Electronic spectra of metal complexes in solution, concepts of microstates, term symbols, spin and Laporte’s selection rules, origin of transitions and assignment of d-d transition bands by using Orgel diagrams.

CM2121: Organic Chemistry 2 (Essential Module)
Workload: 4-1-0-2-3

Aims & Objectives
This module builds on CM1121 (basic organic chemistry) by focusing on the first-principles (fundamentals) of organic chemistry, i.e. the factors, effects, models, selectivity, conformation, and stereochemistry of molecules. Emphasis is on gaining an ability and understanding of reagents, mechanisms, and synthesis through problem-based case-studies and tests.

Syllabus
This module covers fundamental spectroscopy in organic chemistry: IR, 1H-NMR, 13C-NMR, MS; Electrophilic alkene; Enol chemistry: formation of enols and enolates, alkylation of enolates, aldol reactions, Claisen reactions, Michael reactions; Stereoselectivity: on C=C bond, on cyclic system, on simple acyclic system; Chemoselectivity: oxidation, reduction, protection; and basic retrosynthetic analysis.

Part 1
(a) Formation and reactions of enols and enolates
- how carbonyl compounds exist in equilibrium with enols;
- acid or base promotion of enol and enolate formation;
- nucleophilic reactivity of enols and enolates and their application to the introduction of functional groups next to carbonyl groups;
- use of silyl enol ethers and lithium enolates as stable enolate equivalents
(b) Electrophilic alkenes
- conjugate addition of alkenes with electron-withdrawing groups other than C=O (CN and NO₂), which makes them electrophilic and allows nucleophilic attack;
- conjugate substitution of electrophilic alkenes bearing leaving groups and thus promoting substitution reactions at C=C related to those at C=O;
- nucleophilic aromatic substitution on electron-poor aromatic rings that allow substitution reactions with nucleophiles rather than the usual electrophiles;
- special leaving groups and nucleophiles that allow nucleophilic aromatic substitution on electron-rich rings; allylic systems:
how double bonds adjacent to leaving groups share the electrophilic character of the carbon atom carrying the leaving group, and may allow more than one product to form

(c) Chemoselectivity
- selective reactions and protection (what is regio-, stereo-, and chemoselectivity;
- reagents for the reduction of alkenes and carbonyl compounds;
- removal of functional groups; reduction of benzene rings; protection of aldehydes, ketones, alcohols, and amines; reagents for oxidation of alcohols

(d) Alkylation of enolates
- how to make new C–C bonds using carbonyl compounds as nucleophiles;
- how to prevent carbonyl compounds from reacting with themselves

(e) Aldol reaction (reactions with carbonyl compounds as both nucleophile and electrophile; how to make enones by the aldol reaction; how to be sure that you get the product you want from an aldol reaction; different methods for aldol reactions with enolates of aldehydes, ketones, and esters; how to use formaldehyde as an electrophile; how to predict the outcome of intramolecular aldol reactions).

(f) Acylation at carbon
- Claisen condensation;
- how to acylate the enolates of esters and ketones;
- how to get C-acylation and avoid O-acylation; how to make cyclic ketones by intramolecular acylation; e
- namines in acylation reactions

(g) Conjugate addition of enolates
- convergent plans for synthesis;
- thermodynamic control;
- selection of reagents for the enol(ate) conjugate addition; tandem reactions;
- Robinson annelation;
- substitution may be elimination–conjugate addition in disguise; nitriles and nitro compounds

(h) Controlling the geometry of double bond
- difference between E- and Z-alkenes;
- E/Z control;
- eliminations are not stereoselective;
- cyclic alkenes are cis; equilibration of alkenes gives trans;
- Julia olefination and the Wittig reaction;
- reliable reduction of alkynes

(i) Stereoselective reactions of cyclic compounds
- stereoselectivity in cyclic systems;
- flattened 4- and 5-membered rings are attacked anti to large substituents;
- flattened six-membered rings are attacked from an axial direction;
- bicyclic structures are attacked on the outside face;
- tethering together nucleophile and electrophile forces one stereochemical outcome;
- reversal of the normal stereochemical outcome of a reaction by H-bonding

(j) Diastereoselectivity
- making single diastereoisomers from single geometrical isomers;
- predicting the reactions of chiral carbonyl compounds;
- chelation to metal ions can change stereoselectivity;
- predicting the reactions of chiral alkenes;
- stereoselectivity in the aldol reaction;
- making syn and anti aldol products

Part 2
Introduction to disconnectivities and synthon; simple retrosynthesis
Part 3
Spectroscopy
- principles of MS and NMR
- MS (EI, CI) and its applications
- NMR (1-D) and its applications
- IR and its applications to spectroscopic analysis

CM2142: Analytical Chemistry 1 (Essential Module)
Workload: 4-1-0-2-3

Aims & Objectives
This module is an introduction to analytical chemistry. The contents of this course includes data
treatment and analysis, separation science, chromatography and electrochemistry. This course
provides students with the theoretical background necessary for understanding the principles and
applications of selected modern analytical instrumentation.

Syllabus
Discussion on sample treatment and extraction, and sample preparation techniques, separation
science, electrochemistry. Topics covered will be selected from: liquid extraction and solid phase
extraction, some novel extraction technologies; comparison of traditional and modern extraction
procedures; introduction to chromatography, with special emphasis on planar chromatography;
introduction to electroanalytical methods.

(a) Sampling
   i. Standardization; calibration; sample handling
   ii. Preparing samples for analysis
(b) Aqueous solutions and chemical equilibria
   i. Applications of Chemical equilibrium, chemical kinetics
   ii. Gravimetry
   iii. Titrimetry
(c) Fundamentals of sample preparation and extraction
   i. Classical extractions (related to (3) above) and liquid-liquid extractions
   ii. Basics of sorbent-based extraction
(d) Introductory separation science/chromatography, electrophoresis
   i. Theory of chromatography
   ii. Column chromatography
   iii. Planar chromatography
   iv. Gas chromatography
   v. Liquid chromatography
   vi. Ion-exchange separations
   vii. Electrically-driven separations (e.g. capillary zone electrophoresis)
(e) Introductory electroanalysis
   i. Applications of standard electrode potentials
   ii. Oxidation/reduction titrations
   iii. Electrogravimetry
   iv. Coulometry
   v. Voltammetry
CM2191: Experiments in Chemistry 2 (Essential Module)  
Workload: 2-0-6-0-2  

Aims & Objectives  
This is a module designed for chemistry majors. It deals with laboratory experiments on selected topics of synthetic chemistry principles and theoretical contents primarily selected from the modules CM2111 and CM2121.  
In CM2191, by conducting a selected series of experiments, students could strengthen their understanding of the related theoretical aspects. The most important learning outcome is, however, the training in integration of theory and experiment and applications of experimental data in chemical analysis and synthesis.  
The overall training in CM2191 should provide students with a good foundation to do experiments at Levels 3000 and basic research initiatives such as in UROPS.  

Syllabus  
This module deals with laboratory experiments on selected topics of synthetic chemistry principles and theoretical contents primarily selected from the modules CM2111 and CM2121.  
Through this module students could strengthen their understanding of the related theoretical aspects. The most important learning outcome is, however, the training in integration of theory and experiment and applications of experimental data in chemical analysis and synthesis. The overall training in CM2191 should provide students with a good foundation to do experiments at Levels 3000 and basic research initiatives such as in UROPS.  
In Experiment 1 (Synthesis of Carboxylic Acid Derivatives) Fischer esterification is used to synthesize different esters. In this experiment reflux, extraction, neutralization and purification via distillation are used. The final compound obtained was characterized by 1H NMR and IR spectroscopy.  
In Experiment 2 (Oxidation and Reduction) involves two stereoselective nucleophilic addition reactions are carried out on a locked ring system – 4-t-butylcyclohexanone and camphor. The reaction was monitored by TLC with anisaldehyde stain and the final products was characterized by 1H NMR and IR spectroscopy. The diastereexcess (d.e.) value of the reaction mixture can be estimated by integration of peak areas on the 1H NMR spectrum. For the oxidation reaction, Oxone was used as the oxidizing agent to convert (JS)-borneol to camphor. The camphor obtained was purified by sublimation and characterized by IR spectroscopy.  
In Experiment 3 (Nucleophilic Addition Reaction), Grignard reaction with carbon dioxide, ester or benzophenone was carried out. In Experiment 3.4, acetone is used as a protecting agent for 1,2-diol to synthesize acetone derivatives of D-mannose under mild reaction condition.  
In Experiment 4 (Electrophilic Aromatic Substitution), Friedel-Crafts alkylation of tert-butylbenzene using FeCl3 as catalyst, nitration of methyl benzoate and nitration of an unknown aromatic compound are explored. The final products was characterized by 1H NMR and IR spectroscopy.  
In Experiment 5 (A Green Aldol Synthesis) aldol reaction in an environmentally friendly ethanol/water mixture is performed. This procedure produces only the aldol product and water. In Experiment 6 (Synthesis, Electronic Spectra, Structural Isomerism: Octahedral Co (III) Complexes with Chloride and Ethylenediamine Ligands) three octahedral Co(III) complexes with two types of ligands, namely ethylenediamine (en) and chloride (Cl) will be synthesized. One enantiomer of the [Co(en)3]3+ complexes and two geometric isomers: cis- and trans-[Co(en)2Cl2]2+ complexes, are later characterized by FT-IR and UV-VIS spectroscopy. Subsequent reaction gives a crystalline solid containing a racemic mixture of the [Co(en)3]Cl3 complex. The pure Λ-[Co(en)3]3+ complex could be enantioselectively crystallized by a chiral resolution technique from a diastereomeric mixture of this kind of Co(III) complexes with an enantiomerically pure (+)-tartaric acid.  
In Experiment 7 (Magnetic and IR spectroscopic studies of tetragonal Nickel(II) complexes Ni(Et2en)2X2), IR spectroscopy is used to determine the coordination mode of ambidenate ligands, such as SCN- and NO2-.  
In Experiment 8 (Synthesis and IR Spectral Analysis of a Schiff Base Functionalized Triazole Ligand and Its Iron (II) Coordination Polymers) a Schiff base derivative of triazole, N-cinamalidene 4-amino-1,2,4-triazole (Hcintrz) is synthesized. Subsequently, the Hcintrz ligand is used to synthesize three different iron(II) CPs, which will be further studied by IR spectroscopy. The Hcintrz
ligand will adopt the $\mu_{1,2}$ coordination mode, bridging the two iron(II) metal ions, forming 1D infinite chains of metal-ligand complexes, called coordination polymers (CPs). The Hcintrz ligand and its respective Fe (II) complexes are characterized solid IR spectroscopy.

CM2192: Experiments in Chemistry 3 (Essential Module)
Workload: 2-0-6-0-2

Aims & Objectives
This is a module designed for chemistry majors. It deals with various techniques to separate a mixture into its individual components, identify the structure/formula of each component and determine the concentration of each component. Guided under the general principles of analytical and physical chemistry, these techniques include, but not limited to: spectroscopy, chromatography, electrochemistry, etc.

