INSTITUT KIMIA MALAYSIA

MALAYSIAN INSTITUTE OF CHEMISTRY

(Inaugurated on 8 April 1967, incorporated under Chemists Act 1975 on 1 November 1977)

127B, JALAN AMINUDDIN BAKI, TAMAN TUN DR ISMAIL, 60000 KUALA LUMPUR

TEL: 603-7728 3272 **FAX**: 603-7728 9909

EMAIL: ikmhq@ikm.org.my **WEBSITE**: http://www.ikm.org.my **FACEBOOK**: Institut Kimia Malaysia

IKM REFRESHER COURSE FOR FINAL EXAMINATIONS CANDIDATES
MODULE 1: INORGANIC CHEMISTRY

Synopsis of Module Contents

This module provides a clear and structured overview of key topics in inorganic chemistry. It begins with atomic structure, quantum chemistry, and periodic trends, forming the foundation for understanding the properties and behavior of elements. Core concepts such as chemical bonding, molecular geometry, and symmetry are covered to explain the reactivity and physical properties of compounds.

The module explores coordination chemistry, solid-state structures, acids and bases, and the unique properties of transition metals, lanthanides, and actinides. Practical applications in catalysis, biological systems, and industrial processes are highlighted, along with nuclear chemistry and the use of radioisotopes.

Advanced sections focus on the synthesis of new materials, nanotechnology, and environmental solutions, along with applications of zeolites, superconductors, and high-performance ceramics. The module emphasizes both foundational principles and modern innovations in inorganic chemistry.

Key Learning Outcomes

At the end of the Module 1, students can:

1. describe principles of atomic structure, quantum chemistry, and periodic trends to explain element behavior.
2. explain chemical bonding, molecular structures, and symmetry using bonding theories and group theory principles.
3. evaluate the properties, reactivity, and applications of inorganic compounds, including acids, bases, transition metals, and coordination complexes.
4. assess the role of inorganic materials in technology, biological systems, and industrial applications.
5. interpret emerging trends such as nanotechnology, inorganic composites, and environmental chemistry through case studies and research findings

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Module Content Outline and Subtopics

	Topics	Subtopics	Teaching time allocated (h)
1	Atomic Structure and Quantum Chemistry	• Quantum mechanical model of the atom. • Atomic orbitals, quantum numbers, and electron configurations. • Building up of the periodic table - Aufbau principle, Hund's rule, and Pauli exclusion principle. • Energy levels of single electron atoms/systems • Energy levels of multi electron atoms/systems	**2**

2	Periodicity and the Periodic Table	• Historical development of the periodic table.
		• Trends in atomic and ionic size, ionization energy, ele electronegativity.
		• Periodic trends in physical and chemical properties of elements.
		• **Main Group Chemistry**
		  ○ Trends in the s- and p-block elements.
		  ○ Chemistry of hydrogen and its isotopes.
		  ○ Structure, bonding, and reactivity of important compounds (e.g., silicates, boranes).
			1

3	Chemical Bonding and Molecular Structure	• Ionic, covalent, and metallic bonding. • Molecular Orbital Theory and hybridization. • VSEPR theory and prediction of molecular geometry.	**2**
4	Acids, Bases, and Non-Aqueous Solvents	• Theories of acids and bases (Arrhenius, Brønsted-Lowry, Lewis). • Solvent systems and properties of non-aqueous solvents. • Acid-base behavior in different solvents.	**1**
5	Symmetry and Group Theory	• Symmetry elements and operations. • Point groups and their classification.	**2**
6	Solid State Chemistry	• Crystal structures, unit cells, and lattice types. • Packing efficiency and close-packing in solids. • Electrical, magnetic, and optical properties of solids.	**2**
7	Coordination Chemistry	• Werner's theory of coordination compounds. • Types of ligands and nomenclature (ligands and coordination compounds) • Stereochemistry and Isomerism	**2**

