THE UNIVERSITY OF BURDWAN

Syllabus of 3-Year Degree/4-Year Honours

in

Chemistry

Under Curriculum and Credit Framework for Undergraduate Programme (CCFUP) as per National Education Policy 2020

with effect from 2023-24

Semester-wise and Course-wise Distribution of Credit & Marks under CCFUP of NEP, 2020

Sem	Course type	Paper code	Course name	Credit				Marks			
				T	Lec	Prac	Tut	Th	Prac	IA	T
I	Major	CHEM1011	Basic Chemistry-I	4	3	1	0	40	20	15	75
	Minor	CHEM1021	General Chemistry-I	4	3	1	0	40	20	15	75
	Multi/ Interdisciplinary	CHEM1031	Chemistry for household importance	3	3	0	0	40	00	10	50
	Ability Enhancement Course (AEC) MIL (L_1)	AEC1041	Arabic/ Bengali/ Hindi/ Sanskrit/ Santali/ Urdu Or Equivalent Course from SWAYAM or other UGC recognized Platform.	2	2	0	0	40	00	10	50
	Skill Enhancement Course (SEC)	CHEM1051	Drugs and pharmaceuticals	3	3	0	0	40	00	10	50
	Common Value Added (CVA) Course	CVA 1061	Environmental Science/Education	4	3	1	0	60	20	20	100
II	Major	CHEM2011	Basic Chemistry-II	4	3	1	0	40	20	15	75
	Minor	CHEM2021	General Chemistry-II	4	3	1	0	40	20	15	75
	Multi/ Interdisciplinary	CHEM2031	Chemistry of Dyes, pigments, cosmetics and perfumes	3	3	0	0	40	00	10	50
	Ability Enhancement Course (AEC) English (L_2)	ENGL2041	Functional English Or Equivalent Course from SWAYAM or other UGC recognized Platform.	2	2	0	0	40	0	10	50
	Skill Enhancement Course (SEC)	CHEM2051	Basic Analytical Chemistry	3	3	0	0	40	00	10	50
	Common Value Add-ed (CVA) Course	CVA 2061	Understanding India/Digital and Technological solutions, Health & wellness, Yoga education, Sports & fitness	4	3	1/0	0/1	80/ 60	0/20	20	100
III	Major	CHEM3011	Inorganic Chemistry (Th)	5	5	0	0	60	00	15	75
		CHEM3012	Inorganic Chemistry (Prac)	5	0	5	0	00	60	15	75
	Minor (Vocational Education & Training)	MSR3021 OR HRM3021 OR RSA3021	Medical Sales Representative OR Human Resource Management OR Retail Sales Associate	4	3	0	1	60	00	15	75
	Multi/ Inter disciplinary	CHEM3031	Chemistry of Soil and Fertilizer	3	2	0	1	40	00	10	50
	Ability	AEC3041	Arabic/Bengali/Hindi/Sa	2				40		10	50

	Enhancement Course (AEC) MIL (L_1-2)		nskrit/Santali/Urdu or equivalent course form SWAYAM or any other UGC recognized platform								
	Skill Enhancement Course (SEC)	CHEM3051	IT skill in Chemistry	3	2	0	1	40	00	10	50
IV	Major	CHEM4011	Organic Chemistry (Th)	5	5	0	0	60	00	15	75
		CHEM4012	Physical Chemistry (Th)	5	5	0	0	60	00	15	75
		CHEM4013	Organic Chemistry (Prac)	5	0	5	0	00	60	15	75
	Minor	CHEM4021	General Chemistry-III	4	3	1	0	40	20	15	75
	Minor (other than Chemistry)	…….4021		4						15	75
	Ability Enhancement Course (AEC) (English, L_2-2)	ENGL4041	Language and Creativity Or Equivalent Course from SWAYAM or other UGC recognized Platform.	2				40	00	10	50
V	Major	CHEM5011	Inorganic Chemistry	5	4	1	0	40	20	15	75
	Major	CHEM5012	Organic Chemistry	5	4	1	0	40	20	15	75
	Major	CHEM5013	Physical Chemistry	5	4	1	0	40	20	15	75
	Minor (Vocational Education & Training)	MSR5021 OR HRM5021 OR RSA5021	Medical Sales Representative OR Human Resource Management OR Retail Sales Associate	4	3	0	1	60	00	15	75
	Internship	INT5081		2	0	2	0	00	50 (Project/ Field Diary : 30+ Viva-voce: 20)	00	50
VI	Major	CHEM6011	Inorganic Chemistry (Th)	4	4	0	0	60	00	15	75
	Major	CHEM6012	Organic Chemistry (Th)	4	4	0	0	60	00	15	75
	Major	CHEM6013	Physical Chemistry (Th)	4	4	0	0	60	00	15	75
	Major	CHEM6014	Inorganic & Physical Chemistry (Prac)	4	0	4	0	00	60	15	75
	Minor (Vocational Education & Training)	MSR6021 OR HRM6021	Medical Sales Re-presentative OR	4	3	0	1	60	00	15	75

		OR RSA6021	Human Resource Management OR Retail Sales Asso-ciate								
	Grand Total (Semester- I to VI)			**128**							**2325**

Semester-I

Chemistry MAJOR

Paper code: CHEM1011
Paper title: Basic Chemistry-I
Credits 3 + 1

Course objective

- Several fundamental aspects of inorganic, organic and physical chemistry is discussed for the basic understanding of the students
- The topics covered will help the students for studying higher in chemical sciences
- Easy organic chemistry practical using several chemical and physical methods will enhance the basic knowledge of students' hands-on training

Course outcome

Students will be introduced with several basic aspects of theory and practical of chemical sciences. This will grow the foundation of the subject for studying various advanced topics in future semesters.

Theory Credit 3

1. Atomic structure

Bohr's theory- its limitations and atomic spectra of hydrogen atom, Sommerfeld's theory, wave mechanics- de Broglie equation, Heisenberg's uncertainty principle and its significance, Schrödinger's wave equation, significance of ψ and ψ^2, quantum numbers and their significance, Radial and angular wave functions for hydrogen atom, radial and angular distribution curves, shapes of s, p, d and f orbitals, Pauli's exclusion principle, Hund's rules and multiplicity, exchange energy, Aufbau principle and its limitations, Ground state Term symbols of atoms and ions for atomic number upto 30

6 Hours

2. Periodic properties

Modern IUPAC periodic table, effective nuclear charge, screening effects and penetration, Slater's rules, atomic radii, ionic radii (Pauling's univalent), covalent radii, lanthanide contraction; ionization potential, electron affinity and electronegativity (Pauling's, Mulliken's and Allred-Rochow's scales) and factors influencing these properties,

group electronegativities, group trends and periodic trends in these properties in respect of s-, p- and d-block elements, secondary periodicity, relativistic Effect, inert pair effect

6 Hours

3. Acids and bases

Acid-Base concept- Arrhenius concept, theory of solvent system (in H_2O, NH_3, SO_2 and HF); Bronsted-Lowry's concept, relative strength of acids, Pauling's rules, Lux-Flood concept, Lewis concept, group characteristics of Lewis acids, solvent levelling and differentiating effects, thermodynamic acidity parameters, Drago-Wayland equation, superacids, gas phase acidity and proton affinity, HSAB principle, acid-base equilibria in aqueous solution (proton transfer equilibria in water), pH, buffer, acid-base neutralisation curves, indicator, choice of indicators, concept of organic acids and bases, effect of structure, substituent and solvent on acidity and basicity, proton sponge, gas-phase acidity and basicity *6 Hours*

4. Fundamentals in Organic chemistry

Electron displacement phenomena and physical properties: inductive effect, field effect, hyperconjugation, mesomeric effect, resonance energy, bond polarization and bond polarizability, electromeric effect, steric effect, steric inhibition of resonance, influence of hybridization on bond properties, bond dissociation energy (BDE) and bond energy, bond distances, bond angles, concept of bond angle strain (Baeyer's strain theory), melting point/boiling point and solubility of common organic compounds in terms of covalent & non-covalent intermolecular forces, polarity of molecules and dipole moments, relative stabilities of isomeric hydrocarbons in terms of heat of hydrogenation, heat of combustion and heat of formation, calculation of formal charges and double bond equivalent (DBE)

Reactive intermediates: carbocations (carbenium and carbonium ions), carbanions, carbon radicals, carbenes, benzynes and nitrenes, generation and stability, structure using orbital picture and electrophilic/nucleophilic behaviour of the reactive intermediates (elementary idea)

Concept of aromaticity: Hückel's rules for aromaticity up to [10]-annulene (including mononuclear heterocyclic compounds up to 6-membered ring), concept of antiaromaticity and homoaromaticity, non-aromatic molecules, Frost diagram, elementary idea about α and β, measurement of delocalization energies in terms of β for buta-1,3-diene,

cyclobutadiene, hexa-1,3,5-triene and benzene

12 Hours

5. Properties of Gases

Ideal and real gases: Deviation of gases from ideal behaviour, compressibility factor, Boyle temperature, Andrew's and Amagat's plots, van der Waals equation and its features, its derivation and application in explaining real gas behaviour, Dieterici equation of state, existence of critical state, critical constants in terms of van der Waals constants, law of corresponding states, virial equation of state, van der Waals equation expressed in virial form and significance of second virial coefficient, intermolecular forces (Debye, Keesom and London interactions, Lennard-Jones potential - elementary idea)

4 Hours

6. Chemical Kinetics-I

Rate law, order and molecularity: Introduction of rate law, extent of reaction, rate constants, order, forms of rate equations of first-, second- and n-th order reactions, pseudo first-order reactions (example using acid catalyzed hydrolysis of methyl acetate), determination of order of a reaction by half-life and differential method, opposing reactions, consecutive reactions and parallel reactions (with explanation of kinetic and thermodynamic control of products with all steps of first order)

Temperature and theories of reaction rate: Temperature dependence of rate constant; Arrhenius equation, energy of activation, rate-determining step and steady-state approximation – explanation with suitable examples.