Syllabus
In most chemistry synthesis, the product is impure, containing either solvent(s), unreacted starting material(s), catalyst(s), or unwanted side products. In addition, the component(s) of many samples and the concentration of each component need to be determined for various applications, ranging from pure chemistry to life science and environmental sciences. Hence, during development of chemistry, various techniques have been developed to separate a mixture into its individual components, identify the structure/formula of each component and determine the concentration of each component. The experiments covered in this module are:

Analytical:
Experiment 1: Gas Chromatography (GC) for Qualitative and Quantitative Analysis
Experiment 2: High Performance Liquid Chromatography (HPLC) for Rapid Separation and Analysis of Soft Drinks
Experiment 3: High Performance Liquid Chromatography (HPLC) for Rapid Separation and Analysis of a Vitamin C Tablet
Experiment 4: Cyclic and Linear Sweep Voltammetry (CV and LSV)
Experiment 5: Determination of Mass Percentage of Copper in a Wire Using and Ion Selective Electrode (ISE)
Experiment 6: Determination of Fluoride Ion Concentration in Toothpaste Using an Ion Selective Electrode (ISE)
Experiment 7: Equivalency Testing of Potentiometric Titration Versus Indicator Titration for the Determination of Silver Ion Concentration
Experiment 8: Analysis of Seawater
Experiment 9: Liquid-liquid and Solid-phase Extraction of Zinc Pyrithione from Shampoo and Its Quantification
Experiment 10: Determination of Mass % of Copper in a Wire Using Chelate Extraction and VIS Absorbance
Experiment 11: Determination of the Stability Constant of a Molecular Complex
Experiment 12: Raoult’s Law and Binary Liquid-Vapour Phase Diagram
Experiment 13: Kinetics of Methylene Blue Reduction by Ascorbic Acid
Experiment 14: Rovibrational Spectrum of Hydrogen Chloride
Experiment 15: The Electronic Absorption Spectrum of Iodine
LEVEL 3 MODULES

CM3201: Principles of Chemical Processes (Elective Module)
Workload: Workload: 4-1-0-2-3

Aims & Objectives
This module is an introduction to the Chemical Industry and related process industries like the Food Processing and Pharmaceutical Industries, or Petroleum Refining. Process analysis and mass and energy balances of simple and complex systems are covered, including recycle and purge streams. Systems without and with chemical transformations will be treated for batch and steady state flow processes. The concept of unit operations is introduced. Thermal processes (e.g., heat transfer and separation by distillation) will be treated in greater depth. The design of new products and processes is emphasised as an important aspect of the work of an industrial chemist.

Syllabus
Basic engineering calculations. Convert quantities from one set of units to another quickly and accurately; define, calculate, and estimate properties of process streams including fluid density, flow rate, chemical composition variables (mass and mole fractions, concentrations), fluid pressure, and temperature. Understand the principle of steady state.

Material (and energy) balance calculations. Draw and label process flowcharts from verbal process descriptions; carry out degree-of-freedom analyses (process book keeping); write and solve material and (simple) energy balance equations for single-unit and multiple-unit processes, processes with recycle, purge and bypass, and reactive processes.


Fluid Flow. Understand the different flow regimes (laminar and turbulent) and the implications on mass and heat transport.

Heat Transfer. Understand the principal mechanisms of heat transfer: conduction, convection, radiation. Use appropriate correlations involving dimensionless groups to estimate heat transfer coefficients for several geometries.

Computation. Use spreadsheets (EXCEL) and an equation-solving program (EZ-Solve) to solve material and energy balance problems.

Teamwork. State principles of effective team performance and the functions of different team roles (coordinator, recorder, checker, and process monitor), work effectively in problem-solving teams, and carry out meaningful performance assessments of individual team members.

CM3211: Organometallic Chemistry (Elective Module)
Workload: 4-1-0-2-3

Aims & Objectives
This module features the principles of synthesis, structures and reactivity of organometallic compounds. Significance of synergic d-π back bonding and different modes of π bonding will be illustrated. The course covers the applications of physical and spectroscopic methods in order to provide the scientific bases for the elucidation of π bonding metal-metal and metal-hydrogen bonds, isomerism, fluxionality, and molecular structures. The different modes of reactions of organometallic compounds and their applications will be explored. The catalytic cycles and the mechanisms of the different homogeneous catalytic processes will be illustrated.

Syllabus
- Metal-to-ligand π-back bonding and metal-metal bonding, and structures of organometallic compounds including complexes and clusters.
- Wade-Mingos rules and isolobal relationships
- Substitution, addition, elimination and insertion reactions of organometallic compounds and their synthetic applications.
- Different catalytic processes of organometallics and their applications.
  - principles of homogeneous catalysis
  - catalytic cycles and mechanisms
  - hydrogenation (Wilkinson’s catalysis)
  - Wacker process
  - Hydroformylation
  - Monsanto process
  - various C-C coupling reactions

**CM3212: Transition Metal Chemistry (Elective Module)**
**Workload: 4-1-0-2-3**

**Aims & Objectives**
This module covers the chemistry of d-block and f-block metals. An introduction to observed trend in physical and chemical properties of d-block transition metal complexes will be given. A comprehensive discussion on their electronic structures and spectra follows. Magnetic property, ligand substitution and redox reaction of these metal complexes will be illustrated. The f-block metals will be introduced leading to a discussion of the optical spectra of their complexes. Introduction to inorganic supramolecular chemistry, crystal engineering and solid state chemistry will be covered.

**Syllabus**
- The d-block elements: physical properties, trend in chemical properties, representative examples of transition metal complexes.
- Electronic structures and spectra of transition metal complexes: elementary crystal field and ligand field theories for octahedral, tetrahedral and square planar complexes; pectrochemical series; molecular orbital description of transition metal complexes; electronic absorption spectra of atoms and transition metal complexes; Orgel diagrams; magnetism; charge transfer absorption; selection rules and intensities of UV-vis absorption.
- Reaction of transition metal complexes: ligand substitution, redox reaction.
- The f-block metals: lanthanoid and actinoids and the optical spectra of lanthanoid complexes.
- Inorganic supramolecular chemistry and crystal engineering.
  - Molecular self-assembly
  - Molecular recognition and complexation
- Solid state chemistry.
  - Concept of aggregates of molecules

**CM3221: Organic Synthesis and Spectroscopy (Elective Module)**
**Workload: 4-1-0-2-3**

**Aims & Objectives**
This module covers cycloaddition reaction (characteristics of a cycloaddition reaction, rules that govern cycloadditions, photochemical reactions, making 4-, 5- and 6-membered rings, and using cycloaddition to functionalize a compound), sigmatropic reaction (stereochemistry from chair-like transition states, making -unsaturated carbonyl compounds, special chemistry of N, S and P, why substituted cyclopentadienes are unstable, con and dis-rotatory, reactions that open small rings and close larger rings), retrosynthesis and determination of stereochemistry by spectroscopic methods (1- and 2-D NMR, Mass spectrometry (ESI, MALDI) and applications of spectroscopy in the determination of stereochemistry).

**Syllabus**
**PART 1: ORGANIC SYNTHESIS**
- Introduction to retrosynthetic analysis.
- One-group C-X disconnection.
• Two-group C-X disconnections.
• Amine synthesis and protecting groups.
• One-group C-C disconnections.
• Alkenes and alkynes.
• One-group C-C 1,3-difunctional.
• Two-group C-C 1,5-difunctional.
• Two-group C-C 1,2-difunctional.
• Two-group C-C 1,4-difunctional.
• Two-group C-C 1,6-difunctional.
• Sigmatropic reaction
• stereochemistry from chair-like transition states;
• making , -unsaturated carbonyl compounds;
• factors that determine if a pericyclic reactions go ‘forwards’ or ‘backwards’;
• special chemistry of N, S, and P;
• why substituted cyclopentadienes are unstable;
• ‘con’- and ‘dis’-rotatory;
• reactions that open small rings and close larger rings

PART 2: ORGANIC SPECTROSCOPY
• 1D NMR: Spin-Spin Coupling
• 1D NMR: NOESY, TOCSY, APT, DEPT, INERT
• Dynamic NMR Spectroscopy
• 2D NMR: COSY, NOESY, C-H Direct Correlation, C-H Long Range Correlation
• 2D NMR: HMQC and HMBC
• Strategies in Assigning Resonances
• Strategies in Structural Elucidation

CM3222: Organic Reaction Mechanisms (Elective Module)
Workload: 4-1-0-2-3

Aims & Objectives
This module covers the study of a selected series of organic reactions involving reactive intermediates and/or molecular rearrangements. Emphasis is placed on an understanding of their reaction mechanisms. These will include rearrangement reactions involving carbocations and carbenes as intermediates. Stereoelectronic properties leading to fragmentation reactions will be introduced. Reactions initiated by radicals will be covered. Comprehensive discussions on rules and stereochemical consequences in pericyclic reactions will be given. The synthetic applications of all the above reactions will be illustrated.

Syllabus
• Fundamentals of reaction mechanism
• Potential Energy Surfaces and Reaction Kinetics
• Linear Free Energy Relationships
• Stability and Strain of Reactive Intermediates
• Radicals
• Carbenes
• Carbocations
• Carbanions
• Frontier Orbital Theory and Pericyclic Reactions
• Molecular Rearrangements
• Catalysis and Enzymatic Reactions
• Fragmentation reactions
  o electron donation and electron withdrawal combine to create molecules that fragment;
  o anti-periplanar conformation and fragmentation;
  o fragmentation of small rings;
  o making of medium and large rings;
  o controlling the double bond geometry.
CM3225: Biomolecules (Elective Module)
Workload: 4-1-0-2-3

Aims & Objectives
An introduction on the four major classes of biomolecules in life: nucleic acids, proteins, carbohydrates and fatty acids will be given. The bioorganic aspects of these molecules, e.g. how proteins behaves, how DNAs are damaged and repaired, how enzymes catalyze chemical transformations, and how drugs are developed, will be discussed. Fundamentals in biochemistry and physical methods for bioorganic chemistry will be introduced. Basic concepts in how to synthesize biologically active compounds in drug discovery through combinatorial chemistry will be introduced.

Syllabus
- Introduction of Biomolecules
- Chemistry of Lipids and Carbohydrates
- Nucleic Acids/DNA/RNA Chemistry (including DNA damage & repair)
- Amino Acids/Peptides/Proteins Chemistry
- Enzyme Catalysis and Inhibition
  - The docking mechanism
  - Protein-small molecule interactions
- Introduction of Combinatorial Chemistry/Drug Discovery
  - Bioactivity and selectivity
  - Chemical library

CM3231: Quantum Mechanics and Statistical Thermodynamics (Elective Module)
Workload: 4-1-0-2-3

Aims & Objectives
This module looks at quantum chemistry and statistical thermodynamics. A deeper understanding of quantum chemistry beginning from its postulates and basic systems such as particle-in-a-box to atomic and molecular models is explored. The second part of the module looks at the relationship between molecular and bulk properties of matter, including examples such as the use of partition functions in equilibrium, transition states and heat capacity of chemical systems.