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		• Crystal Field Theory (CFT) and Ligand Field Theory (LFT). • Spectral and magnetic properties of coordination complexes	
8	Transition Metal Chemistry	• General properties of transition metals. • Oxidation states, electronic configurations, and variable valency. • Transition metals in biological systems (e.g., hemoglobin, chlorophyll) – bioinorganic chemistry	**2**
9	Lanthanides and Actinides	• Electronic configurations, oxidation states, and lanthanide contraction. • Extraction and separation techniques or rare earth elements. • Lanthanides and Actinide applications.	**1**
10	Organometallic Chemistry	• Classification and bonding in organometallic compounds. • 18-electron rule and stability. • Industrial applications (e.g., hydroformylation, olefin polymerization)	**1.5**
11	Nuclear Chemistry and Radioactivity	• Types of radioactive decay and stability of nuclei. • Half-life of radioactive elements • Applications of radioisotopes in medicine, energy, and industry (eg carbon dating).	**1.5**
12	Synthesis of new inorganic materials	• Current synthetic methods of emerging inorganic composites.	**1**
13	Advanced Topics and Applications	• Metalloproteins and enzymes (e.g., carbonic anhydrase, cytochromes). • Medical applications of bioinorganic compounds (e.g., cisplatin). • Supramolecular chemistry and host-guest complexes. • Inorganic materials: nano, zeolites, high performance ceramics, and superconductors. • Environmental Inorganic Chemistry - Inorganic pollutants and their effects (e.g., heavy metals, nitrates). • Other emerging technologies (e.g., inorganic nanomaterials, photochemical applications).	**2**
		TOTAL NUMBER OF LECTURE HOURS	**21**

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References

1. Inorganic Chemistry 5th Edition by Shiver and Atkins. Publisher: Oxford University Press (2010) ISBN: 9781429218207
2. Inorganic Chemistry 5th Edition by Catherine E Housecroft and Alan G Sharpe. Publisher: Person Education (2018) ISBN: 978-1292139913
3. Advanced Inorganic Chemistry 6th Edition by F Albert Cotton, Geoffrey Wilkinson, Carlon A Murillo & Manfred Bochmann. Publisher: Wiley (1999). ISBN: 978-0-471-19957-1
4. Inorganic Chemistry 5th Edition by Gary L Miessler, Paul J Fisher and Donald A Tarr. Publisher: Pearson Education (2014), ISSBN: 0321917790, 9780321917799
5. Inorganic Chemistry Revised Edition by Mark T Weller. Publisher: Oxford University Press (2014) ISBN: 978-0199641826

Student Learning Time

Lecture: 8.30 a.m. to 12.30 p.m. (4 h)

Lunch: 12.30 p.m. to 2 p.m.

Lecture Continues: 2 p.m. to 5 p.m. (3 h)

Total: 7 h per day, Total per module: 7 h × 3 days = 21 h

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IKM REFRESHER COURSE FOR FINAL EXAMINATIONS CANDIDATES
MODULE 2: ORGANIC CHEMISTRY

Synopsis of Module Contents

This Organic Chemistry refresher course revisits essential concepts and principles, focusing on theoretical understanding and practical applications. Designed for students with a foundational knowledge of organic chemistry, the course covers core topics such as nomenclature, isomerism, reaction mechanisms, spectroscopy, and the industrial applications of organic compounds.

Key areas include the naming and classification of organic compounds, the study of structural and stereoisomerism, and an overview of organic reactions, including polymerization and organometallic chemistry. Students will also explore the use of spectroscopic techniques (MS, NMR, UV, IR, CD) for compound identification and structure elucidation.

The course emphasizes the role of organic chemistry in diverse industries, including petrochemicals, biotechnology, pharmaceuticals, and sustainable practices like bioplastics and biodiesel. By the end of the course, students will have a solid understanding of how organic chemistry underpins technological advancements and industrial processes, and how it contributes to environmental sustainability.
This course is ideal for students or professionals looking to refresh their knowledge of organic chemistry, particularly in the context of industrial and biotechnological applications.

Key Learning Outcomes

At the end of the Module 2, students can:

1. Name and classify organic compounds using IUPAC nomenclature and functional groups.
2. Differentiate and explain types of isomerism, including structural and stereoisomerism.
3. Describe organic reaction mechanisms and their role in synthesis and material production.
4. Interpret spectroscopic data to deduce compound structures and functional groups.
5. Understand key experimental methods for synthesis, separation, and identification of compounds.
6. Explain organic chemistry's role in industries like petrochemicals, polymers, biotechnology, and specialized chemicals.
7. Discuss the environmental impact and sustainable practices in organic chemistry.
8. Apply organic chemistry principles to real-world applications in various industries.