5 Hours

7. Thermodynamics-I

Zeroth and 1st law of Thermodynamics: intensive and extensive variables, state and path functions, isolated, closed and open systems, zeroth law of thermodynamics, concept of heat q, work wand internal energy U, statement of first law, enthalpy H, relation between heat capacities, calculations of q, w, U and H for reversible, irreversible and free expansion of gases (ideal and van der Waals) under isothermal and adiabatic conditions, Joule’s experiment and its consequence

Thermochemistry: standard states, heats of reaction, enthalpy of formation of molecules and ions and enthalpy of combustion and its applications, laws of thermochemistry, bond energy, bond dissociation energy and resonance energy from

thermochemical data, Kirchhoff's equations and effect of pressure on enthalpy of reactions, adiabatic flame temperature, explosion temperature *6 Hours*

Reference Books

1. Lee, J. D. Concise Inorganic Chemistry ELBS, 1991.

2. Douglas, B.E. and McDaniel, D.H. Concepts & Models of Inorganic Chemistry Oxford, 1970.

4. Atkins, P. Shriver & Atkins' Inorganic Chemistry 5th Ed. Oxford University Press (2010).

5. Cotton, F.A., Wilkinson, G. and Gaus, P.L., Basic Inorganic Chemistry 3rd Ed.; Wiley India.

6. Sharpe, A.G., Inorganic Chemistry, 4th Indian Reprint (Pearson Education) 2005.

7. Huheey, J. E.; Keiter, E.A. &Keiter, R.L. Inorganic Chemistry, Principles of Structure and Reactivity 4th Ed., Harper Collins 1993, Pearson, 2006.

8. Mingos, D.M.P., Essential trends in inorganic chemistry. Oxford University Press (1998).

9. Winter, M. J., The Orbitron, http://winter.group.shef.ac.uk/orbitron/ (2002). An illustrated gallery of atomic and molecular orbitals.

10. Burgess, J., Ions in solution: basic principles of chemical interactions. Ellis Horwood (1999).

11. Clayden, J., Greeves, N. & Warren, S. Organic Chemistry, Second edition, Oxford University Press, 2012.

12. Smith, J. G. Organic Chemistry, Tata McGraw-Hill Publishing Company Limited.

13. Morrison, R. N. & Boyd, R. N. Organic Chemistry, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).

14. Pathak & Saha, Organic Chemistry (Volume-1), Books and Allied (P) Ltd.

15. Finar, I. L. Organic Chemistry (Volume 1), Dorling Kindersley (India) Pvt. Ltd., (Pearson Education).

16. Morrison, R. T. Study guide to organic Chemistry, Pearson.

17. Atkins, P. W. & Paula, J. de Atkins' Physical Chemistry, Oxford University Press.

18. Castellan, G. W., Physical Chemistry, Narosa Publishing House.

19. McQuarrie, D. A. & Simons, J. D. Physical Chemistry: A Molecular Approach, Viva Press.

20. Engel, T. & Reid, P. Physical Chemistry, Pearson.

21. Maron, S. &Prutton, Principles of Physical Chemistry, Collier Macmillan Ltd.

22. Mortimer, R. G. Physical Chemistry, Elsevier.

23. Ball, D. W., Physical Chemistry, Thomson Press.

24. Glasstone, S. & Lewis, G.N. Elements of Physical Chemistry.

25. Rakshit, P.C., Physical Chemistry, Sarat Book House.

26. Zemansky, M. W. &Dittman, R.H. Heat and Thermodynamics, Tata-McGraw-Hill.

27. Rastogi, R. P. & Misra, R.R. An Introduction to Chemical Thermodynamics, Vikas Publishing House.

28. Clauze& Rosenberg, Chemical Thermodynamics: Basic concepts & Methods, John Wiley & Sons, 2008.
29. Sharma, K. K. & Sharma, L. K., A Textbook of Physical Chemistry, Vikas Publishing House.
30. Rajaram, J. Chemical Thermodynamics: Classical, Statistical and Irreversible, Pearson.
30. Chatterjee Hrishikesh, Physical Chemistry (Volume-1), Platinum Publisher
31. Kapoor, K.L., Textbook of Physical Chemistry (Volume 1 and Volume-2), McGraw Hill Education
32. Ghoshal, A. Numerical problems & short questions on Physical Chemistry, Books and Allied (P) Ltd.
33. Bajpai, D. N., Advanced Physical Chemistry, S. Chand Publication.
34. Levine, I. N. Physical Chemistry, Tata McGraw-Hill.

Practical Credit 1

(i) Separation, purification and melting point determination

Separation of components of a binary solid mixture based on solubility by using common laboratory reagents like water (cold, hot), dil. HCl, dil. NaOH, dil. $NaHCO_3$, etc., purification of any one of the separated components by crystallization and determination of its melting point. The composition of the mixture may be of the following types: Benzoic acid/*p*-toluidine, *p*-nitrotolune/*p*-anisidine, benzoic acid/benzophenone, urea/benzophenone, salicylic acid/*p*-nitrotoluene, etc. *6 Hours*

(ii) Determination of boiling point

Boiling points of common organic liquid compounds e.g., ethanol, cyclohexane, ethyl methyl ketone, cyclohexanone, acetylacetone, anisole, crotonaldehyde, mesityl oxide, etc.

6 Hours

[Boiling points of the chosen organic compounds should preferably be less than 160°C]

(iii) Identification of a pure organic compound by chemical test(s)

Solid compounds: oxalic acid, succinic acid, resorcinol, urea, glucose and salicylic acid.

Liquid Compounds: acetic acid, ethyl alcohol, acetone, aniline and nitrobenzene

3 Hours

Reference Books

1. Bhattacharyya, R. C, A Manual of Practical Chemistry.

2. Vogel, A. I. Elementary Practical Organic Chemistry, Part 2: Qualitative Organic Analysis, CBS Publishers and Distributors.

3. Mann, F.G. & Saunders, B.C. Practical Organic Chemistry, Pearson Education (2009).

4. A.K. Manna, Practical Organic Chemistry, Books & Allied (P) Ltd.

Ghosh, Das Sharma, Majumdar, Manna, Chemistry in Laboratory, Santra Publication (P) Ltd.

Chemistry MINOR

Paper code: CHEM1021

Paper title: General Chemistry-I Credit 3 + 1

Theory Credit 3

Course objective

- Several fundamental aspects of the subject are discussed so that the principles can be useful for studying other branches of science (physical and/or biological sciences)
- Practical experiments are designed in such a way that the students of other disciplines can have an experience of hands-on training in chemistry at the primary level

Course outcome

On studying the course, the students will have an idea of chemical sciences, which may be applied for in-depth study of other science streams.

1. **Atomic structure**

   Bohr's theory for hydrogen atom (simple mathematical treatment), atomic spectra of hydrogen and Bohr's model, Sommerfeld's model, quantum numbers and their significance, Pauli's exclusion principle, Hund's rule, electronic configuration of many-electron atoms, Aufbau principle and its limitations

   6 Hours

2. **Periodic properties**

   Classification of elements on the basis of electronic configuration: general characteristics of s-, p-, d- and f-block elements, positions of hydrogen and noble gases, atomic and ionic radii, ionization potential, electron affinity and electronegativity,periodic and group-wise variation of above properties in respect of s- and p- block elements

   6 Hours

3. **Acids and bases**

Brönsted–Lowry concept, conjugate acids and bases, relative strengths of acids and bases, effects of substituent and solvent, differentiating and levelling solvents,Lewis acid-base concept, classification of Lewis acids and bases, Lux-Flood concept and solvent system concept, hard and soft acids and bases (HSAB concept), applications of HSAB process, acidity and basicity of common organic compounds

7 Hours

4. Aliphatic hydrocarbons

Functional group approach for the following compounds to be studied in context of their preparations, properties, structures and reactions

Alkanes (up to 5 carbons): preparation- catalytic hydrogenation, Wurtz reaction, Kolbe's synthesis using Grignard reagent; Reaction mechanism for free radical substitution, halogenation

Alkenes (up to 5 carbons): preparation- elimination reactions, dehydration of alcohols and dehydrohalogenation of alkyl halides, *cis* alkenes (partial catalytic hydrogenation) and trans alkenes (Birch reduction), reactions- *cis*-addition (alkaline KMnO4) and trans-addition (bromine) with mechanism, addition of HX [Markownikoff's (with mechanism) and anti-Markownikoff's addition], hydration, ozonolysis, oxymercuration-demercuration and hydroboration-oxidation reaction

Alkynes (up to 5 carbons):preparation- acetylene from CaC_2 and conversion into higher alkynes; by dehalogenation of tetra halides and dehydrohalogenation of vicinal dihalides, formation of metal acetylides, addition of bromine and alkaline $KMnO_4$, ozonolysis and oxidation with hot alkaline $KMnO_4$