Syllabus
QUANTUM CHEMISTRY
- Exact Solutions for free particle motion in one, two and three dimensions. Application to linear conjugated polyene systems, Spherical coordinates, Particle on a ring and on a sphere and the rigid rotor.
- Particle experiencing potential energy, Tunnelling, Harmonic oscillator and relationship to the infrared spectrum of a diatomic molecule.
- Review of the hydrogen atom, Quantum numbers, Orbital angular momentum, Many-electron atoms, Alkali metals and helium atom, Pauli principle, Term symbols using angular momenta, Spin-orbit coupling.
- Molecules - The Born–Oppenheimer approximation, Molecular orbitals, Electronic states in diatomic molecules, Variational principle, perturbation theory, the secular equations and Hückel theory.

STATISTICAL THERMODYNAMICS
- The Laws of Thermodynamics. Internal Energy, Entropy and Heat Capacity. Maxwell–Boltzmann Distribution and the most probable distribution, leading to the partition function.
- Translational partition function, the Sackur-Tetrode equation. Rotational, Vibrational and Electronic and Nuclear partition function as applied to diatomic molecules.
- Rewriting chemical equilibrium in terms of partition functions. Transition state theory, heat capacities of molecules and solids and ortho and para hydrogen.
CM3232: Physical Chemistry of the Solid State & Interfaces (Elective Module)
Workload: 4-1-0-2-3

**Aims & Objectives**
This module introduces the basic concepts on crystal structure, reciprocal lattice, chemical classifications of solids, the electronic structure of solids, materials of solids, lattice dynamics, surfaces. Energy band structure theory will be taught based on crystal orbitals. Elements of interface chemistry such as the interfaces of liquid-gas, liquid-liquid, solid-gas, and solid-liquid will be covered.

**Syllabus**

**Part I**
Crystal structure, Periodic arrays of atoms, Lattices, Index systems for crystal planes, Simple crystal structures, Nonideal crystal structures.
Reciprocal lattice, Crystal diffraction of waves, Bragg law, Scattered wave amplitude, Brillouin zones.
Chemical classifications of solids, Atomic and molecular interactions in solids, Schrodinger equation and Born-Oppenheimer Approximation, Energy band structure, Crystal binding, Electronic conductivity, Band structure and spectroscopy, Fermi surface and Fermi energy.
The electronic structure of solids, Interatomic and molecular forces
Band structure of solids and physicochemical properties

**Part II**
Crystal defects, non-stoichiometry: Perfect and imperfect crystals types of defect (Schottky, Frenkel, Color centres, vacancies, interstitials, substitutional, extended), lattice distortions, polarons.
Electrical properties: Survey of electrical properties and materials, metals, intrinsic semiconductors, extrinsic semiconductors, ionic conduction, electrolytes, dielectric materials, Hall effect
Heterointerfaces: Electron affinity, metal-semiconductor junction, Schottky barrier, p-n junctions, rectification
Optical properties: Optical constants, dispersion, absorbance, reflectance, transmittance, Hagen-Rubens relation, damping, plasma frequency, interband and intraband transition, excitons, optical spectra of materials, spontaneous and stimulated emission, laser, photonics
Magnetic properties: Basic concepts, spin, magnetic moment, magnetic domain, diamagnetism, paramagnetism, ferromagnetism
Spectroscopy and microscopy techniques: General principles, photoemissions spectroscopy, X-ray emission and absorption spectroscopy, scanning tunneling microscopy and spectroscopy
Solid surfaces: Surface growth, surface structure, physisorption and chemisorption, adsorption isotherms, electrode-soluton interface, rate of electron transfer, voltametry, electrolysis
Synthesis of Solids: Solid state reaction, Sol-gel, hydrothermal synthesis, intercalation and deintercalation, vapour phase transport, chemical vapour deposition, crystal growth.

CM3242: Instrumental Analysis (Elective Module)
Workload: 4-1-0-2-3

**Aims & Objectives**
This module covers the advanced treatment of some concepts that are applied to the analytical chemistry field already taught in other modules (CM1131, CM2161, CM2192 (practical module)), plus advanced techniques important in the fast moving world of modern analytical chemistry. More advanced considerations of the instrumentation aspects (for example, hyphenation or coupling of two or more) of important analytical techniques are discussed, and wide-ranging applications of these techniques to solving problems in various fields are taught. The topics covered include advanced separation science, electrophoresis, spectrophotometry, spectrometry, electroanalysis, and flow injection analysis.

**Syllabus**
(1) Advanced separation sciences – principles, and particularly, applications
   (a) Capillary gas chromatography; instrumentation
   (b) Capillary/nano/ultra pressure liquid chromatography; instrumentation; new separation mechanisms
   (c) Micellar electrokinetic chromatography, capillary electrochromatography; instrumentation
   (d) GCxGC, multidimensional chromatography; instrumentation
   (e) Detection systems for chromatography and electrophoresis

(2) Mass spectrometric applications
   (a) Fundamentals of mass spectrometry
   (b) Essential ionization approaches in mass spectrometry
   (c) Hyphenated techniques with mass spectrometry
      (i) Gas chromatography/mass spectrometry
      (ii) Liquid chromatography/mass spectrometry
      (iii) Capillary electrophoresis/mass spectrometry, etc.

(3) Spectrochemical analysis, atomic spectrometry, elemental analysis, atomic absorption spectrometry, atomic emission spectrometry, inductively-coupled plasma-optical emission, and mass spectrometry, molecular absorption spectroscopy, automation
   - Instrumentation
   - Applications

(4) Electroanalytical methods and applications
   (a) Thermodynamics and kinetics of electrochemical reactions
   (b) Polarographic techniques
   (c) Voltammetry and stripping voltammetry
   (d) Electrode reactions with coupled chemical reactions
   (e) Ion selective electrodes, chemically modified electrodes and electrochemical biosensors

(5) Thermal and gravimetric methods; Radiochemical methods/imaging

(6) Flow injection analysis

CM3251: Nanochemistry (Elective Module)
Workload: 4-1-0-2-3

Aims & Objectives
This multidisciplinary module provides an in-depth view of the synthesis, characterisation and application of nanostructures using chemical routes. Necessarily, it will incorporate various concepts from colloidal chemistry, supramolecular chemistry, polymer chemistry and electrochemistry. The application of these concepts in nanoscale synthesis will be emphasized and presented in a cohesive manner. The module also highlights the applications of nanostructures such as quantum dots, nanoparticles, nanorods, nanowires, etc. in the areas of biosensors, bioimaging, LEDs and photonic crystals, etc.

Syllabus
• Common techniques for nano-structure fabrication
  • Top-down versus bottom-up approaches. Emphasis will be placed on the basic principles for techniques such as CVD, Sol-gel, SAM, various lithography methods, etc.
  • Various forms of nano building blocks
    • small molecules, colloids, emulsions, surfactants, polymers, liquid crystals, thin films, etc.
  • Nanoparticulate materials and nanocomposites
    • Basic principles involved in the synthesis of nanoparticles and nanocomposites, present and future applications of nanocomposites including solar cells, fuel cells, hydrogen storage, catalysis, magnetic and optical materials.
  • Materials and techniques involved in supramolecular chemistry
    • From carbon atoms to functionalized polymers, from single molecules to self-assembling supramolecular structures.
  • Other unique nanosystems
- Fluorescent QDs, photonic crystals, NLO materials, photovoltaic and LED materials, bioimaging, biosensors, biomimetic nanostructures and biomedical application in terms of various tags for identification.

**CM3252: Polymer Chemistry 1 (Elective Module)**
**Workload: 4-1-0-2-3**

**Aims & Objectives**
Polymer science is the study of plastic materials of everyday life and the development of new materials that meet technological needs. This module covers classification and synthesis of polymers by different polymerization techniques; copolymerization reactions and industrial polymers. Physical properties of polymers both in the solid state and in solution will also be discussed. Knowledge in laboratory techniques in polymerization, determination of molecular weight and stability and spectroscopic studies will be introduced.

**Syllabus**
1. Classification of polymers
   - Thermoplastics and thermosets
   - Polymerization mechanism
   - Polymer structures
     - Copolymers
     - Tacticity
     - Geometrical isomers
2. Polymer synthesis
   - Step-growth polymerization
   - Chain-growth polymerization
   - Ionic & metal catalyzed polymerizations
   - Copolymerization: types, MRR, Q & e scheme
3. Polymerization techniques
   - Bulk polymerization
   - Solution polymerization
   - Suspension polymerization
   - Emulsion polymerization
   - Solid and gas phase polymerization
4. Solid state properties
   - Amorphous state
   - Crystalline state
   - Transitions in polymers
   - Structure-property relationships
   - Mechanical properties (introduction to viscoelasticity)
   - Thermal properties
5. Polymer solutions and molecular weights
   - Thermodynamics
   - Flory-Higgins Theory
   - Viscosity and Viscometry
6. Characterization of polymers
   - Spectroscopies
   - Thermal analysis
   - Tensile tests

**CM3253: Materials Chemistry 1 (Elective Module)**
**Workload: 4-1-0-2-3**

**Aims & Objectives**
Fundamentals of solid state chemistry will first cover the primary and secondary types of bonding in solids followed by lattice energy in ionic solids. Crystalline solids and their crystal structure will be studied. Metals, insulators and semiconductors will be distinguished using the band theory of solids. Defects occur in crystals – point, line and surface – and their effects on properties of solid materials will be explained. Factors affecting
crystallization and glass formation, and different components of glasses and their uses will be discussed. Formation of different types of glasses and their applications will be highlighted.

**Syllabus**

1. Introduction to Materials Chemistry
   - Historical perspectives
   - Considerations in the design of new materials
2. Fundamentals of solid state chemistry
   - Amorphous vs crystalline materials
   - Types of bondings in solids
   - Ionic solids
   - Metallic solids
   - Molecular solids
   - Covalent network solids
3. Crystalline state
   - Unit cell
   - Crystal lattices
   - Metal oxide lattices
   - Crystal growth techniques
   - Techniques for studying crystalline structure
4. Crystal imperfections
   - Types of defects
   - Effects on properties – harness, fracturing, color, conductivity
   - Properties resulting from crystal anisotropy
5. Phase transformation
   - Phase diagrams for binary system
   - Interpretation of phase diagrams
6. Amorphous State
   - Glasses
   - Sol-gel processing
   - Cementitious materials

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**CM3261: Environmental Chemistry (Elective Module)**

**Workload:** 4-1-0-2-3

**Aims & Objectives**

The module provides an introduction to the chemistry of the environment and the human impacts on those chemistries. After a brief summary of the formation of the planet and its four major components, a more detailed examination of the chemistry of soils, waters and atmosphere follows. Using case studies, the transport and transformation of some substances and pollutants through these reservoirs is examined, along with the tools used to identify, quantitate, some of these substances. The tools to audit, control and remediate the effects of the impacts of some of these substances is also examined.