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Module Content Outline and Subtopics

	Topics	Subtopics	Teaching time allocated (h)
1	Introduction to Organic Chemistry	• Overview of Organic Chemistry • Importance of Organic Chemistry in Everyday Life • Natural vs. Synthetic Organic Molecules (characteristics, examples and applications) • Macromolecules (polymers, proteins, carbohydrates & lipids): Types, functions/ applications • Representation of Organic Molecules (molecular and structural formulas)	**3**
2	Classification and Naming Organic Compounds	• Hydrocarbons (alkanes, alkenes, alkynes) • Functional Groups (alkyl halides, alcohols and phenols, ethers, carboxylic acids and derivatives, aldehyde, ketones, amines) • IUPAC Nomenclature	**4**
3	Isomerism	• Structural Isomerism (chain, position, functional group, conformation) • Stereoisomerism (geometric, cyclic, optical)	**2**
4	Reactions and Mechanism in Organic Chemistry	• Free radical • Substitution • Addition • Elimination • Rearrangement • Tests for organic compounds • Others (organometallic, fibers, nanoparticles, polymerization)	**5**
5	Organic synthesis and Experimental Techniques	• Organic Synthesis: Methods and Strategies • Characterization Techniques (chromatographic, spectroscopic, spectrometric) • Separation and Extraction Techniques (distillation, filtration, chromatography) • Application of Experimental Techniques	**4**
6	Applications of Organic Chemistry	• Petrochemicals & Refining (catalytic and refining crude oil key processes) • Polymerization and Polymers (biodegradable plastics, resins, automotive, rubber and tires) • Synthesis of Bulk Chemicals (fuels, organic solvents)	**3**

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		• Biotechnology Applications (fermentation, bioplastics, biocatalysts) • Sustainable Chemistry (biodiesel and renewable fuels) • Specialized Organic Chemicals (pharmaceuticals, nutraceuticals, agrochemicals, surfactants, detergents) • Oleo Chemistry and Natural Products • Paints & Coatings (pigments & dyestuffs, resin & binders, additives) • Other Industrial Applications (cement & concrete, lubricants, textiles, fibers)	
		TOTAL NUMBER OF LECTURE HOURS	**21**

References

1. Organic Chemistry as a Second Language: First Semester Topics, 4th Edition by David R. Klein. Publisher: Wiley (2016) ISBN: 1119110661
2. Organic Chemistry: A Short Course,13th Edition by Harold Hart, Christopher M. Hadad, Leslie E. Craine, and David J. Hart. Publisher: Cengage Learning (2011) ISBN: 1111425566
3. Introduction to Organic Laboratory Techniques: A Small-Scale Approach, 2nd Edition by Donald L. Pavia, Gary M. Lampman, George S. Kriz, and Randall G. Engel. Publisher: Brooks Cole (2004) ISBN: 0534408338
4. Spectrometric Identification of Organic Compounds, 8th Edition by Robert M. Silverstein, Francis X. Webster, David J. Kiemle, David L. Bryce. Publisher: Wiley (2014) ISBN: 0470616377

Student Learning Time

Lecture: 8.30 a.m. to 12.30 p.m. (4 h)
Lunch: 12.30 p.m. to 2 p.m.
Lecture Continues: 2 p.m. to 5 p.m. (3 h)
Total: 7 h per day, Total per module: 7 h × 3 days = 21 h

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MODULE 3: PHYSICAL CHEMISTRY

Synopsis of Module Contents

Physical Chemistry delves into the fundamental principles governing matter's physical and chemical properties. This module covers properties of gases, solids, thermodynamics, phase equilibria, electrochemistry, chemical equilibrium, reaction kinetics, surface chemistry, and quantum chemistry. The module also explores experimental techniques like spectroscopy and X-ray diffraction to reinforce theoretical concepts and practical applications.

Key Learning Outcomes

At the end of the Module 3, students can:

1. Explain the physical properties of gases, solids, and their associated theoretical models and equations.
2. Outline the principles of thermodynamic principles, including state functions, enthalpy changes, and laws of thermodynamics.
3. Apply phase equilibrium concepts and relevant laws and equations to predict phase changes and properties.
4. Examine electrochemical systems, reaction kinetics, and their applications in energy storage and chemical processes.
5. Utilise the underlying principles of surface chemistry, colloidal systems, and spectroscopy for material characterization.