10 Hours

5. Ideal and real gases

Concept of pressure and temperature, Deviation of gases from ideal behaviour, compressibility factor, Boyle temperature, Andrew's and Amagat's plots, van der Waals equation and its features, derivation and application in explaining real gas behaviour, existence of critical state, critical constants in terms of van der Waals constants, law of corresponding states

Viscosity of gases and effect of temperature and pressure on coefficient of viscosity (qualitative treatment only)

5 Hours

6. Thermodynamics-I

Intensive and extensive properties state and path functions, isolated, closed and open systems, zeroth law of thermodynamics,concept of heat, work, internal energy and statement of first law; enthalpy, H, relation between heat capacities, calculations of q, w, U and H for reversible, irreversible and free expansion of gases

Standard states, heat of reaction, enthalpy of formation of molecules and ions, enthalpy of combustion and its applications, laws of thermochemistry, bond energy, bond dissociation energy and resonance energy from thermochemical data, Kirchoff's equation and effect of pressure on enthalpy, adiabatic flame temperature, explosion temperature

7 Hours

7. Chemical Kinetics-I

Introduction of rate law, order and molecularity, extent of reaction, rate constants, rates of first-, second- and n-th order reactions and their integrated forms (with derivation), pseudo first order reactions, determination of order of a reaction-half-life and differential method, opposing reactions, consecutive reactions and parallel reactions (elementary idea)

Theories of reaction rate: Temperature dependence on reaction rate, Arrhenius equation, energy of activation

4 Hours

Reference Books

1. Lee, J. D. Concise Inorganic Chemistry ELBS, 1991.

2. Douglas, B.E. and McDaniel, D.H. Concepts & Models of Inorganic Chemistry Oxford, 1970.

4. Atkins, P. Shriver & Atkins' Inorganic Chemistry 5th Ed. Oxford University Press (2010).

5. Cotton, F.A., Wilkinson, G. and Gaus, P.L., Basic Inorganic Chemistry 3rd Ed.; Wiley India.

6. Sharpe, A.G., Inorganic Chemistry, 4th Indian Reprint (Pearson Education) 2005.

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12. Morrison, R. N. & Boyd, R. N. Organic Chemistry, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
13. Finar, I. L. Organic Chemistry (Volume 1), Dorling Kindersley (India) Pvt. Ltd., (Pearson Education).
14. Morrison, R. T. Study guide to organic Chemistry, Pearson.
15. Pathak & Saha, Organic Chemistry (Volume-1), Books and Allied (P) Ltd.
16. Atkins, P. W. & Paula, J. de Atkins' Physical Chemistry, Oxford University Press.
17. Castellan, G. W., Physical Chemistry, Narosa Publishing House.
18. McQuarrie, D. A. & Simons, J. D. Physical Chemistry: A Molecular Approach, Viva Press.
19. Engel, T. & Reid, P. Physical Chemistry, Pearson.
20. Mortimer, R. G. Physical Chemistry, Elsevier.
21. Ball, D. W. Physical Chemistry, Thomson Press.
22. Glasstone, S. & Lewis, G.N. Elements of Physical Chemistry.
23. Rakshit, P.C., Physical Chemistry, Sarat Book House.
24. Zemansky, M. W. &Dittman, R.H. Heat and Thermodynamics, Tata-McGraw-Hill.
25. Rastogi, R. P. & Misra, R.R. An Introduction to Chemical Thermodynamics, Vikas Publishing House.
26. Clauze& Rosenberg, Chemical Thermodynamics: Basic concepts & Methods, John Wiley & Sons, 2008.
27. Sharma, K. K. & Sharma, L. K., A Textbook of Physical Chemistry, Vikas Publishing House.
28. Bajpai, D. N., Advanced Physical Chemistry, S. Chand Publication.
29. Rajaram, J. Chemical Thermodynamics: Classical, Statistical and Irreversible, Pearson.
30. Chatterjee Hrishikesh, Physical Chemistry (Volume-1), Platinum Publisher
31. Kapoor, K.L., Textbook of Physical Chemistry (Volume 1 and Volume-2), McGraw Hill Education
32. Ghoshal, A. Numerical problems & short questions on Physical Chemistry, Books and Allied (P) Ltd.
33. Maron, S. &Prutton, Principles of Physical Chemistry, Collier Macmillan Ltd.
34. Levine, I. N. Physical Chemistry, Tata McGraw-Hill.

Practical Credit 1

(i) Determination of boiling points

Boiling points of common organic liquid compounds e.g., ethanol, cyclohexane, ethyl methyl ketone, cyclohexanone, acetylacetone, anisole, crotonaldehyde, mesityl oxide,etc.

8 Hours

(ii) Identification of a pure organic compound

Solid compounds: oxalic acid, succinic acid, resorcinol, urea, glucose, benzoic acid and salicylic acid.

Liquid Compounds: acetone, aniline and nitrobenzene

7 Hours

Reference Books

1. Bhattacharyya, R. C, A Manual of Practical Chemistry.

2. Vogel, A. I. Elementary Practical Organic Chemistry, Part 2: Qualitative Organic Analysis, CBS Publishers and Distributors.

3. Mann, F.G. & Saunders, B.C. Practical Organic Chemistry, Pearson Education (2009).

4. A.K. Manna, Practical Organic Chemistry, Books & Allied (P) Ltd.

Ghosh, Das Sharma, Majumdar, Manna, Chemistry in Laboratory, Santra Publication (P) Ltd.

MULTIDISCIPLINARY

Paper code: CHEM1031

Paper title: Chemistry for Household Importance Credit 3

Course objective

Several topics related to everyday life have been included to grow interest among students for the subject

Course outcome

After studying the topics these may help the students to get employment.

Theory

1. Food chemistry: Food additive, food flavor, adulterant, preservative, artificial sweeteners *8 Hours*
2. Drugs and pharmaceuticals: Structure and function, antipyretic and analgesic drugs – aspirin, paracetamol, ibuprofen *8 Hours*
3. Vitamins: Vitamin C and B_{12} *2 Hours*
4. Antibiotics: Penicillin, sulphaguanidine, chloramphenicol *4 Hours*
5. Glass and ceramics: Definition and manufacture of glasses, optical and colour glasses *6 Hours*
6. Surface chemistry: Soaps and detergents *2 Hours*

7. Chemistry of fuels: Conventional and non-conventional energy sources, classification of fuels, calorific values of fuels like kerosene, coal, coal gas, petrol, liquefied petroleum gas, octane number, biogas *15 Hours*

Reference Books

1) Thapar, Food Chemistry, Pacific Book International
2) Gayatri Baidya, Textbook of Food Chemistry, Book Rivers
3) Mandal, S.K., Pharmaceutical Chemistry and Production: An Introductory Textbook Rebeca Ghanta; Bentham Science Publishers 2022, ISBN: 978-1-68108-890-7
4) Sengupta,S.,Application Oriented Chemistry Books Syndicate Pvt. Ltd., 2000

SKILL ENHANCEMENT COURSE

Paper code: CHEM1051

Paper title: Drugs and pharmaceuticals

Theory Credit 3

Course objective

- Design and development of several organic drugs
- The very detail discussion for growing of very clear idea about the drugs, their synthesis and physiological action

Course outcome

The clear idea about the drugs may not only grow the general sense about the synthesis and mode of action of the drugs but also help them to have employment in pharmaceutical industry.

Drug discovery, design and development, synthesis of the representative drugs of the following classes: analgesics agents, antipyretic agents, anti-inflammatory agents (aspirin, paracetamol, ilbuprofen), antibiotics (penicillin, chloramphenicol), antibacterial and antifungal agents (sulphonamides, sulphanethoxazol, sulphacetamide, trimethoprim); antiviral agents (acyclovir), central nervous system agents (phenobarbital, diazepam), cardiovascular (glyceryl trinitrate), antilaprosy (dapsone), HIV-AIDS related drugs (AZT-Zidovudine)

45 Hours

Reference Books

1. Patrick, G. L. Introduction to Medicinal Chemistry, Oxford University Press, UK, 2013.

2. Singh, H. & Kapoor, V.K. Medicinal and Pharmaceutical Chemistry, Vallabh Prakashan, Pitampura, New Delhi, 2012.
3. Foye, W.O., Lemke, T.L. & William, D.A.: Principles of Medicinal Chemistry, 4th ed., B.I. Waverly Pvt. Ltd. New Delhi.
4. El-Mansi, E.M.T., Bryce, C.F.A., Ddemain, A.L., Allman, A.R., Fermentatias Microbiology and Biotechnology, 2nd Ed. Taylor & Francis.
5. Prescott & Dunn's Industrial Microbiology, 2004, CBS Publisher.

Semester-II

Chemistry MAJOR
Paper code: CHEM2011

Paper title: Basic Chemistry-II Credit 3 + 1

Theory Credit 3

Course objective

- Several basic topics from inorganic, organic and physical chemistry have been chosen for the development of the general chemistry knowledge of the students.
- This will help to grow the foundation for studying the several aspects of applied chemistry in future.

Course outcome

The topics will grow the foundation of the students for the subject chemistry for learning any further advanced topics.

1. **Chemical bonding-I**

   Ionic bond: general characteristics, types of ions, size effects, radius ratio rule and its application and limitations, packing of ions in crystals Born-Landé equation with derivation and importance, Kapustinskii expression for lattice energy, Madelung constant, Born-Haber cycle and its application, solvation energy, solubility energetics of dissolution process.