**Syllabus**

1. Context & Background
   - population, impacts and economics
   - the need for food, modern farming: impacts of process
   - resource and mineral extraction: impacts of process
2. Chemical interaction terrestrial troposphere, fresh waters and geosphere
   - the Hydrological Cycle
   - water was a reaction and transport medium
   - chemical weathering processes
   - terrestrial waters, chemistry
   - troposphere, Henry’s Law, pH of precipitation
• role of biota in chemical interactions
• formation and chemistry of soils
• mineral deposition
• biogeochemistry

(3) Movement, measurement and modelling of substances in the environment
• environmental measurement & monitoring
• pollutants – the REACH system
• Water Framework Directive as a framework, case studies:
  (a) measurement and monitoring of water pollutants
  (b) measurement and monitoring of soil pollutants
  (b) measurement and monitoring of atmospheric pollutants
• modelling of pollutants - plume dispersion modelling

(4) Toxicology and Ecotoxicology
• transformations of pollutants
• exposure and dose
• dose-response curves
• life effects: biomagnification
• mineral deposition

(5) Applications
• air quality
• water pollution and cleanup
• desalination
• soil health and nutrients
• waste disposal

**CM3291: Advanced Experiments in Organic & Inorganic Chemistry (Essential Module)**
**Workload: 2-0-6-0-2**

**Aims & Objectives**
The module provides laboratory work in both inorganic and organic chemistry. This practical module is a major requirement for Chemistry students

**Syllabus**
The syllabus of this module contains a series of experiments in synthetic organic and inorganic/organometallic chemistry. This module is to consolidate and advance the theoretical background of the chemistry contents, as well as the synthetic skill or technique of these experiments.

Experiment 1: Synthesis and Catalytic Study of Metalloporphyrin Complex: Iron(III) meso-tetraphenylporphyrinato chloride [Fe(TPP)Cl]
Experiment 2: Synthesis of a Ruthenium Alkylidene Complex: Making a Grubbs’ Type Catalyst
Experiment 3: Synthesis of Nickelocene
Experiment 4: Inorganic Networks of Copper(I) Iodide
Experiment 5: Synthesis and Characterization of Zn(II)-Tetraphenylporphinate
Experiment 6: Synthesis and Reaction of Palladium(II) Olefin Complexes
Experiment 7: Preparation a Silver (I) NHC (N-Heterocyclic Carbene) Compound
Experiment 8: A Nickel (II) Complex with 1,2-Diaminopropane and Pyrrole-2-aldehyde
Experiment 9: Synthesis and Characterization of 4′-(4″-Pyridyl)- 2,2′ : 6′,2″-terpyridine and its Fe(II) Complex
Experiment 10: Synthesis, Characterization and Reversible Thermochromism of Metal-Organic Framework
Experiment 11: Palladium Catalyzed Coupling of a Terminal Alkyne to 4-Iodo-1-nitrobenzene
Experiment 12: Multistep Synthesis of Ibuprofen
Experiment 13: Asymmetric Epoxidation

CM3292: Advanced Experiments in Analytical & Physical Chemistry (Essential Module)
Workload: 2-0-6-0-2

Aims & Objectives
This module is a major requirement for Chemistry students and is designed to build independent lab skills and science sense to help prepare students for Final Year Project or employment. In successfully completing this module, students will:

(i) Knowledge and Understanding
   a. appreciate the types of real world issues involved with measurement and analysis.
   b. understand the processes of identifying and quantitating experimental, systematic and sampling errors.
   c. experience ‘idea to application of result’ in the context of sampling and measurement.

(ii) Disciplinal/Professional Skills:
   d. be able to work safely and competently in a wet laboratory situation
   e. be able to write a risk assessment for an experiment.
   f. keep good laboratory records
   g. operate advanced instrumentation in a laboratory setting
   h. be able to obtain information on the structure, composition and behaviour of a complex system through experiment
   i. operate a rudimentary QA/QC system
   j. be able to use a computer to draw the structure of a molecule, calculate its energy levels, assess the HOMO and LUMO energy, and predict its behaviour in a chemical reaction
   k. be able to obtain other spectroscopic or thermodynamic parameters of a molecule based on computer generated parameters
   l. design, execute and critically evaluate an environmental sampling, measurement and assessment programme
   m. report the results of laboratory work in diverse forms and modes that would be beneficial in their future employment.
   n. communicate orally about theoretical and practical aspects of the experiments.

(iii) Transferable Skills
   o. manage their own learning progress
   p. work productively as members of a small group

Teaching and Learning Experience:
Students completing this module will have been given the opportunity to:
   q. attend lectures to assist learning of content
   r. work individually or in small groups to assist in the learning of practical chemistry skills and techniques.

Syllabus
Experiment 1: Measurement of Atmospheric NO₂
Experiment 2: Bioavailability of Heavy Metals in Soils
Experiment 3: Micro-extraction with GCMS Quantitation
Experiment 4: Analysis of Essential Oils
Experiment 5: Capillary Electrophoresis of Three Anions
Experiment 6: Luminescence and Phosphorescence
Experiment 7: Thermal Properties of a Binary Eutectic System
Experiment 8: Thermodynamics of Micellization
Experiment 9: Adsorption at a Liquid/Solid Interface
Experiment 10: Synthesis of Au Nanoparticles and Study of their Surface Assembly
Experiment 11: Distillation
Experiment 12: Heat Exchanger
Experiment 13: Surface Tension
Experiment 14: Investigation of Diels-Alder Cycloadditions Using Computational Chemistry

In the analytical side of the module, the laboratory exercises often include environmental sampling, microextraction, and inter-instrument/technique comparisons. The range of instruments has been expanded to include Inductively Coupled Spectrometry, Ion Chromatography, flow/auto-analysis UV-VIS spectrophotometry, Gas Chromatography-Mass Spectrometry, Fluorescence Spectrophotometry, and Capillary Electrophoresis.

The physical side of the module focuses on the physical properties of complex systems such as solid or/and liquid mixtures and solid/liquid interfaces. Instruments that can directly or indirectly measure those properties are employed, including UV-VIS spectrophotometer, scanning differential calorimeter, tensiometer, conductivity meter and TEM.

In the practical training to date (CM1191, CM2191,CM2192), the training has been progressive but focused on safe and competent laboratory working, and the development of practical and instrumental skills. The practicals in those modules are reasonably closed loop, with largely “known knowns” and “known unknowns”. Large parts of the experimental cycle are provided for the students.

This compulsory year III module is additionally progressive as above, but also includes “unknown unknowns”, broadens further the scope of laboratory and instrumental skills, and does not provide as much of the experimental cycle.

For example, students will have to organize how they will do multiple experiments at once, turn on and prepare their own equipment, design and execute their own sampling strategies and report their results in both conventional and non-conventional formats and routes.

This module is a bridge between their previous laboratory experience and either the honours project, or post university scientific or teaching employment.

CM3296: Molecular Modelling: Theory & Practice (Elective Module)
Workload: 4-1-0-2-3

Aims & Objectives

The objective of this module is to cover fundamental concepts of molecular modelling; basic numerical techniques; survey of computational methods; semi-empirical methods; Ab initio theory; basis sets; electron correlation methods; density functional theory; application to isolated molecular systems, periodic bulk materials, and molecular junctions.

Syllabus

Major topics include
1) Principles of Quantum Mechanics: Basic assumptions; Schrodinger equation; Eigenvalues and measurable physical quantities; Some 'puzzles'.
3) Computational modelling of molecular systems: Hartree Fock method; CI; Density Functional Theory; Green's functions' techniques; Landauer formula.
LEVEL 4 MODULES

CM4214: Structural Methods in Inorganic Chemistry (Elective Module)
Workload: 3-1-0-3-3

Aims & Objectives
This module enables students to learn hand-on applications of single-crystal X-ray diffraction, multinuclear NMR, Mossbauer and IR/Raman techniques to solve structural problems of modern inorganic and organometallic compounds. Practical aspects and relevant training in terms of data interpretation, analyses and presentation will be emphasized. X-ray crystal structure database and crystallographic softwares will be briefly covered.

Syllabus
Introduction (Week 1)
Overviews and basic concepts on chemical structures, other useful techniques not covered, such as mass spectrometry, UV-vis absorption spectroscopy and magnetic measurements

Space Groups (Week 1-3)
Symmetry elements and operations in crystalline solids; space group diagrams

Single crystal X-ray diffraction (SCXRD) (Week 4-6),
Crystal growth, selection and mounting of crystals, preliminary evaluation on crystal specimens, unit cells, lattices, miller planes, reciprocal lattices, data collection, Friedel's law, data processing, intensity statistics, space group determination, structure solution, model building / re-building, structure refinement and quality indicators for X-ray structures, structural validations and presentations of structures, Cambridge structure databases and crystallographic software - OLEX2 for performing hand-on structural determination of authentic or students' crystal specimens using datasets.

NMR spectroscopy (NMR) (Week 7-9)
NMR properties of selected inorganic nuclei (1H, 10/11B, 13C, 19F, 31P and 195Pt), data interpretation and analysis on spectra derived from spectra libraries, dynamic NMR of fluxional metal complexes, special topics on paramagnetic compounds and solid-state NMR spectra.

Mossbauer spectroscopy (Week 10-11)
Basic theory, instrumentation and applications, data interpretation and analysis on 57Fe and selected elements with variable oxidation (or spin) states.

IR/Raman spectroscopy (Week 11-13)
Qualitative identification of characteristic functional groups in inorganic and organometallic complexes, analysis on molecular symmetry, irreducible representations of vibrational modes of molecules using reduction and projection formula.

CM4215: Bioinorganic Chemistry (Elective Module)
Workload: 4-1-0-2-3

Aims & Objectives
This module is designed for chemistry majors which introduces basic principles and concepts of bioinorganic chemistry including the mechanisms of reactions catalyzed by metalloproteins, spectroscopic and electronic properties of metal sites, and kinetics of electron transfer in proteins. This module covers major areas in modern bioinorganic chemistry including synthetic model compounds for metal sites of metalloproteins, basic protein chemistry, biological electron transfer; hydrolytic enzymes, oxygen transporters; oxygen reacting proteins such as monooxygenase, peroxidase, catalase and superoxide dismutase; physical methods in bioinorganic chemistry. The module is directed towards students majoring in chemistry and related disciplines.
**Syllabus**
The module includes basic protein chemistry and structures, mechanisms of reactions catalyzed by metalloproteins, spectroscopic and electronic properties of metal sites, and synthetic model compounds for metal sites of metalloproteins. Specific topics are biological heme and non-heme oxygen transporters and their synthetic models, heme and non-heme monoxygenases and their synthetic models, zinc-containing hydrolytic enzymes and their model compounds, biological electron transfer; oxygen-reacting enzymes such as peroxidase, catalase and copper-zinc superoxide dismutase, radicals in biology (e.g. coenzyme B12 and galactose oxidase), interactions of metal complexes with DNA and inorganic medicine with an emphasis on the chemistry of cisplatin.

**CM4227: Chemical Biology (Elective Module)**
**Workload: 4-1-0-2-3**

**Aims & Objectives**
This module provides an overall view on an emerging new discipline that blends chemistry with many fields of biology to unravel the complexities of life at the interface of chemistry and biology. This course illustrates how biological processes are explained in chemical terms. The key objective is to highlight the basic principles of chemical biology to show its important linkages to life sciences.

This course teaches classical and current topics in chemical biology and allows students to understand how chemical principles and tools can be applied to biological problems. A huge focus of the course is to develop students to be able to think critically and design experiments/methods to tackle biological problems. The skills required for this development will be taught through the use of case studies.