Module Content Outline and Subtopics

	Topics	Subtopics	Teaching time allocated (h)
1	Properties of Gases	• Ideal Gas Law • Collision Frequency • Ideal Gas Equation • Effusion • Kinetic Molecular Theory • Diffusion • Mixtures of Gases • Viscosity • Van der Waals Equation	**3**
2	The Solid State	• Bragg's Law • X-ray diffraction and Applications (Surface characterization) • Ionic Radii/ Cation Site Size • Photovoltaics/Semiconductors/Band Theory	**2**

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3	Thermodynamics	• Thermodynamics Variables • State Function • 1st, 2nd and 3rd Law of Thermodynamics • Enthalpy Changes • Heat Capacity • Adiabatic Process • Thermochemistry • Hess's Law • Standard Enthalpy of Formation • Bond Energies/Enthalpies • Kirchoff's Equation	**3**
4	Phase Equilibria	• Colligative Properties • Vapour Pressure and Vaporization • Boiling Points Elevation • Freezing Point Depression • Osmosis • Clausius-Clapeyron Equation • Phase Diagram • Gibbs-Duhem Equation • Raoult's Law • Henry's Law	**3**
5	Electrolytes and Electrochemistry	• Electrochemical Cells/Cell Potentials • Solubility • Acid and Bases • Hydrolysis of Salts • Conductance and Conductivity • Kohlrausch's Law • Energy storage (Rechargeable Batteries/ Supercapacitors)	**3**
6	Chemical Equilibrium and Reaction Kinetics	• Le Chatelier's Principle • The Law of Mass Action • Homogeneous & Heterogenous Equilibrium • Chemical Kinetics • Kinetics Molecular Theory • Activation Energy • The Arrhenius Equation • Rate of Reaction • Zero Order Reaction • 1st Order Reactions/ • Half-Life of 1st Order • 2nd Order Reactions	**3**

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7	Surface Chemistry and Colloids	• Surface Phenomena • Surface Characterization • Surface Corrosion and Prevention • Particulate System (Size and Shape Distribution) • Charged Particles and Their Stability • Electrical Double Layer • Colloidal System and Stability • Self-assembly and Aggregation • Hybrid Composite Particles • Emulsion and Foam • Film Formation of Elastomeric Particles	**2**
8	Quantum Chemistry and Molecular Spectroscopy	• FTIR, UV-VIS, Raman Spectroscopy (Principles and Selection Rules)	**2**
		TOTAL NUMBER OF LECTURE HOURS	**21**

References

1. Atkins' Physical Chemistry, 12th Edition Authors: Peter Atkins, Julio de Paula, and James Keeler. Publisher: Oxford University Press (2022) ISBN: 9780198847816.
2. Fundamentals of Materials Science and Engineering: An Integrated Approach, 6th Edition. Authors: William D. Callister Jr., David G. Rethwisch. Publisher: Wiley (2021). ISBN: 978-1-119-68894-5.
3. Physical Electrochemistry: Fundamentals, Techniques, and Applications, 2nd Edition. Authors: Noam Eliaz, Eliezer Gileadi. Publisher: Wiley (2018). ISBN: 978-3-527-34139-9.
4. Introduction to Applied Colloid and Surface Chemistry. Author: Georgios M. Kontogeorgis and Sren Kiil. Publisher: Wiley (2016). ISBN: 9781118881200.
5. Molecular Spectroscopy: A Quantum Chemistry Approach. Editors: Yukihiro Ozaki, Marek Janusz Wojcik, Jurgen Popp. Publisher: Wiley (2019). ISBN:9783527344611.

Student Learning Time

Lecture: 8.30 a.m. to 12.30 p.m. (4 h)

Lunch: 12.30 p.m. to 2 p.m.

Lecture Continues: 2 p.m. to 5 p.m. (3 h)

Total: 7 h per day, Total per module: 7 h × 3 days = 21 h

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MODULE 4: ANALYTICAL CHEMISTRY

Synopsis of Module Contents

This module provides a clear and structured overview of key topics in analytical chemistry. It covers major conventional methods and techniques in chemical analysis, forming the foundation for understanding the basic concept that involves in separation, qualitative and quantitative chemical analyses. Besides, the module also emphasizes quality assurance in chemical analysis, typically focusing on how to perform correct data treatment to measure precision and accuracy. An equally important component of the module also includes several chemical safety topics to evaluate the risks arising from the use of chemicals and to discuss conditions under which safety uses of chemicals for the protection of both human health and the environment. To ensure that awareness is created towards the latest developments in methods of chemical analysis, advanced instrumentation techniques that focus on material and surface characterizations, as well as sensors and microfluidic devices, will be introduced in this module. This is to aim at enabling students to keep up-to-date on newly emerging techniques in the field of analytical chemistry.