   Covalent bond: polarizing power and polarizability, ionic potential, Fazan's rules,Lewis structures, formal charge, Valence Bond Theory- hydrogen molecule (Heitler-London approach), directional character of covalent bonds, hybridizations, equivalent and non-equivalent hybrid orbitals, Bent's rule, dipole moments, VSEPR

theory, shapes of molecules and ions containing lone pairs and bond pairs (examples from main groups chemistry) and multiple bonding (σ and π bond approach)

6 Hours

2. Redox Reactions and Precipitation Reactions

Balancing of redox reactions: ion-electron method, elementary idea on standard redox potentials- Nernst equation (without derivation), influence of complex formation, precipitation and pH, formal potential

Redox titrations: feasibility, redox potential at the equivalence point, redox indicators, redox potential diagram (Latimer and Frost diagrams) of common elements and their applications Disproportionation and comproportionation reactions (typical examples), solubility product principle, common ion effect and their applications to the precipitation and separation of common metallic ions as hydroxides, sulfides, phosphates, carbonates, sulfates and halides

4 Hours

3. Stereochemistry-I

Bonding geometries and representation of carbon compounds: tetrahedral nature of carbon and concept of asymmetry: Fischer, sawhorse, flying-wedge and Newman projection formulae and their inter translations

Chirality and symmetry: symmetry elements and point groups (C_v, C_{nv}, C_{nh}, C_n, D_h, D_{nh}, D_{nd}, D_n, S_n (C_s, C_i), molecular chirality and centre of chirality, asymmetric and dissymmetric molecules, enantiomers and diastereomers, epimers, stereogenicity, chirotopicity and pseudoasymmetry, chiral centres and number of stereoisomerism, systems involving 1/2/3-chiral centre(s)- AA, AB, ABA and ABC types

Relative and absolute configuration: D/L and R/S descriptors, erythro/threo and meso nomenclature of compounds, syn/anti nomenclatures for aldols, E/Z descriptors- C=C, conjugated diene, triene, C=N and N=N systems, combination of R/S- and E/Z-isomerisms

Optical activity compounds: optical rotation, specific rotation and molar rotation, racemic compounds, racemisation (through cationic, anionic, radical intermediates and through reversible formation of stable achiral intermediates), resolution of acids, bases and alcohols via diastereomeric salt formation, optical purity and enantiomeric excess. *6 Hours*

4. General Treatment of Reaction Mechanism

Free energy profiles: one-, two- and three-step reactions, catalyzed reactions- electrophilic and nucleophilic catalysis, kinetic control and thermodynamic control of reactions, isotope effect- primary and secondary kinetic isotopic effect (k_H /k_D), principle of microscopic reversibility

Tautomerism: prototropy (keto-enol, amido-imidol, nitroso-oximino, diazo-amino and enamine-imine systems) and ring-chain tautomerism, composition of the equilibrium in different systems (simple carbonyl; 1,2- and 1,3-dicarbonyl systems, phenols and related systems), factors affecting keto-enol tautomerism, application of thermodynamic principles in tautomeric equilibria

6 Hours

5. Substitution and Elimination Reactions

Nucleophilic substitution reactions: substitution at sp3 centre- mechanisms (with evidence), relative rates, stereochemical features, S_N1, S_N2, S_N2', S_N1' (allylic rearrangement) and S_Ni, effects of solvent, substrate structure, leaving group and nucleophiles (including ambident nucleophiles, cyanide & nitrite), electrofuges and nucleofuges, substitutions involving NGP, role of crown ethers and phase transfer catalysts [systems: alkyl halides, allyl halides, benzyl halides, alcohols, ethers, epoxides]

Elimination reactions: E_1, E_2, E_1cB and Ei (pyrolytic syn eliminations), formation of alkenes and alkynes, mechanisms (with evidence), reactivity, regioselectivity (Saytzeff/Hofmann) and stereoselectivity, comparison between substitution and elimination

6 Hours

6. Kinetic Theory of gases:

Concept of pressure and temperature; collision of gas molecules, collision diameter, collision number and mean free path, frequency of binary collisions (similar and different molecules), wall collision and rate of effusion

Maxwell's distribution of speed and energy: Nature of distribution of velocities, Maxwell's distribution of speeds in one, two and three dimensions, kinetic energy distribution in one, two and three dimensions, calculations of average, root mean square and most probable values in each case, calculation of number of molecules having energy $\geq \varepsilon$, equipartition principle and its application to calculate

the classical limit of molar heat capacity of gases.

5 Hours

7. Liquid state

Viscosity: General features of fluid flow (streamline and turbulent flow); Newton's equation, viscosity coefficient; Poiseuille's equation; principle of determination of viscosity coefficient of liquids by falling sphere method; temperature variation of viscosity of liquids and comparison with that of gases

Surface tension and energy: Surface tension, surface energy, excess pressure, capillary rise and surface tension; work f cohesion and adhesion, spreading of liquids over other surfaces; vapour pressure over curved surface; temperature dependence of surface tension, principle of surface tension measurement

6 Hours

8. Thermodynamics-II

Second Law: its need and statement, concept of heat reservoirs and heat engines, Carnot cycle, physical concept of entropy, Carnot engine and refrigerator, Kelvin – Planck and Clausius statements and their equivalence in entropic formulation, Carnot's theorem,values of §dQ/T and Clausius inequality, entropy change of systems and surroundings for various processes and transformations, entropy and unavailable work, auxiliary state functions (G and A) and their variations (with T, P and V), criteria of spontaneity and equilibrium

Thermodynamic relations: Maxwell's relations, Gibbs- Helmholtz equation, Joule-Thomson experiment and its consequences, inversion temperature, Joule-Thomson coefficient for a van der Waals gas, general heat capacity relations.

6 Hours

Reference Books

1. Lee, J. D. Concise Inorganic Chemistry ELBS, 1991.

2. Douglas, B.E. and McDaniel, D.H. Concepts & Models of Inorganic Chemistry Oxford, 1970.

4. Atkins, P. Shriver & Atkins' Inorganic Chemistry 5th Ed. Oxford University Press (2010).

5. Cotton, F.A., Wilkinson, G. and Gaus, P.L., Basic Inorganic Chemistry 3rd Ed.; Wiley India.

6. Sharpe, A.G., Inorganic Chemistry, 4th Indian Reprint (Pearson Education) 2005.

7. Huheey, J. E.; Keiter, E.A. &Keiter, R.L. Inorganic Chemistry, Principles of Structure and Reactivity 4th Ed., Harper Collins 1993, Pearson, 2006.

8. Mingos, D.M.P., Essential trends in inorganic chemistry. Oxford University Press (1998).

9. Winter, M. J., The Orbitron, http://winter.group.shef.ac.uk/orbitron/ (2002). An illustrated gallery of atomic and molecular orbitals.

10. Burgess, J., Ions in solution: basic principles of chemical interactions. Ellis Horwood (1999).

11. Clayden, J., Greeves, N. & Warren, S. Organic Chemistry, Second edition, Oxford University Press, 2012.

12. Smith, J. G. Organic Chemistry, Tata McGraw-Hill Publishing Company Limited.

13. Morrison, R. N. & Boyd, R. N. Organic Chemistry, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).

14. Pathak & Saha, Organic Chemistry (Volume-1), Books and Allied (P) Ltd.

15. Rajaram, J. Chemical Thermodynamics: Classical, Statistical and Irreversible, Pearson.

16. Finar, I. L. Organic Chemistry (Volume 1), Dorling Kindersley (India) Pvt. Ltd., (Pearson Education).

17. Morrison, R. T. Study guide to organic Chemistry, Pearson.

18. Atkins, P. W. & Paula, J. de Atkins' Physical Chemistry, Oxford University Press.

19. Castellan, G. W. Physical Chemistry, Narosa Publishing House.

20. Maron, S. &Prutton, Principles of Physical Chemistry, Collier Macmillan Ltd.

21. Laidler, K. J. Chemical Kinetics, Pearson.

22. Glasstone, S. & Lewis, G.N. Elements of Physical Chemistry.

23. Rakshit, P.C., Physical Chemistry, Sarat Book House.

24. Rastogi, R. P. & Misra, R.R. An Introduction to Chemical Thermodynamics, Vikas.

25. Sharma, K. K. & Sharma, L. K., A Textbook of Physical Chemistry, Vikas Publishing House.

26. Nasipuri, D. Stereochemistry of Organic Compounds, New Age International (P) Ltd.

27. Sengupta,S. Basic Stereochemistry of Organic Molecules, Oxford University Press

28. Manna, A.K. Organic Molecular Spectroscopy, Books and Allied (P) Ltd.

29. Bajpai, D. N., Advanced Physical Chemistry, S. Chand Publication.

30. Engel, T. & Reid, P. Physical Chemistry, Pearson.

31 Levine, I. N. Physical Chemistry, Tata McGraw-Hill.

32. Ball, D. W. Physical Chemistry, Thomson Press.

33. Chatterjee Hrishikesh, Physical Chemistry (Volume-1), Platinum Publisher

34. Kapoor, K.L., Textbook of Physical Chemistry (Volume 1 and Volume-2), McGraw Hill Education

35. Ghoshal, A. Numerical problems & short questions on Physical Chemistry, Books and Allied (P) Ltd.

Practical Credit 1

1. Study of kinetics of acid-catalyzed hydrolysis of methyl acetate

2. Study of kinetics of decomposition of H_2O_2 by KI

3. Determination of pH of unknown strong alkali and acid solution by colour matching method

4. Determination of pH of unknown buffer solution by colour matching method

5. Study of viscosity of unknown liquid (glycerol, sugar) with respect to water

6. Determination of surface tension of a liquid using Stalagmometer

15 Hours

Reference Books

1. Bhattacharyya, R. C, A Manual of Practical Chemistry.

2. Nad, Mahapatra, Ghosal, An Advance course in Practical Chemistry, New Central Book Agency (P) Ltd.

3. K. S. Mukherjee, Textbook on Practical Chemistry, New Central Book Agency (P) Ltd.

4. Ghosh, Das Sharma, Majumdar, Manna, Chemistry in Laboratory, santra Publication (P) Ltd.

5. Poddar and Ghosh, Degree Practical Chemistry, Book Syndicate (P) Ltd.

Chemistry MINOR

Paper code: CHEM2021

Paper title: General Chemistry-II Credit 3 + 1

Theory Credit 3

Course objective

- Several basic aspects from inorganic, organic and physical chemistry have been discussed
- Generation of idea for studying physical and biological sciences in future

Course outcome

The idea created from this course may help to understand students for further studying physical, biological and material sciences.