**Syllabus**
(a) Physical properties of nucleic acids.
(b) Physical properties of proteins.
(c) Novel biosyntheses of proteins.
(d) Mechanistic enzymology.
(e) De novo protein design.
(f) Rational protein engineering.
(g) Molecular evolution.
(h) Nucleic acid catalysis.
(i) Emerging Roles of RNA.
(j) DNA damage.
(k) Mechanisms of DNA repair.
(l) Novel natural proteins.
(m) Metabolic engineering.
(n) Molecular mechanisms of drug action and drug resistance.
(o) Rational design of macromolecular ligands.
(p) Combinatorial approaches to small molecule discovery.
(q) Chemical genetics.
(r) Genomics.
(s) Proteomics.

**CM4228: Catalysis (Elective Module)**
**Workload: 4-1-0-2-3**

**Aims & Objectives**
This module covers the principles and characteristics of heterogeneous, homogeneous and enzymatic catalysis. Reaction cycles are analysed at the molecular level, and a microkinetic
approach is used to describe the processes. Selected industrial processes and commercial devices are discussed to illustrate practical applications of the studied topics. At the end of the module, students will have the knowledge to demonstrate the principles and practice of homogeneous, enzymatic and heterogeneous catalysis, and to understand the chemistry associated with the use of catalysts in small molecule synthesis as well as in the construction of complex molecules.

**Syllabus**

**Part I**

A  Introduction - Definition of catalysis  
  a)  Reduction of Activation Energy  
  b)  Thermodynamic principles and Microscopic Reversibility  
  c)  A catalyst cannot change equilibrium, but can change selectivity  
  d)  Concept of active sites; Langmuir isotherm  

B  Heterogenous Catalysis  
  a)  Principles of Heterogenous Catalysis: Lindemann-Hinshelwood Kinetics; Adsorption without and with dissociation; micro-kinetic analysis  
  b)  Catalytic processes  
      ➢  sulfuric acid: lead chamber, contact process, change from V₂O₅ to Pt-based catalysts  
      ➢  ammonia, methanol; Fischer-Tropsch process  
  c)  Catalysis in Energy  
      ➢  petrochemicals: cracking; hydrotreating; reforming  
      ➢  fuel cells  
      ➢  Catalysis for environmental protection: car (three-way) catalytic converter, NOx selective catalytic reduction  
  d)  Catalyst Characterization:  
      ➢  BET, pore size, XRD, TEM, XPS, EXAFS, etc.  
  e)  Fouling and Catalyst Deactivation  
  f)  Preparation of Catalysts  
  g)  Structure of Catalyst Supports  
      ➢  Zeolites  
      ➢  metal-organic frameworks  
      ➢  refractory oxides, etc.  
  h)  Photocatalysis  

C  Homogenous Catalysis  
  a)  General Aspects: Activation Modes, Efficiency, Chemo- and Stereoselectivity  
  b)  Transition Metal Catalysis  
      Coupling Chemistry Catalyzed by Palladium and other group VII metals  
      ➢  Heck reaction  
      ➢  Cross Coupling to form Carbon-Carbon bonds  
      ➢  Cross Coupling to Form Carbon-Nitrogen bonds  
      Functionalization of Alkenes  
      ➢  Hydrogenation and Oxidation of Alkenes  
      ➢  Hydroformylation and H₂ Mediated Carbon-Carbon Bond formation  
      ➢  Nucleophilic Addition to Alkenes  
      ➢  Olefin Metathesis  
      C-H Activation Reactions  
      ➢  Cₛᵖ₂-H Activation  
      ➢  Cₛᵖ₃-H Activation  
  c)  Organic Catalysis  
      Reactions Catalyzed by Nucleophilic Bases  
      ➢  Nucleophilic Amine (Enamine, Iminium, etc)  
      ➢  Phosphine and Carbene Catalysis  
      Reactions Catalyzed by Acids  
      ➢  Brønsted acids
Lewis acids
Phase Transfer Catalysis (PTC)
  - Cationic PTC
  - Anionic PTC

D Enzymatic Catalysis
  a) Protein Structure and Function
  b) Enzyme kinetics
  c) Example of Amide Hydrolysis
     - Serine Protease: Catalytic triad
  d) Oxidation and Reduction Reactions

CM4238: Selected Topics in Physical Chemistry (Elective Module)
Workload: 4-1-0-2-3

Aims & Objectives
Several topics highlighting physical chemistry principles such as thermodynamics, spectroscopy, kinetics and quantum chemistry will be covered. In photochemistry, kinetics and quantum chemistry are used to illustrate how quantization and energy level interactions lead to different radiative processes and rates of excited and ground state reactions. The use of spectroscopy yields the precise determination of reaction rates. In the chemistry of liquids, thermodynamics will be heavily featured in describing intermolecular potentials in liquids and colloids. In biophysical chemistry, the thermodynamics and kinetics of biomolecules together with spectroscopic techniques used to determine their interactions will also be included. Students should be able to appreciate the extent of physical chemistry in various topics in chemistry. Students will understand (i) how light interacts with matter through quantum mechanics, (ii) how photochemical rates are determined via spectroscopy and kinetic laws, (iii) how to describe the liquid phase using thermodynamic models and (iv) how to apply physical chemistry principles to molecules in a biological environment.

Syllabus
Photochemistry :
Quantum nature of matter and light; quantum yield; ground and excited states; fluorescence, phosphorescence and radiationless transfer; photochemistry of alkenes, carbonyls and inorganic compounds; photochemical rates and mechanisms.

Liquids :

Biophysical Spectroscopy :
Light spectroscopy techniques such as spectrometers, lifetime measurements, quenching, anisotropy, correlation methods, single molecule methods, surface sensitive fluorescence and absorption methods and energy transfer methods. They will be applied to Biophysical Chemistry in order to obtain kinetic information and equilibrium measurements for small biomolecules, proteins and DNA.

CM4241: Trace Analysis (Elective Module)
Workload: 4-1-0-2-3
**Aims & Objectives**

How old is the Earth? Was Napoleon poisoned? Do I get enough iron from food to stay healthy? Is the water that I drink safe or not? Questions that can be answered by quantifying traces of inorganic and organic compounds in a sample are countless in virtually any area of science and daily life. However, reliable quantification of analytes at the trace (parts per million range and less) or ultra-trace level (parts per trillion concentration range or less) comes with its own challenges and limitations. High measurement sensitivity increases risks for measurement artefacts. Analyte concentrations may be altered artificially during sampling, storage or sample preparation either by loss of analyte or sample contamination. Uncertainty contributions from sampling might be higher than that of the actual laboratory analysis.

This objective of this module is to familiarize students with current possibilities for quantification of organic and inorganic analytes at the trace and ultra-trace level in different matrices for different applications. Students will be introduced to state-of-the-art instrumental methods for organic and inorganic trace analysis not covered in previous modules. Possible sources of analytical bias throughout the entire analytical chain including sampling, sample storage, sample preparation, analyte separation and pre-concentration, instrumental analysis and data evaluation will be identified and discussed.

**Syllabus**

This module is meant as a comprehensive introduction to the art of trace analysis in theory and laboratory practice. Students will be introduced to state-of-the-art methods for organic and inorganic trace analysis. Building on earlier modules, knowledge of students in instrumental analysis will be deepened and further expanded to immunochemical methods, stable isotope techniques and nuclear analytical techniques for trace analysis as well as methods for studying element speciation. Possible sources of analytical bias throughout the entire analytical chain including sampling, sample storage, sample preparation, analyte separation and pre-concentration, instrumental analysis and data evaluation will be identified and discussed.

Students will be introduced not only to technical and practical aspects of trace analysis but will also learn how trace analysis can be used in a wider context to answer actual questions in biomedical research, environmental sciences, geochemistry and cosmochemistry, hydrology, material science, archaeology etc. In particular in clinical medicine or in forensic applications, analytical errors can have major consequences as they may lead to wrong decisions. As such, students will learn how to make use of current concepts of Chemical Metrology to ensure data traceability, to assess measurement uncertainty and how to monitor and ensure data quality in an analytical laboratory. Detailed syllabus of the module:

1. Challenges in Trace Analysis
2. Sources of Bias in Trace Analysis
   1. Sampling
   2. Sample Storage
   3. Sample Digestion
   4. Analyte Separation/Preconcentration
   5. Instrumental Analysis
   6. Data Evaluation and Analysis
   7. Data Communication
3. Design and Evaluation of an Analytical Strategy
   1. Differences in Scientific Language and Thinking between Disciplines
   2. Definition of the Scientific and Analytical Question
   3. The “Fit for Purpose” Concept
   4. Fishbone Diagram
   5. Strategies for Method Validation
   1. National and International Organization and Bodies
   2. Introduction to Vim and GUM
(iii) Traceability and Uncertainty
(iv) Certification, Accreditation and Quality Control

(5) Inorganic Trace Analysis
(i) Sample Digestion
(ii) Sample Preconcentration and Analyte Separation
(iii) Spectroscopic Techniques
(iv) Mass Spectrometric Techniques
(v) Ultra-Trace Analysis
(vi) Surface Analysis
(vii) Speciation Analysis

(6) Isotopic Techniques
(i) Stable versus Radioactive Isotopes
(ii) Radiation based Techniques
(iii) Isotope Dilution Mass Spectrometry
(iv) Isotope Ratio Mass Spectrometry
(v) Radiogenic Isotope Abundance Variations
(vi) Natural Isotope Effects
(viii) Tracing of Element Transport Processes

(7) Organic Trace Analysis
(i) Enrichment and Preconcentration Techniques
(ii) Chromatographic Techniques
(iii) Mass Spectrometric Techniques
(iv) Hyphenated Techniques
(v) Immunochemical Techniques
(vi) Nanomaterial based Techniques

(8) Set-up of a Trace Analysis Laboratory

(9) Management of a Trace Analysis Laboratory

Sections 1-4 are content based and are designed to familiarize students with basic concepts of trace analysis. Sections 5-7 are problem based, i.e. the different analytical techniques will be introduced and discussed within the context of an applied scientific question that requires trace analytical techniques. Examples will be taken from Biomedical Research, Clinical Medicine, Forensic Sciences, Environmental Sciences, Geochemistry, Cosmochemistry, Hydrology, Material Sciences and Archaeology. Knowledge in Instrumental Analysis will be deepened or expanded to techniques that have not been discussed. Sections 8-9 are more practical orientated and will be used to illustrate working practices in a Trace Analysis Laboratory.

CM4242: Advanced Analytical Techniques (Elective Module)
Workload: 4-1-0-2-3

Aims & Objectives
This module is aimed at the principles and particularly applications of advanced analytical techniques. The student will gain familiarity with the fundamental principles, instrumentation aspects as well as analytical applications of modern separation techniques as well as advances in microscopy and mass spectrometry. Topics discussed are selected from capillary electrophoresis and related techniques, hyphenated techniques involving gas chromatography and liquid chromatography, etc., with a focus on qualitative analysis; multidimensional chromatography; current advances in microscopy, mass spectrometry, etc., including applications.
After having read this module, students should have gained expertise in advanced analytical techniques to play leadership roles in industrial and academic research laboratories in different fields, including biomedical, environmental, food, forensic, materials, and pharmaceutical analysis.