Key Learning Outcomes

At the end of the Module 4, students can:

1. Explain the underlying theoretical principles of a range of analytical chemistry methods.
2. Perform relevant statistical methods for data analysis and interpretation.
3. Describe important considerations of modern instrumental techniques in solving problems.
4. Perform sample analysis using modern instrumental techniques.

Module Content Outline and Subtopics

	Topics	Subtopics	**Teaching time allocated (h)**
1	Extraction & Gravimetric	• Principle of extraction separation • Application of extraction in separation • Principle of gravimetric analysis • Procedure of gravimetric analysis.	**2**
2	Titrimetric	• Principle of the titrimetric method • Acid-base titration • Redox titration • Argentometric • Complexometric	**2**
3	Chromatography	• Principles of chromatography • Classification of chromatography techniques • Instrumentation in chromatography techniques:	**3**

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		• High-Performance Liquid Chromatography (HPLC) • Gas Chromatograph (GC) • Gel Permeation Chromatography (GPC) • Ion Chromatography (IC)	
4	Spectroscopy	• Basic principle of spectroscopy for analysis • Attenuated Total Reflectance Fourier-Transform Infrared (ATR-FTIR) instrumentation • Ultraviolet-visible (UV-Vis) spectrophotometry instrumentation	**2**
5	Elemental Analysis	• Principle of elemental analysis using atomic spectroscopy • Atomic Absorption Spectroscopy (AAS) • Inductively Coupled Plasma Mass Spectrometry (ICP-MS) • Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES) • Atomic Fluorescence Spectroscopy (AFS) • X-ray Fluorescence (XRF)	**2**
6	Electroanalytical Methods	• Concepts of electroanalysis • Polarography • Potentiometry • Voltammetry • Amperometry • Electrochemical Impedance Spectroscopy (EIS)	**3**
7	Quality assurance in chemical analysis	• Accuracy & Precision • Validation: Limit of detection (LOD), limit of quantification (LOQ), repeatability, reproducibility, recovery, linear range • Verification • Measurement of uncertainty	**1**
8	Chemical Safety	• OSHA Act 514 • Laboratory management system • Laboratory accreditation • Management of chemicals in laboratories • Management of chemical waste • Classification and labeling of chemicals	**1**
9	Material & Surface Characterization	• Field Emission Scanning Electron Microscopy with Energy Dispersive X-Ray Spectroscopy (FESEM-EDX) • Transmission Electron Microscopy (TEM) • Atomic Force Microscopy (AFM) • X-ray Diffraction (XRD) • X-ray Photoelectron Spectroscopy (XPS)	**3**

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		• Raman Spectroscopy, Surface-Enhanced Raman Spectroscopy (SERS) • Zeta-potential	
10	Sensors and Microfluidic Devices	• Principle of chemical sensors & biosensors • Microfluidic devices • Lab-on-chips • Applications of sensor devices in chemical analysis	**2**
		TOTAL NUMBER OF LECTURE HOURS	**21**

References

1. G. D. Christian, Purnendu K. Dasgupta, Kevin A. Schug (2013) Analytical Chemistry, 7th Edition, John Wiley & Sons.
2. Skoog, D.A., West, D.M., Holler, F.J., Crouch, S.R. (2013) Fundamentals of Analytical Chemistry, 9th edition, Thomson.
3. Skoog, D.A., Holler, F.J., Crouch, S.R. (2017) Principles of Instrumental Analysis, 7th edition, Cengage Learning.
4. Harris, D.C. & Charles A. Lucy (2019) Quantitative Chemical Analysis, 10th Edition, W. H. Freeman.

Student Learning Time

Lecture: 8.30 a.m. to 12.30 p.m. (4 h)
Lunch: 12.30 p.m. to 2 p.m.
Lecture Continues: 2 p.m. to 5 p.m. (3 h)
Total: 7 h per day, Total per module: 7 h × 3 days = 21 h