1. **Thermodynamics-II**

   Statement of the second law of thermodynamics, concept of heat reservoirs and heat engines, Carnot cycle, physical concept of entropy, Carnot engine, refrigerator and efficiency, entropy change of systems and surroundings for various processes and transformations, auxiliary state functions (G and A) and criteria for spontaneity and equilibrium

   5 Hours

2. Ideal gas

Collision of gas molecules, collision diameter, collision number and mean free path, frequency of binary collisions (similar and different molecules), rate of effusion

Nature of distribution of velocities, Maxwell's distribution of speed and kinetic energy, average velocity, root mean square velocity and most probable velocity, equipartition principle and its application to calculate the classical limit of molar heat capacity of gases.

5 Hours

3. Chemical Kinetics-II

Collision theory, Lindemann theory of unimolecular reaction, outline of Transition State theory (classical treatment)

5 Hours

4. Fundamentals of Organic Chemistry

Electronic displacement phenomena- inductive effect, resonance and hyperconjugation, cleavage of bonds- homolytic and heterolytic, structures of organic molecules on the basis of VBT, nucleophiles, electrophiles, reactive intermediates- carbocations, carbanions and free radicals.

6 Hours

5. Stereochemistry

Isomerism- geometrical and optical isomerism, concept of chirality and optical activity (up to two carbon atoms), asymmetric carbon atom, elements of symmetry (plane and centre), interconversion of Fischer and Newman representations, enantiomerism and diastereomerism, meso compounds, threo and erythro, D and L, cis- and trans- nomenclatures, CIP rules: R/S (upto 2 chiral carbon atoms) and E/Z nomenclatures.

6 Hours

6. Nucleophilic Substitution and Elimination Reactions

Nucleophilic substitutions- S_N1, S_N2 and S_Ni reactions, eliminations- E_1 and E_2 reactions (elementary mechanistic aspects), Saytzeff and Hofmann eliminations, elimination vs. substitution

6 Hours

7. Chemical Bonding and Molecular Structure

Ionic Bonding: general characteristics, energy considerations, lattice energy and solvation energy and their importance for stability and solubility of ionic

compounds, statement of Born-Landé equation for lattice energy, Born-Haber cycle and its applications, polarizing power and polarizability, Fajans' rules, ionic character in covalent compounds, bond moment, dipole moment and percentage ionic character

Covalent bonding: Valence Bond (VB) theory approach, shapes of some inorganic molecules and ions on the basis of VSEPR and hybridization with suitable examples of linear, trigonal planar, square planar, tetrahedral, trigonal bipyramidal and octahedral arrangements

Concept of resonance and resonating structures in various inorganic and organic compounds

Molecular orbital (MO) theory approach -the LCAO method, bonding and antibonding MOs and their characteristics for s-s, s-p and p-p combinations of atomic orbitals, nonbonding combination of orbitals, MO treatment of homonuclear diatomic molecules of 1st and 2nd periods. (including the idea of s-p mixing) and heteronuclear diatomic molecules such as CO, NO and NO+, comparison of VB and MO approaches *12 Hours*

Reference Books

1. Lee, J. D. Concise Inorganic Chemistry ELBS, 1991.

2. Douglas, B.E. and McDaniel, D.H. Concepts & Models of Inorganic Chemistry Oxford, 1970.

4. Atkins, P. Shriver & Atkins' Inorganic Chemistry 5th Ed. Oxford University Press (2010).

5. Cotton, F.A., Wilkinson, G. and Gaus, P.L., Basic Inorganic Chemistry 3rd Ed.; Wiley India.

6. Sharpe, A.G., Inorganic Chemistry, 4th Indian Reprint (Pearson Education) 2005.

7. Huheey, J. E.; Keiter, E.A. &Keiter, R.L. Inorganic Chemistry, Principles of Structure and Reactivity 4th Ed., Harper Collins 1993, Pearson, 2006.

8. Mingos, D.M.P., Essential trends in inorganic chemistry. Oxford University Press (1998).

9. Burgess, J., Ions in solution: basic principles of chemical interactions. Ellis Horwood (1999).

10. Clayden, J., Greeves, N. & Warren, S. Organic Chemistry, Second edition, Oxford University Press, 2012.

11. Smith, J. G. Organic Chemistry, Tata McGraw-Hill Publishing Company Limited.

12. Morrison, R. N. & Boyd, R. N. Organic Chemistry, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).

13. Finar, I. L. Organic Chemistry (Volume 1), Dorling Kindersley (India) Pvt. Ltd., (Pearson Education).

14. Morrison, R. T. Study guide to organic Chemistry, Pearson.

15. Pathak & Saha, Organic Chemistry (Volume-1), Books and Allied (P) Ltd.

16. Castellan, G. W. Physical Chemistry, Narosa Publishing House.

17. Engel, T. & Reid, P. Physical Chemistry, Pearson.

18. Maron, S. &Prutton, Principles of Physical Chemistry, Collier Macmillan Ltd.

19. Laidler, K. J. Chemical Kinetics, Pearson.

20. Glasstone, S. & Lewis, G.N. Elements of Physical Chemistry.

21. Rakshit, P.C., Physical Chemistry, Sarat Book House.

22. Rastogi, R. P. & Misra, R.R. An Introduction to Chemical Thermodynamics, Vikas Publishing House.

23. Sharma, K. K. & Sharma, L. K., A Textbook of Physical Chemistry, Vikas Publishing House.

24. Bajpai, D. N., Advanced Physical Chemistry, S. Chand Publication.

25. Rajaram, J. Chemical Thermodynamics: Classical, Statistical and Irreversible, Pearson.

26. Nasipuri, D. Stereochemistry of Organic Compounds, New Age International (P) Ltd.

27. Sengupta,S.Basic Stereochemistry of Organic Molecules, Oxford University Press

28. Chatterjee Hrishikesh, Physical Chemistry (Volume-1), Platinum Publisher

29. Kapoor, K.L., Textbook of Physical Chemistry (Volume 1 and Volume-2), McGraw Hill Education

30. Ghoshal, A. Numerical problems & short questions on Physical Chemistry, Books and Allied (P) Ltd.

31. Atkins, P. W. & Paula, J. de Atkins' Physical Chemistry, Oxford University Press.

Practical Credit 1

1. Determination of pH of unknown strong alkali and acid by colour matching method
2. Study of kinetics of acid-catalyzed hydrolysis of methyl acetate
3. Estimation of Mohr's salt by titrating with $KMnO_4$/ $K_2Cr_2O_7$
4. Estimation of sodium carbonate and sodium hydrogen carbonate in a mixture *15 Hours*

Reference Books

1. Bhattacharyya, R. C, A Manual of Practical Chemistry.

2. Nad, Mahapatra, Ghosal, An Advance course in Practical Chemistry, New Central Book Agency (P) Ltd.

3. K. S. Mukherjee, Textbook on Practical Chemistry, New Central Book Agency (P) Ltd.

4. Ghosh, Das Sharma, Majumdar, Manna, Chemistry in Laboratory, santra Publication (P) Ltd.

5. Poddar and Ghosh, Degree Practical Chemistry, Book Syndicate (P) Ltd.

MULTIDISCIPLINARY

Paper code: CHEM2031

Paper title: Chemistry of Dyes, Pigments, Cosmetics and Perfumes Credit 3

Course objective

Introduction of idea of every day products of chemical industries

Course outcome

Development of idea of several molecules and materials related to dye and cosmetics industry

Theory

Definition and classification, structures and theories of coloration, preparation, properties and uses of dyes like phenolphthalein, methyl orange, malachite green, alizarin, indigo, different types of pigments like chlorophyll, carotenoids, anthocyanins, flavonoids (elemental idea)

Preparation and uses of the following: hair dye, hair spray, shampoo, suntan lotions, face powder, lipsticks, talcum powder, nail enamel, creams (cold, vanishing and shaving creams), antiperspirants and artificial flavours

Essential oils and their importance in cosmetic industries with reference to eugenol, geraniol, sandalwood oil, eucalyptus, rose-oil, 2-phenyl ethyl alcohol, jasmone, civetone, muscone

45 Hours

Reference Books

1. Finar, I. L. Organic Chemistry (Volume 1), Dorling Kindersley (India) Pvt. Ltd., (Pearson Education).
2. Bahl and Bahl, A Text book of Organic Chemistry, S. Chand publication
3. StocchiE.: Industrial Chemistry, Vol -I, Ellis Horwood Ltd. UK.
4. Jain, P.C.&Jain,M:.Engineering Chemistry, Dhanpat Rai & Sons, Delhi.
5. Sharma, B.K. & Gaur, H. Industrial Chemistry, Goel Publishing House, Meerut (1996).