**Syllabus**

1. **Advanced capillary electrophoresis and lab-on-chips**

   Introduction and Basic Concepts: Historical development of capillary electrophoresis; Electrically driven flow; Electroosmotic flow (EOF); Factors affecting electroosmotic flow: Modifying and reversing EOF; Measuring electrophoretic velocities and mobilities; Peak variance; Selectivity; Resolution.

   Principles of Separation: Different modes of capillary electrophoresis; CZE – capillary zone electrophoresis' CGE – capillary gel electrophoresis; MEKC – micellar electrokinetic chromatography; CEC – capillary electrokinetic chromatography.

   CIEF – capillary isoelectric focusing; CITP – capillary isotachophoresis; Additional separation mechanisms: e.g. inclusion complexation, chiral CE, CD-MEKC; Factors affecting peak shape.

   Instrumentation: Sample introduction; Electromigration injection; Hydrostatic injection; Pneumatic injection; Detection techniques; UV/Vis detector; Fluorescence detector; Conductivity detector; Electrochemical detector; Mass spectrometry.

   Column Technology and Electrolyte Systems: Column technology; Coated columns; Packed columns; Gel filled columns/dynamic sieving; CE on chip; Buffers and additives; Buffers; Micelles; Ion pairing/ ion exchange; Inclusion complexes: Cyclodextrins, Crown ethers.

   Miniaturized Analytical Systems (e.g. lab-on-chip, capillary electrophoresis-on-chip): Soft lithography; Advantages of soft lithography; Soft lithography processes; Microcontact printing; Micro molding in capillaries; Micro transfer molding; Replica molding; Bonding; Microchip CE; Controlled dilution; Electrokinetic injection; Applications: Amino acids; Oligonucleotides; Voltage switching – sample withdrawal.

   DNA sequencing; Enzymatic digestion; Synchronized cyclic CE; Field flow electrophoresis; HPLC chip; Micropump; Micro heat exchanger; Micromixer.

2. **Membrane module; Microreaction system; Example: hydrogenation with immobilized Pd Catalyst.**

   Advanced scanning probe techniques.

   Scanning Probe Microscopy (SPM): Nanoscale imaging; Scanning tunneling microscopy; Tunneling current; Constant current and constant height modes; Scanners; Tripod and tube scanners; Tip approach mechanism; Atomic force microscopy (AFM); Contact mode; Non-contact mode; Tapping mode.

   Other scanning probe techniques: Lateral force microscopy (LFM); Force modulation microscopy (FMM); Phase detection microscopy (PDM); Magnetic force microscopy; Electrostatic force microscopy; Scanning capacitance microscopy; Near-field scanning optical microscopy; Nanolithography; Forces and their relevance to microscopy; AFM cantilevers – spring constant and frequency; Applications of SPM technology; SPM techniques for nanoscale analysis and characterization; SPM for elucidation of structure/properties relationships of nanomaterials; Morphological/structure information by scanning probe microscopy and other analytical techniques; Use of SPM methods to improve/modify nanomaterials and nanostructures to meet application requirements.

3. **Advanced mass spectrometry**

   Mass spectrometry (MS): Ion separation in MS; Resolution; Ionization methods; Chemical ionization; Electron impact; Electrospray; Fast atom bombardment; Field ionization; Laser ionization; Matrix assisted laser desorption ionization (MALDI); Plasma desorption; Resonance; ICP-MS

   Ion detection systems and mass analyzers; Ion detectors; Channeltron; Daly; Electron multiplier tube; Faraday cup; Microchannel plate; Mass analyzers: Magnetic sector; Quadruple; Fourier-transform; Time-of-flight; Ion-trap; Orbitrap.
Sample introduction: Gas-chromatography-mass spectrometry (GC-MS); Direct coupling; Open-split coupling; Probe inlets; Liquid chromatography-mass spectrometry (LC-MS).
Tandem mass spectrometry: Unimolecular ion dissociation; Collision-induced dissociation (CID); Triple quadrupole instruments; Hybrid instruments.
Quantitative analysis: Specificity; Sensitivity and limits of detection; Sources of error; Selected ion monitoring; Multiple reaction monitoring; Derivatization.

CM4251: Characterization Techniques in Materials Chemistry (Elective Module)
Workload: 4-1-0-2-3

Aims & Objectives
Preparation and characterization of materials form crucial and vital aspects of materials research. Highly developed instruments are now available to apply an interdisciplinary study to understand the structure-property relationship. This module provides undergraduates an introduction to modern materials characterization techniques which comprise surface analysis techniques, X-ray diffraction, microscopy, thermal analyses, mechanical tastings and spectroscopies. Students will be better equipped to use a combination of different techniques to solve complex problems and to correlate between structure of materials and their technological properties.

Syllabus
1. Surface Analysis Techniques
   - Contact Angle Measurement
   - X-ray photoelectron spectroscopy
   - Auger electron spectroscopy
2. X-ray diffraction
   - Thin film diffraction
   - Grazing angle diffraction
3. Microscopy
   - Scanning electron microscopy
   - Transmission electron microscopy
   - Scanning tunneling microscopy
   - Atomic force microscopy
   - Fluorescence microscopy
4. Thermal analyses
   - Differential scanning calorimetry
   - Thermogravimetry
5. Mechanical Testing
   - Tensile strain-stress properties
   - Compressive strength
   - Impact strength
   - Hardness
6. Infrared Spectroscopy and UV/Vis Spectroscopy
   - Emphasis on applications

CM4252: Polymer Chemistry 2 (Elective Module)
Workload: 4-1-0-2-3

Aims & Objectives
This module prepares the students for the polymer related industry. It covers the chemistry of polymer degradation under the influence of heat, oxygen and UV light and ways of retardation. The science and technology of elastomers or rubber like polymeric materials will be discussed and compared to solid plastics. The synthesis, properties and applications of contemporary engineering and specialty polymers and the role of additives in plastics will also be discussed.

Syllabus
Polymer degradation and stabilization
- Thermal degradation
- Oxidative and UV degradation
- Chemical and hydrolytic degradation
- Stabilizers – antioxidants, UV absorbers, PVC heat stabilizers
- Biodegradable polymers
- Elastomers – synthesis, properties and applications
- Differences and similarities between elastomers and plastics
- Diene elastomers
- Nondiene elastomers
- Thermoplastic elastomers
- Engineering and specialty polymers - synthesis, properties and applications
  • Engineering polymers - polyamide, ABS, polycarbonates, poly(phenylene oxide), polyacetal, polysulfones, polyimides, poly(phenylene) sulfide, fluoro-polymers, epoxy resins.
  • Specialty polymers – conducting polymers, liquid crystalline polymers, polymer resists, and biopolymers.
- Additives, blends and composites
  • Plasticizers
  • Fillers and reinforcements
  • Other important additives
  • Polymer blends
  • Toughened plastics
  • Interpenetrating network
  • Mechanical properties of polymer composites
  • Composite fabrication

**CM4253: Materials Chemistry 2 (Elective Module)**

**Workload:** 4-1-0-2-3

**Aims & Objectives**
This module aims to discuss important contemporary topics in the field of materials chemistry, e.g. nanostructured materials, hybrid composites, and polymeric materials as active components in electronic applications. Self-assembly of monolayers on metal surfaces and semiconductors, and other nanostructures (carbon nanotubes, nanoparticles, graphene) will be covered. Material synthesis, processability in device matrix and stability will be emphasized, together with structure-performance relationship. Formal teaching may be accompanied by presentations and case studies delivered by selected Industry researchers.

**Syllabus**
1. Introduction to Materials Chemistry
   • self-assembled monolayers
   • nanoparticles
   • thin films of polymers
   • carbon based nanomaterials
   • metal-molecule interfaces
   • semiconductor-molecule interfaces
   • junctions
2. Fabrication techniques: top-down
   • lithography
   • printing/imprinting
   • e-beam/ion-beam
   • Scanning probe techniques
3. Fabrication techniques: bottom-up
   • Layer-by-layer self-assembly
   • Molecular self-assembly
   • Coating/growth
   • Printing/SPM
   • Direct assembly
   • CVD/ALD
4. Fabrication of devices
- Molecular electronics
- Organic electronics
- Nanoelectronics

5. Applications
- OFET
- OLED
- Photovoltaics
- Battery
- Sensors
- Molecular electronics

CM4254: Chemistry of Semiconductors (Elective Module)
Workload: 4-1-0-2-3

Aims & Objectives
An understanding of dimensional dependence of energy levels, Fermi energy, and band gap in crystals form the basis for learning newly developed devices and applications in transistors, solar cells, etc. The principles of device operation and fabrication will be introduced in relation to electrical and structural properties of Silicon, GaAs and the operation of p-n junctions and transistors. Chemistry in the fabrication of integrated circuits from growth of single crystals, photolithography, etching, dielectric deposition to packaging of circuit, and electrochemistry of semiconductors, charge transfer across electrolyte-semiconductor interface, band bending and Mott Schottky analysis will be covered.

Syllabus
1. Solid state chemistry
   - Linear combination of atomic orbitals to nearly free electron model
   - Fermi energy
   - Correlation between free electron concentration and Fermi energy
   - Density of states function for 1-D, 2-D, 3-D
   - Fermi Dirac and Boltzmann statistics
   - Equilibrium concentration of electrons and holes
   - Intrinsic and extrinsic semiconductors
2. Basic operation of p-n junction
   - MOSFET
   - MESFET
   - Metal-semiconductor junction
   - Capacitor
   - Photoconductor
   - Solar cell
3. Surface chemistry of semiconductors
   - Microelectronic processing
   - Dielectric materials
   - Metallization process
   - Photoresist materials
   - Chemistry in molecular beam epitaxy
   - Metal organic chemical vapour epitaxy
   - Atomic layer Deposition.
4. Chemical synthesis of semiconductor
   - Nanocrystals
   - Organic semiconductors
   - Solar cells
   - Semiconductor electrochemistry
Mott Schottky analysis

CM4268: Advanced Polymer Science (Elective Module)
Workload: 4-1-0-2-3

Aims & Objectives
The students who choose this module are expected to have taken classes in basic polymer chemistry. This module will introduce advanced topics in polymer science. After finishing this module, the student will have a comprehensive knowledge in polymer science. This knowledge will be helpful for their future career either in industry or in the academia.