SKILL ENHANCEMENT COURSE

Paper title: CHEM2051

Paper code: Basic Analytical Chemistry Credit 3

Course objective

- Development of skill for analyzing several natural and synthetic samples to find out their purity, composition, etc
- Development of skill for advanced separation techniques for natural and synthetic samples

Course outcome

This course will develop the analysis as well as separation skills of the students which may help them to motivate for joining research and/or have employment.

Theory Credit 3

1. **General principle**

Introduction to analytical chemistry and its interdisciplinary nature, concept of sampling, importance of accuracy, precision and sources of error in analytical measurements, presentation of experimental data and results, role of significant figures

8 Hours

3. **Analysis of soil**

Composition of soil, concept of pH and pH measurement, complexometric titrations, chelation, chelating agents, use of indicators

6 Hours

3. Analysis of water

Definition of pure water, contaminants (different types), water sampling methods, water purification methods

6 Hours

4. Analysis of food products

Nutritional value of a food, idea about food processing and food preservations, and adulteration *6 Hours*

5. **Chromatography**

Definition, general introduction on principles of chromatography, paper chromatography, TLC etc., column chomatography, ion-exchange chromatography, etc., determination of ion exchange capacity of anion /cation exchange resin *10 Hours*

6. Analysis of cosmetics

Major and minor constituents of cosmetics and their functions, analysis of deodorants and antiperspirants, Al, Zn, boric acid, chloride, sulphate

9 Hours

Reference Books

1. Willard, H.H., Merritt, L.L., Dean, J. &Settoe, F.A. Instrumental Methods of Analysis, 7th Ed. Wadsworth Publishing Company Ltd., Belmont, California, USA, 1988.
2. Skoog, D.A., Holler, F.J. & Crouch, S. Principles of Instrumental Analysis, Cengage Learning India Edition, 2007.
3. Skoog, D.A.; West, D.M. & Holler, F.J. Analytical Chemistry: An Introduction sixth Ed., Saunders College Publishing, Fort Worth, Philadelphia (1994).
4. Harris, D. C. Quantitative Chemical Analysis, 9th ed. Macmillan Education, 2016.
5. Dean, J. A. Analytical Chemistry Handbook, McGraw Hill, 2004.
6. Day, R. A. & Underwood, A. L. Quantitative Analysis, Prentice Hall of India, 1992.
7. Freifelder, D.M. Physical Biochemistry 2nd Ed., W.H. Freeman & Co., N.Y. USA (1982).
8. Cooper, T.G. The Tools of Biochemistry, John Wiley & Sons, N.Y. USA. 16 (1977).
9. Vogel, A. I. Vogel's Qualitative Inorganic Analysis 7th Ed., Prentice Hall, 1996.
10. Mendham, J., A. I. Vogel's Quantitative Chemical Analysis 6th Ed., Pearson, 2009.
11. Robinson, J.W. Undergraduate Instrumental Analysis 5th Ed., Marcel Dekker, Inc., New York (1995).
12. Christian, G.D. Analytical Chemistry, 6th Ed. John Wiley & Sons, New York, 2004.

Semester-III

Chemistry MAJOR

Paper code: CHEM3011 (3 and 4 years)
Paper title: Inorganic Chemistry (Theory)
Credit: 5

Course objective

- Discussion of bonding theories (advanced parts)
- Application of the basic theories discussed so far towards coordination chemistry and s- and p-block elements

Course outcome

After studying several basic aspects of chemistry, students will go through their applications in studying coordination chemistry, s- and p-block elements. On studying different comparative properties s- and p-block elements, proper chemical logic will start to be developed among the students.

1. Chemical Bonding-II

Molecular orbital concept of bonding (The approximations of the theory, Linear combination of atomic orbitals (LCAO) (elementary pictorial approach): sigma and pi-bonds and delta interaction, multiple bonding. Orbital designations: gerade, ungerade, HOMO, LUMO. Orbital mixing, MO diagrams of H_2, Li_2, Be_2, B_2, C_2, N_2, O_2, F_2, and their ions wherever possible; Heteronuclear molecular orbitals: CO, NO, NO^+, CN^-, HF, BeH_2, CO_2 and H_2O. Bond properties: bond orders, bond lengths.

Metallic Bond: Qualitative idea of valence bond and band theories. Semiconductors and insulators, defects in solids – stoichiometric and non-stoichiometric.

Weak Chemical Forces: van der Waals forces, ion-dipole forces, dipole-dipole interactions, induced dipole interactions, Instantaneous dipole-induced dipole interactions. Repulsive forces, Intermolecular forces: Hydrogen bonding (theories of hydrogen bonding, valence bond treatment), receptor-guest interactions, Halogen bonds. Effects of chemical force, melting and boiling points. *20 Hours*

2. Coordination Chemistry-I

Double and complex salts. Werner's theory of coordination complexes, Classification of ligands, chelates, coordination numbers, IUPAC nomenclature of coordination complexes (up to two metal centers), Isomerism in coordination compounds, constitutional and stereo isomerism, Geometrical and optical isomerism in square planar and octahedral complexes. *12 Hours*

3. Chemistry of s and p-block elements

Relative stability of different oxidation states, diagonal relationship and anomalous behaviour of first member of each group. Allotropy and catenation. Study of the following compounds with emphasis on structure, bonding, preparation, properties and uses. Beryllium hydrides and halides. Boric acid and borates, boron nitrides, borohydrides (diborane) and

graphitic compounds, silanes. Oxides and oxoacids of nitrogen, phosphorus, sulphur and chlorine. Peroxo acids of sulphur. Sulphur-nitrogen compounds, Basic properties of halides and polyhalides, interhalogen compounds, pseudohalides, fluorocarbons and chlorofluorocarbons. *35 Hours*

Noble Gases

Occurrence and uses, rationalization of inertness of noble gases, Clathrates; preparation, structures (VSEPR theory) and properties of XeF_2, XeF_4 and XeF_6; Nature of bonding in noble gas compounds (Valence bond treatment and MO treatment for XeF_2 and XeF_4). Xenon-oxygen compounds. *8 Hours*

Reference Books

1) Huheey, J. E.; Keiter, E.A. & Keiter, R.L. Inorganic Chemistry, Principles of Structure and Reactivity 4th Ed., Harper Collins 1993, Pearson, 2006
2) Greenwood, N.N. & Earnshaw A. Chemistry of the Elements, Butterworth-Heinemann, 1997
3) Cotton, F.A., Wilkinson, G., Murrillo, C. A., Bochmann, M., Advanced Inorganic Chemistry, 6th Ed. 1999., Wiley
4) Miessler, G. L. & Donald, A. Tarr. Inorganic Chemistry 4th Ed., Pearson, 2010
5) Purecell, K.F. and Kotz, J.C., An Introduction to Inorganic Chemistry, Saunders: Philadelphia, 980
6) Mingos, D.M.P., Essential trends in inorganic chemistry. Oxford University Press (1998)
7) Sarkar, R, General and inorganic chemistry, Volume II, New central book agency, (2012)

Chemistry MAJOR

Paper code: CHEM3012 (3 and 4 Years)

Paper title: Inorganic Chemistry (Practical)

Credit: 5

Course objective

- Development of chemical knowledge through several hands-on qualitative experiments
- Learning to synthesize several coordination compounds

Course outcome

Towards qualitative detection of several radicals, different experiments have to be covered. These will actually grow a clear knowledge and conception in chemistry. Moreover, preparation of modern coordination compounds will create an insight to the synthetic coordination chemistry.

1. *Qualitative analysis of Acid and Basic radicals from an inorganic sample* containing four radicals (oxide, hydroxide and carbonate may not be counted among four radicals). Emphasis should be given to the understanding of the chemistry of different reactions and to assign the most probable composition. Semi-micro analysis may also be followed. The use of centrifuge machine, thioacetamide instead of H_2S and spot tests for specific radicals should be introduced

Basic radicals: Na^+, K^+, Ca^{2+}, Sr^{2+}, Ba^{2+}, Al^{3+}, Cr^{3+}, Mn^{2+}/Mn^{4+}, Fe^{2+}/Fe^{3+}, Co^{2+}/Co^{3+}, Ni^{2+}, Cu^{2+}, Zn^{2+}, Pb^{2+}, Cd^{2+}, Bi^{3+}, Sn^{2+}/Sn^{4+}, As^{3+}/As^{5+}, Sb^{3+}/Sb^{5+}, NH_4^+, Mg^{2+}.

Acid Radicals: F^-, Cl^-, Br^-, I^-, $S_2O_3^{2-}$, S^{2-}, SO_4^{2-}, SO_3^{2-}, NO_3^-, NO_2^- , PO_4^{3-}, AsO_4^{3-}, BO_3^{3-}, CrO_4^{2-}.

Insoluble Materials: Al_2O_3 (ig), Fe_2O_3 (ig), Cr_2O_3 (ig), SnO_2, $SrSO_4$, $BaSO_4$, CaF_2, $PbSO_4$.

45 Hours

2. *Inorganic preparations*

1) $[Cu(CH_3CN)_4]PF_6/ClO_4$
2) Potassium dioxalatodiaquachromate(III)
3) Tetraamminecarbonatocobalt(III) ion
4) Potassium tris(oxalato)ferrate(III)

5) Tris(ethylenediamine) nickel(II) chloride

6) $[Mn(acac)_3]$ and $[Fe(acac)_3]$ (acacH = acetylacetone)

30 Hours

Reference Books

1) Vogel, A. I. Vogel's Qualitative Inorganic Analysis 7th Ed., Prentice Hall, 1996.

2) Karmakar, P., Sarkar (Sain), R., Ray, S., Ghosh, A.K. Concise Practical Chemistry (B.Sc. General and Honours), PART-I, The New Book Stall, Kolkata (2018).

3) Ghosh, Das Sharma, Majumdar, Manna, Chemistry in Laboratory, Santra Publication (P) Ltd.

4) Ghoshal, A., Mahapatra, B., Nad, A. K. An Advanced Course in Practical Chemistry, New Central Book Agency (2007).

5) Bhattacharyya, R. C, A Manual of Practical Chemistry.

6) K. S. Mukherjee, Textbook on Practical Chemistry, New Central Book Agency (P) Ltd.

MULTIDISCIPLINARY

Paper code: CHEM3031

Paper title: Chemistry of Soil, Fertilizer and detergent

Credit: 3

Course objective

- Development of knowledge of soil
- Development of knowledge of fertilizer
- Idea of pesticide, etc
- Idea of development of several surface-active agents like soap, etc

Course outcome

Exploring the knowledge of fundamental chemistry towards soil, fertilizer, detergent will not only create general chemical knowledge of the students but also will generate the possibility of employability.

1. Soil: Composition, texture, micro & macro nutrients, soil health, soil conditioner, growth factor, NPK and their determination, soil productivity and effect of pH

10 hours

2. Fertilizer: Different types of fertilizers. Manufacture of the following fertilizers: Urea, ammonium nitrate, calcium ammonium nitrate, ammonium phosphates; polyphosphate, superphosphate, compound and mixed fertilizers, potassium chloride, potassium sulphate. *15 hours*

3. Fungicide, pesticide, herbicide with examples, advantage and disadvantage. *10 hours*

4. Soap & Detergents: Different types of soap and detergents with example, surface active and surface inactive substances *10 hours*

Reference Books

1) Thapar, Food Chemistry, Pacific Book International
2) Gayatri Baidya, Textbook of Food Chemistry, Book Rivers
3) Mandal, S.K., Pharmaceutical Chemistry and Production: An Introductory Textbook Rebeca Ghanta; Bentham Science Publishers 2022, ISBN: 978-1-68108-890-7
4) Sengupta, S. Application Oriented Chemistry Books Syndicate Pvt. Ltd., 2000

SKILL ENHANCEMENT COURSE

Paper code: CHEM3051

Paper title: IT skills in Chemistry

Credit: 3

Course objective

- Development of mathematical knowledge and knowledge for computer programming
- Development of knowledge for different data handling softwares

Course outcome

The course will help the students sound for doing several chemical computations.

Mathematical tools

1. Fundamentals: mathematical functions, polynomial expressions, logarithms, the exponential function, units of a measurement, interconversion of units, constants and variables, equation of a straight line, plotting graphs.

2. Uncertainty in measurement: Displaying uncertainties, types of uncertainties, combining uncertainties. Statistical treatment. Mean, standard deviation, relative error. Data reduction and the propagation of errors. Graphical and numerical data reduction. Numerical curve fitting: the method of least squares (regression).

3. Algebraic operations on real scalar variables (e.g. manipulation of van der Waals equation in different forms). Roots of quadratic equations analytically and iteratively (e.g. pH of a weak acid). Numerical methods of finding roots (Newton-Raphson, binary-bisection, e.g. pH of a weak acid not ignoring the ionization of water, volume of a van der Waals gas, equilibrium constant expressions).

4. Differential calculus: The tangent line and the derivative of a function, numerical differentiation (e.g., change in pressure for small change in volume of a van der Waals gas, potentiometric titrations).

5. Numerical integration (Trapezoidal and Simpson's rule, e.g. entropy/enthalpy change from heat capacity data).

15 Hours

Computer Programming

Constants, variables, bits, bytes, binary and ASCII formats, arithmetic expressions, hierarchy of operations, inbuilt functions. Simple programs using these concepts. Matrix addition and multiplication. Statistical analysis.

Fortran or C programming for curve fitting, numerical differentiation and integration (Trapezoidal rule, Simpson's rule), finding roots (quadratic formula, iterative, Newton-Raphson method). *15 Hours*

Handling numeric data

Spreadsheet software (Excel), creating a spreadsheet, entering and formatting information, basic functions and formulae, creating charts, tables and graphs. Incorporating tables and graphs into word processing documents. Simple calculations, plotting graphs using a spreadsheet (Planck's distribution law, radial distribution curves for hydrogenic orbitals, gas kinetic theory- Maxwell Boltzmann distribution curves as function of temperature and molecular weight), spectral data, pressure-volume curves of van der Waals gas (van der Waals isotherms), data from phase equilibria studies. Graphical solution of equations.

15 Hours

Reference Books

1) McQuarrie, D. A. Mathematics for Physical Chemistry University Science Books (2008).

2) Mortimer, R. Mathematics for Physical Chemistry. 3rd Ed. Elsevier (2005).

3) Steiner, E. The Chemical Maths Book Oxford University Press (1996).

4) Yates, P. Chemical calculations. 2nd Ed. CRC Press (2007).

5) Harris, D. C. Quantitative Chemical Analysis. 6th Ed., Freeman (2007) Chapters 3-5.

6) Levie, R. de. How to use Excel in analytical chemistry and in general scientific data analysis, Cambridge Univ. Press (2001) 487 pages.

7) Noggle, J. H. Physical chemistry on a Microcomputer. Little Brown & Co. (1985).

8) Venit, S.M. Programming in BASIC: Problem solving with structure and style. Jaico Publishing House: Delhi (1996).

Semester-IV

Chemistry MAJOR

Paper code: CHEM4011 (3 and 4 Years)

Paper title: Organic Chemistry (Theory)

Credit: 5

Course objective

Development of knowledge for several basic and advanced topics of organic chemistry

Course outcome

The course will help the students to develop a complete knowledge on stereochemistry, reaction mechanism and others of organic chemistry.

1. Stereochemistry II

Chirality arising out of stereoaxis: stereoisomerism of substituted cumulenes with even and odd number of double bonds; chiral axis in allenes, spiro compounds, alkylidenecycloalkanes and biphenyls; related configurational descriptors (Ra/Sa and P/M); atropisomerism; racemisation of chiral biphenyls; buttressing effect.

Concept of prostereoisomerism: prostereogenic centre; concept of (pro)n-chirality: topicity of ligands and faces (elementary idea); pro-R/pro-S, pro-E/pro-Z and Re/Si descriptors; pro-r and pro-s descriptors of ligands on propseudoasymmetric centre.

Conformation: conformational nomenclature: eclipsed, staggered, gauche, syn and anti; dihedral angle, torsion angle; Klyne-Prelog terminology; P/M descriptors; energy barrier of rotation, concept of torsional and steric strains; relative stability of conformers on the basis of steric effect, dipole-dipole interaction and H-bonding; butane gauche interaction; conformational analysis of ethane, propane, n-butane. 2-methylbutane and 2,3-dimethylbutane; haloalkane, 1,2-dihaloalkanes and 1,2-diols (up to four carbons); 1,2-halohydrin; conformation of conjugated systems (*s*-cis and *s*-trans).

18 Hours

2. Chemistry of alkenes and alkynes

Addition to C=C and C≡C: Mechanism (with evidence wherever applicable), reactivity, regioselectivity (Markownikoff and anti-Markownikoff additions) and stereoselectivity; reactions: hydrogenation, halogenations, hydrohalogenation, hydration, oxymercuration-demercuration, hydroboration-oxidation, ozonolysis; epoxidation, syn and anti-hydroxylation, iodolactonisation, addition of singlet and triplet carbenes (for alkenes); electrophilic addition to diene (conjugated dienes and allene); radical addition: HBr addition; use of NBS for allylic and benzylic bromination with mechanism, competition with brominations across C=C;; Birch reduction of benzenoid aromatics; interconversion of *E*- and *Z*-alkenes. dissolving metal reduction of alkynes (Birch); reactions of terminal alkynes by exploring its acidity. *15 Hours*

3. Aromatic Substitution

Electrophilic aromatic substitution: mechanisms and evidences in favour of it; orientation and reactivity; reactions: nitration, nitrosation, sulfonation, halogenation, Friedel-Crafts reaction; one-carbon electrophiles (reactions: chloromethylation, Gatterman-Koch, Gatterman, Houben-Hoesch, Vilsmeier-Haack, Reimer-Tiemann, Kolbe-Schmidt); Ipso substitituion.