Syllabus
This module will be focused on some advanced topics which are not covered in basic polymer science. The topics include:
(1) new polymerization methods (e.g. controlled radical polymerization, metallocene polymerization and olefin metathesis polymerization);
(2) block copolymers and their applications;
(3) dendritic macromolecules;
(4) naturally occurring polymers and biopolymers;
(5) inorganic and organometallic polymers;
(6) supramolecular polymers and smart polymers;
(7) conducting polymers and their applications

CM4269: Sustainable and Green Chemistry (Elective Module)
Workload: 4-1-0-2-3

Aims & Objectives
In successfully completing this module, students will be able to:
(i) Knowledge and Understanding
   a. understand the fundamentals of green and sustainable chemistry;
   b. understand the principles and practical tools for the reduction of the environmental impact in the production of chemical products (CleanTech)
   c. describe the economic paradigm in which the chemical industry sits
   d. understand how and why released substances move through the environment.
   e. understand the effect of changing the main parameters that affect yield from an industrial process
(ii) Disciplinal/Professional Skills:
   f. apply mathematical and chemical tools to the environment and use simple modelling approaches to estimate fluxes, residence times, and amount
   g. use mathematical techniques to design a chemical process
   h. optimise/evolve a laboratory process along Green Chemistry lines
(iii) Transferable Skills
   i. manage their own learning progress
   j. work productively as members of a small group

Syllabus
The module covers:
[1] Context - good business is green business
   the traditional model - externalities and pollution; the tragedy of the Commons; economics drives environment; national and global competitiveness; value add
[2] Sustainability
society and sustainability; sustainable use of matter and energy; "renewable" sources of raw materials and energy; Life cycle Analysis and Cradle to Grave Assessment; chemistry of biodegradability and recycling; Is anything truly "sustainable"?; metrics of environmental risk


- Green chemistry as a reduction process: pollution prevention and waste minimization, reduction of: energy consumption, risk and hazard.
- Techniques and process intensification: Microwave chemistry, supercritical solvents, sonochemistry, ionic liquids, domino reactions, membrane reactors, reactive distillation, microreactors


[6] Selectivity and yield improvements in chemical processes via statistical methods: design of experiments and factorial design as an optimization tools.


CM4271: Medicinal Chemistry (Elective Module)
Workload: 4-1-0-2-3

Aims & Objectives
This module builds on Biomolecules (CM3225) as well as Organic Chemistry (CM 2121). A major focus will be understanding how drugs work, and why these molecules succeed when so many others fail. To achieve this, the course will introduce interdisciplinary concepts, and thereby bridge, chemistry, biology and medicine. Classes will be accompanied by presentations and case studies, occasionally delivered by guest lecturer(s) from the pharmaceutical industry (with a visit, if possible, to a local pharmaceutical R&D firm). The following aspects will be covered: 1) The role of the chemist in the drug discovery process, 2) Target selection and considerations, 3) Library design 4) Combinatorial chemistry and high-throughput screening 5) Pre-clinical development, ADME-Tox 6) Clinical drug development, 7) Intellectual property for medicinal chemists. The
module is suited for advanced students majoring in chemistry or applied chemistry, to provide a broad and balanced perspective of medicinal chemistry and the global pharmaceutical industry.

**Syllabus**
The module is designed to take the students through the journey of drug discovery, introducing concepts at key stages across the 15 year drug discovery cycle. Questions to think about along the way, are why are these steps necessary? Can the drug discovery process be even further streamlined, made faster and less costly? The syllabus for this module would include:
- the general properties and functions of drugs, with noted case studies;
- an in depth idea of how drugs are designed, developed and tested;
- the use of structural modifications, asymmetric synthesis to get the desired optical isomer;
- the requirements of pre-clinical and clinical trials, before drugs are introduced to the public;
- an awareness of the contribution that medicinal chemistry makes towards maintaining the health and well-being of the world’s population.

**CM4273: Computational Drug Design (Elective Module)**
**Workload: 4-1-0-2-3**

**Aims & Objectives**
This module introduces modern computational methods used in drug discovery and drug development. It covers topics such as drug design process, structure and ligand based drug design, molecular mechanics methods, homology model, molecular docking, pharmacophore models, quantitative structure-reactivity relationship (QSAR), de novo ligand design, quantum mechanics techniques, cheminformatics, database search tools, and virtual screening. Hands-on experience in using computational software and visualization tools will be provided.

**Syllabus**
This course introduces the computational methods and molecular modelling tools that are relevant to drug design. The syllabus for this module is:

**Part I: Drug Design Process**
- a) Introduction to drug design process
- b) Properties that make a molecule a good drug
- c) Target identification and target characterization
- d) Drug design process for a known protein target - structure based ligand design
- e) Drug design process for an unknown target
- f) Drug design for other targets
- g) Compound library design

**Part II: Computational Tools and Techniques**
- a) Molecular mechanics
  - i) Introduction to molecular mechanics
  - ii) Energy terms
  - iii) Parametrization and force fields
  - iv) Potential energy surface and energy minimization
  - v) Force field for drug design
- b) Protein structure modelling
  - i) Folding algorithms
  - ii) Conformational analysis
- c) Homology model building
  - i) Homology modelling
  - ii) Process of building a homology model
  - iii) Template identification, alignment and model validation
d) Molecular docking
   i) Principle of docking
   ii) Protein-ligand structures and molecular interactions
   iii) Searching algorithms (e.g. genetic algorithm)
   iv) Active site and ligand representations
   v) Scoring functions and binding free energies
   vi) Comparison of search and scoring methods
   vii) Virtual screening

e) Pharmacophore Models
   i) Components of a pharmacophore model
   ii) Models from active compounds and active sites
   iii) Searching compound databases

f) Quantitative structure-reactivity relationship (QSAR)
   i) Linear free energy relationship
   ii) QSAR and 3D-QSAR
   iii) Pharmacophore mapping

g) De novo ligand design and other AI techniques

h) Quantum Mechanics in Drug Design
   i) Quantum mechanics algorithms and software
   ii) Modeling systems with metal
   iii) Computing reaction paths
   iv) Computing spectra

i) Cheminformatics
   i) Similarity and substructure searching
   ii) 2D-to-3D structure generation
   iii) Clustering algorithms
   iv) Database systems and search tools
   v) Virtual libraries
   vi) Virtual screening
   vii) Screening result analysis

Part III: Hands-on learning of modeling software and visualization tools

a) Search of protein structure database (Protein Data bank)
b) Force field minimization and conformational analysis of drug molecules (Spartan)
c) Properties, spectra and reaction pathway of small molecules (Spartan)
d) Protein visualization (Ramsol, Swiss-PDB viewer and Chimera)
e) Docking process – protein preparation, ligand building, setting up of boundary, docking options, docking calculation, analysis of result (Autodock Vina)

Part IV: Case studies of successful applications of computer aided drug design

CM4274: The Art and Methodology in Total Synthesis (Elective Module)
Workload: 4-1-0-2-3

Aims & Objectives
This module comprises of a study of the total synthesis of useful functional molecules. Both general and advanced strategies are covered. Concepts of the classical multistep and the greener cascade sequences are explored. The concepts and strategies are illustrated with classical and modern examples.
Syllabus

(i) Introduction
- What is total synthesis?
- Formal synthesis
- Enantioselective synthesis
- The importance of total synthesis
  - Natural products
  - Bioactive molecules
  - Materials

(ii) General approaches
- Convergent synthesis
- Stepwise synthesis
- Assembly of multiple fragments
- Comparison of the approaches

(iii) Retrosynthetic analysis
- Analysis of molecular complexity
- Transforms and retrons
- Transform-based strategies
- Structure-based strategies
- Stereochemical strategies
- Functional group strategies

(iv) Synthetic approaches
- Target oriented synthesis
- Diversity oriented synthesis
- Protecting group-free synthesis

(v) Cascade sequences
- Nucleophilic cascades
- Electrophilic cascades
- Radical cascades
- Pericyclic cascades
- Transition-metal-catalyzed cascades

(vi) Advanced topic
- Biomimetic strategies
- Classic and contemporary strategies for the control of relative and absolute stereochemistry

(vii) Case studies
- Classical examples: e.g. estrone
- Recent examples: e.g. platensimycin

CM4282: Energy Resources (Elective Module)
Workload: 4-1-0-2-3

Aims & Objectives
This module comprises of a physico-chemical study of the energy resources and the environmental, chemical and economic implications of their exploitation. Following the history of energy consumption, the current situation is summarized, and the implications of the continuation of the status quo identified. Concepts of fitness for purpose, and environmental and economic sustainability are explored. Key technologies areas cover generation, use efficiency, and storage and transmission. These are illustrated with quantitative case studies.
Syllabus

(1) Context
a. energy and entropy
b. current and projected human energy demand
c. morphology and geography of energy consumption
d. finite nature of planetary reserves – renewable-non renewable
e. issues with the status quo (fitness for purpose)
f. general approaches – energy policies
g. the energy landscape (generation, transport, industry, lifestyle)
h. impacts of the status quo

(2) Generation Technologies
a. thermal
b. kinetic
c. solar

(3) Efficiency-Use Technologies
a. hydrogen economy
b. ‘green’ buildings
c. reuse
d. transport – internal combustion petroleum

(4) Storage and Distribution Technologies
a. batteries
b. fuel cells
c. pumped hydro storage
d. grid distribution design

(5) Case Studies

(6) Outlook
a. free market economics
b. how do we measure?
c. the role of scientists
LEVEL 5 MODULES

CM5161 Advanced Chemical Laboratory Safety
Workload: 4-0-0-2-4
Prerequisite : Nil

This module is an essential module and is designed primarily to raise the safety awareness among our graduate students, particularly those carrying out chemistry research in laboratories. After completing this module, the students will be able to
• understand and apply Singapore laws and legislation pertaining to workplace safety;
  rationalise and apply NUS safety policies to laboratories
• understand the fundamentals of chemical safety and therefore appreciate the basis for safety regulations
• identify, analyse and understand potential risk involved in laboratories and be able to perform labs in a safe manner.
• perform risk assessments and plan for an experiment safety; interpret safety notes/symbols eg. MSDS and search for safety resources

CM5198 – Graduate Seminar Module in Chemistry

• Module coordinator: A/P Ang Wee Han
• Instructors: Prof Loh Kian Ping, A/P Ang Wee Han, A/P Simon Watts, Dr Foo Maw Lin, Dr Liu Mei Hui

Description

• This is a compulsory 4 MC module for all research Masters and PhD students admitted from AY2016/2017. The main purpose of this module is to help graduate students to improve their scientific communication skills, in the form of writing and presentation, and to participate in scientific seminars/exchanges in a professional manner. Students would be introduced to the different types of scientific communication modalities that chemistry researchers used to communicate scientific ideas. This includes seminar-style presentation, manuscript writing as well as posters.
• The module will be conducted over 1 semester and be graded on the basis of student presentation, marked assignments and participation.

Structure

1) Structured Learning: There will be a total of 12x 90 min lectures covering aspects of scientific writing, presentation and literature survey in the context of chemistry research. Students will be given 3x graded assignments for this part of the module.

2) Discipline-Specific Discussion Groups: The discussion group will be conducted after the lectures. The discussion group will be a platform for the students to practice their scientific delivery in the seminar format. The students will be given an opportunity to choose 1 of 4 discussion groups which is discipline specific. The discussion group would take place over 6 weeks (2-3 student presentation per group). Students will also be given the opportunity to moderate and host a discussion group.

The discussion groups are divided along 4 broad categories to cover the core disciplines and specialization areas namely (1) Organic/Inorganic/Medicinal chemistry; (2) Physical/Materials Chemistry; (3) Analytical/Energy and Environment Chemistry; and (4) Food Science Technology. Each discussion group will be led by 1 faculty members with domain expertise in that area.
Syllabus

1) **Scientific Writing**
   a) Understanding the purpose of scientific communications and knowing the targeted audience
   b) How to select and organize content so that the paper can target a broad audience, or a specialized audience
   c) How to explain motivation and hypothesis
   d) How to communicate outcome
   e) Explaining conventional way of structuring chronologically: first, *Introduction*; then *Materials and Methods*, *Results*, and *Discussion* and finally, *Conclusion*.
   f) How to write an abstract of the work

2) **Scientific Presentation**
   a) Master basic mechanics (making slides, organizing information) of giving a scientific talk
   b) Learn about strategies of presenting scientific information in a poster format
   c) Learn to explain scientific ideas clearly and succinctly
   d) Learn to critique other presentations in a helpful manner
   e) Personal feedback on the individual presentation style

3) **Gathering Scientific Information and Literature Review**
   a) Learn about types of scientific writing in chemistry journals and the peer-review process
   b) Familiarize with information sources on chemistry topics and electronic tools to gather these information
   c) Learn about bibliography and tools to manage references and citations
   d) Learn about conducting literature survey in chemistry

**Assignment/Assessment**

1) 3 graded assignments including a literature survey, a poster and abstract (60%)
2) 1 seminar presentation and participation (40%)
CM5211 Contemporary Organometallic Chemistry
Workload: 3-1-0-3-3
Prerequisite: CM4212 or by permission

The module aims to cover current aspects of research in the field of organometallic chemistry. It is assumed that students taking this module are already familiar with general organometallic chemistry at roughly the level covered in CM4212. The course materials can be divided into two parts. The first part of the module will cover topics relating to general organometallic chemistry to function as a refresher but with a practicing researcher’s bent. The second part of the module will cover some special topics. Introductory Concepts in Organometallic Chemistry - concepts such as EAN rule, oxidation states and inert-atmosphere manipulations. Characterization of Organometallic Compounds - major methods of characterizing organometallic compounds, incl. IR, NMR, MS, and X-ray crystallography. Important Inorganic Ligands - ligands such as CO, hydride and dihydrogen, halides, phosphines, and related ligands such as Tp, nitriles, isonitriles, arsines, stibines, dinitrogen, etc. Important Organic Ligands - (i) \( \pi \)-donor ligands such as alkyls and aryls, carbenes and carbynes, and (ii) \( \pi \)-bound ligands such as alkenes, allyl, dienes, Cp, etc. Mechanistic Concepts - reaction types such as reductive elimination, oxidative addition, \( \pi \)-bond metathesis, migratory insertion/insertion, nucleophilic/electrophilic addition/substitution, kinetics, etc. Special Topics - Homogeneous Catalysis - general principles of homogeneous catalysis, with reference to selected catalytic reactions, namely, alkene hydrogenation and isomerization, CO insertion, and olefin polymerization. Organometallic Compounds in Organic Synthesis - the employment of organometallic compounds in enantioselective FGIs, hydrocarbon functionality protection, stereochemical control, and C-C bond formation via insertion and cyclization reactions. Computational Organometallic Chemistry – introductory concepts in computational chemistry and use of Gaussian program.

CM5212: Crystal Engineering
Workload: 3-1-0-3-3

Aim
This module aims to provide the basic understanding of intermolecular interactions in the context of crystal packing and how to utilize these weak supramolecular interactions in the design of new solids with desired physical and chemical properties. This interdisciplinary subject highlights the link among physics, chemistry, materials and pharmaceuticals.

OBJECTIVE
Upon completion of the module, the students are expected to be able to:
1. Critically evaluate the factors that influence the crystal packing and their properties.
2. Familiarize with the data mining and retrieval methods from the databases, visualizing tools, journals related to this area.
3. Simplify the description of complicated structures in terms of well-known inorganic structures.
4. Realize the role of thermodynamics and kinetics in the self-assembly of molecules to form solids.
5. Utilize the tool-box in crystal engineering to design crystalline solids to have desired properties that will find applications in catalysis, gas sorption, ion exchange, separation, magnetism, conductivity, optics, etc.
Prerequisites: CM4214 or by permission

Syllabus
Intermolecular interactions – All types of supramolecular weak interactions and crystal packing
Crystal Design Strategies – Evaluate the strategies to construct or synthesize crystals; different types of synthons used.
Crystallization and Crystal Growth – different types of crystallizations, nucleation and crystal growth; thermodynamics and kinetics.
Polymorphism – Definition; importance, occurrence and understanding; case studies from the pharmaceutical industry
Multi-component Molecular Crystals – solid solutions; host-guest & donor-acceptors complexes, solvates, co-crystals & salts
Coordination Polymers – classification, strategies, network topologies, supramolecular isomerism, interpenetration, porous & metal-organic frameworks (MOFs), properties & applications.

CM5224 Emerging Concepts in Drug Discovery
Workload: 2-1-0-1-6
Prerequisite: By permission
This module introduces selected contemporary topics and emerging concepts in medicinal chemistry and the drug discovery process. The latest ideas in lead discovery, lead optimization, and assay development, will be discussed. Industrial case studies will be presented by guest lecturers from the pharmaceutical industry.

CM5225 Asymmetric Catalysis
Workload:
Prerequisite: By permission
This module builds on the principles and concepts introduced in CM4222. It addresses the major concepts in asymmetric catalysis. To module will introduce students to enantiomeric purity, absolute stereochemistry and resolution. In addition, it will concentrate on chiral pool and chiral auxiliaries, chiral reagents and chiral catalysis, substrate control and asymmetric synthesis.

CM5232 Topics in Chemical Kinetics
Workload:
Prerequisite: By permission
Elementary reactions in the gas phase: rate of a bimolecular reaction, reaction cross section, unimolecular reactions, potential energy surface, transition state theory; reactions in solution: theoretical considerations, reactions between ions, reactions between ions and molecules, linear free energy relationship, fast reactions; catalysis: homogeneous catalysis in the gas phase and in solution, acid-base catalysis, autocatalysis and oscillating reactions, heterogeneous catalysis.

CM5237 Advanced Optical Spectroscopy and Imaging
Workload: 2-1-0-4-3
Prerequisite: By permission
This module will provide essential knowledge of fundamental photon-molecule interactions and novel laser based techniques that are important for frontier research. Topics include: organic photophysics and photochemistry, laser fundamentals, linear and nonlinear optical spectroscopy, time-resolved spectroscopy, single molecule spectroscopy, fluorescence and Raman microscopy, femtochemistry, laser reaction control and optical manipulation, laser applications in biochemistry and medicine, optical properties of novel materials and some optoeletronic applications.
Fundamental Electronic States and Transitions - Fluorescence quantum yield and quenching; Energy Transfer; Electron Transfer; Spectra Line broadening, Laser Fundamentals - CW laser; Laser pulse generation; Pulse broadening and compensation, Linear optical spectroscopy - Raman, SRS, CARS, SERS; Phase matching; Nonlinear optics; 2nd order and 3rd order
nonlinear phenomenon; time-resolved spectroscopy (fluorescence lifetime, pump probe, four-wave-mixing), Fluorescence and Raman Microscopy; Single Molecule Spectroscopy.

Femtochemistry
- Laser Reaction Control; Optical tweezers; Laser cooling. Lasers applications - Biochemistry, Medicine and optoelectronics: photosynthesis; vision process; DNA damage and repair; photodynamic therapy; solar cell, solar hydrogen generation by water splitting.

CM5241 Modern Analytical Techniques
Workload : 3-1-0-3-3
Prerequisite : CM4242 or by permission

Sample preparation, including miniaturised procedures of extraction; advanced coupled chromatography/mass spectrometry; advanced mass spectrometric techniques. Capillary electrophoresis: different modes of capillary electrophoresis, injection techniques, detection techniques and column technology. Scanning probe microscopy: scanning tunneling microscopy, atomic force microscopy, scanning electrochemical microscopy and scanning near-field optical microscopy. Determination of crystal and molecular structures by single crystal x-ray diffraction techniques.

CM5244 Topics in Environmental Chemistry
Workload : 2-1-0-4-3
Prerequisite: By permission

The module involves sampling strategies for volatile, semi-volatile and non-volatile compounds in ambient air and stack gas analysis. These include preparation of gas standards, sampling on sorbents, canisters, passive samplers, high volume solid samplers, isokinetic sampling and others. Topics include Bioaccumulation factors, biomarkers in the environmental risk assessment and the role of bio-indicators in environmental monitoring, environmental concerns over microorganisms, food toxins and their current detection methods, bioaccumulative indoor air pollutants and remediation approaches. Trace level metal and organometallic pollutants in the environment and methods for their detection, organotins and its environmental impact. Potential health risks and toxicity of nanomaterials in the environment, endocrine-disrupting compounds in the environment and their analytical challenges. Various quantitative methods for the determination of organic pollutants in environmental samples, on-site environmental techniques and their perspective. Applications of porous membranes in water treatment technology, remediation of metals from waste water using algal/microbial biomass. Recent trends in soil and sediment remediation. After reading this module, students will have an understanding of analytical methods employed for analyses of different types of environmental samples, and knowledge on proper environmental sampling methodologies, adaptation of existing procedures, and regulations in environmental problem-solving.

CM5245 Bioanalytical Chemistry
Workload : 2-1-0-4-3
Prerequisite : By permission

This is an elective analytical chemistry module which addresses the basics in the latest bioanalytical techniques and those which are just emerging. It is aimed at students who are interested in the applications of modern analytical techniques for bioanalytical research and development. The module will acquaint students with background knowledge of advanced and specialised bioanalytical techniques, with elaboration on the materials aspects employed in these techniques. Coverage is aimed more at breadth rather than depth but without sacrificing the fundamental rigors.
CM5262 Contemporary Materials Chemistry
Workload : 3-1-0-2-4
Prerequisite: By permission

This module aims to discuss important contemporary topics in the field of Materials Chemistry, e.g. nanostructured materials, hybrid composites, macromolecular materials, biocomposites, biocompatible materials, fibrous materials, etc. These are materials that we encounter in day-to-day life. The chemistry of their formation, stability as well as the relationship between their structures and properties will be emphasized. After taking this module, students should have a good fundamental knowledge and understanding of how to design and to fabricate useful devices such as LEDs, optical switches, modulators, and dispersion compensators.

CM5268 Advanced Organic Materials
Workload: 2-1-0-0-7
Prerequisite By permission

Polymer Chemistry II (CM3221), Advanced Polymer Science (CM4268). For Chemistry students: Organic Reaction Mechanisms (CM3221). This module builds on the module Advanced Polymer Science (CM 4268). A major focus will be directed towards the preparation and application of advanced polymers and biopolymers. It will be accompanied by presentations and case studies delivered by selected Industry researchers.

The following aspects will be covered:
(1) Liquid Crystals
(2) Photovoltaics Materials
(3) Organic Electronics & Devices
(4) Nanostructured Surfaces
(5) Sensors
(6) Nanoparticles and Quantum Dots
(7) Biomimetic and Intelligent Materials
(8) Tissue Engineering

The module is suited for final year students majoring in chemistry, applied chemistry and related disciplines.