Nucleophilic aromatic substitution: addition-elimination mechanism and evidences in favour of it; cine substitution (benzyne mechanism), structure of benzyne and unimolecular mechanism. *10 Hours*

4. Carbonyl and Related Compounds

Addition to C=O: structure, reactivity and preparation of carbonyl compounds; mechanism (with evidence), reactivity, equilibrium and kinetic control; Burgi-Dunitz

trajectory in nucleophilic additions; formation of hydrates, cyano hydrins and bisulphite adduct; nucleophilic addition-elimination reactions with alcohols, thiols and nitrogen- based nucleophiles; reactions: benzoin condensation, Cannizzaro and Tischenko reactions, reactions with ylides: Wittig reaction; oxidations and reductions: Clemmensen, Wolff-Kishner, LiAlH4, NaBH4, MPV, Oppenauer, Bouveault-Blanc, acyloin condensation; oxidation of alcohols with PDC and PCC; periodic acid and lead tetraacetate oxidation of 1,2-diols.

Exploitation of acidity of α-H of C=O: formation of enols and enolates; kinetic and thermodynamic enolates; reactions (mechanism with evidence): halogenation of carbonyl compounds under acidic and basic conditions, Hell-Volhard-Zelinsky (H. V. Z.) reaction, nitrosation, SeO_2 (Riley) oxidation; condensations (mechanism with evidence): Aldol, Tollens', Knoevenagel, Claisen-Schmidt, Claisen ester including Dieckmann, Stobbe; Mannich reaction, Perkin reaction, Favorskii rearrangement; alkylation of active methylene compounds; preparation and synthetic applications of diethyl malonate and ethyl acetoacetate; specific enol equivalents (lithium enolates, enamines) in connection with alkylation, acylation and aldol type reaction.

Nucleophilic addition to α, β-unsaturated carbonyl system: general principle and mechanism (with evidence); direct and conjugate addition, addition of enolates (Michael reaction), Robinson annulation.

Substitution at sp^2 carbon (C=O system): mechanism (with evidence): BAC^2, AAC^2, AAC^1, AAL^1 (in connection to acid and ester); acid derivatives: amides, anhydrides and acyl halides (formation and hydrolysis including comparison).

24 Hours

5. Organometallics

Grignard reagent; Organolithiums; Gilman cuprates: preparation and reactions (mechanism with evidence); addition of Grignard and organo-lithium to carbonyl compounds; substitution on - COX; conjugate addition by Gilman cuprates; Corey-House synthesis; abnormal behavior of Grignard reagents; comparison of reactivity among Grignard, organo-lithium and organo-copper reagents; Reformatsky reaction; concept of umpolung and base-nucleophile dichotomy in case of organometallic reagents.

8 Hours

Reference Books

1) Clayden, J., Greeves, N. & Warren, S. Organic Chemistry, Second edition, Oxford University Press, 2012.
2) Smith, J. G. Organic Chemistry, Tata McGraw-Hill Publishing Company Limited.
3) Morrison, R. N. & Boyd, R. N. Organic Chemistry, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
4) Pathak & Saha, Organic Chemistry (Volume-1 & 2), Books and Allied (P) Ltd.
5) Finar, I. L. Organic Chemistry (Volume 1), Dorling Kindersley (India) Pvt. Ltd., (Pearsonn Education).
6) Morrison, R. T. Study guide to organic Chemistry, Pearson.
7) Nasipuri, D. Stereochemistry of Organic Compounds, New Age International (P) Ltd.
8) Sengupta, S. Basic Stereochemistry of Organic Molecules, Oxford University Press

Chemistry MAJOR

Paper code: CHEM4012 (3 and 4 Years)

Paper title: Physical Chemistry (Theory)

Credit: 5

Course objective

Development of knowledge of theories of several experimental and theoretical aspects of chemistry

Course outcome

The course will help to develop physical chemistry knowledge of solid, liquid and gaseous states of matter. Students will also learn to do quantum chemical calculations for various systems.

1. Chemical Kinetics-II and Catalysis

Theories of reaction rate: Collision theory; Lindemann theory of unimolecular reaction; outline of Transition State theory (classical treatment).

Homogeneous catalysis: Homogeneous catalysis with reference to acid-base catalysis; Primary kinetic salt effect; Enzyme catalysis; Michaelis-Menten equation, Lineweaver-Burk plot, turn over number, autocatalysis; periodic reactions. *12 Hours*

2. Electrochemistry-I

Conductance and transport number: Ion conductance; Conductance and measurement of conductance, cell constant, specific conductance and molar conductance; Variation of specific and equivalent conductance with dilution for strong and weak electrolytes; Kohlrausch's law of independent migration of ions; Equivalent and molar conductance at infinite dilution and their determination for strong and weak electrolytes; Debye-Hückel theory of ion atmosphere (qualitative)-asymmetric effect, relaxation effect and electrophoretic effect; Ostwald's dilution law; Ionic mobility; Application of conductance measurement (determination of solubility product and ionic product of water); Conductometric titrations.

Transport number, Principles of Hittorf's and Moving-boundary method; Wien effect, Debye-Falkenhagen effect, Walden's rule. *15 Hours*

3. Partial molar properties and Chemical potential

Chemical potential and activity, partial molar quantities, relation between Chemical potential and Gibb's free energy and other thermodynamic state functions; variation of Chemical potential (μ) with temperature and pressure; Gibbs-Duhem equation; fugacity and fugacity coefficient; Variation of thermodynamic functions for systems with variable composition; Equations of states for these systems, Change in G, S, H and V during mixing for binary solutions. *12 Hours*

4. Chemical Equilibrium

Thermodynamic conditions for equilibrium, degree of advancement; van't Hoff's reaction isotherm (deduction from chemical potential); Variation of free energy with degree of advancement; Equilibrium constant and standard Gibbs free energy change; Definitions of K_P, K_C and K_x; van't Hoff's reaction isobar and isochore from different standard states; Shifting of equilibrium due to change in external parameters e.g. temperature and pressure; variation of equilibrium constant with addition to inert gas; Le Chatelier's principle and its derivation. *14 Hours*

5. Specific heats of solid

Coefficient of thermal expansion, thermal compressibility of solids; Dulong –Petit's law; Perfect Crystal model, Einstein's theory – derivation from partition function, limitations;

Debye's T^3 law – analysis at the two extremes (without derivation of T^3 law).

5 Hours

6. Thermodynamics-III

Third law of Thermodynamics: Absolute entropy, Planck's law, Calculation of entropy, Nernst heat theorem *3 Hours*

7. Quantum Mechanics-I

Beginning of Quantum Mechanics: Wave-particle duality, light as particles: photoelectric and Compton effects; electrons as waves and the de Broglie hypothesis; Uncertainty relations (without proof).

Postulates of Quantum Mechanics, Wave function: Schrödinger time-independent equation; nature of the equation, acceptability conditions imposed on the wave functions and probability interpretations of wave function.

Concept of Operators: Elementary concepts of operators, eigenfunctions and eigenvalues; Linear and Hermitian operators; Commutation of operators, commutator and uncertainty relation; Expectation value. *14 Hours*

Reference Books

1) Atkins, P. W. & Paula, J. de Atkins' Physical Chemistry, Oxford University Press.
2) Castellan, G. W., Physical Chemistry, Narosa Publishing House.
3) McQuarrie, D. A. & Simons, J. D. Physical Chemistry: A Molecular Approach, Viva Press.
4) Engel, T. & Reid, P. Physical Chemistry, Pearson.
5) Maron, S. & Prutton, Principles of Physical Chemistry, Collier Macmillan Ltd.
6) Mortimer, R. G. Physical Chemistry, Elsevier.
7) Ball, D. W., Physical Chemistry, Thomson Press.
8) Glasstone, S. & Lewis, G.N. Elements of Physical Chemistry.
9) Rakshit, P.C., Physical Chemistry, Sarat Book House.
10) Zemansky, M. W. &Dittman, R.H. Heat and Thermodynamics, Tata-McGraw-Hill.
11) Rastogi, R. P. & Misra, R.R. An Introduction to Chemical Thermodynamics, Vikas Publishing House.
12) Clauze & Rosenberg, Chemical Thermodynamics: Basic concepts & Methods, John Wiley & Sons, 2008.

13) Sharma, K. K. & Sharma, L. K., A Textbook of Physical Chemistry, Vikas Publishing House.
14) Chatterjee Hrishikesh, Physical Chemistry (Volume-1), Platinum Publisher
15) Kapoor, K.L., Textbook of Physical Chemistry (Volume 1 and Volume-2), McGraw Hill Education
16) Ghoshal, A. Numerical problems & short questions on Physical Chemistry, Books and Allied (P) Ltd.
17) Bajpai, D. N., Advanced Physical Chemistry, S. Chand Publication.
18) Levine, I. N. Physical Chemistry, Tata McGraw-Hill.

Chemistry MAJOR

Paper code: CHEM4013 (3 and 4 Years)

Paper title: Organic Chemistry (Practical)

Credit: 5

Course objective

- Detection of several elements in organic molecules
- Detection of functional group in organic molecules
- Organic preparations

Course outcome

Students will have a hands-on training for detection of elements (N, S, Cl, Br, etc) and synthesis/derivatization of several organic compounds.

A. ***Qualitative Analysis of single solid organic compound***

1) Detection of special elements (N, S, Cl, Br) by Lassaigne's test
2) Solubility and classification (solvents: H_2O, 5% HCl, 5% NaOH and 5% $NaHCO_3$)
3) Detection of the following functional groups by systematic chemical tests:
4) Aromatic amino ($-NH_2$), aromatic nitro ($-NO_2$), amido ($-CONH_2$), anilide (-CONHAr), phenolic – OH, carboxylic acid (-COOH), ester (-COOR), carbonyl (-CHO and > C=O)
5) Melting point of the given compound
6) Preparation of one suitable derivative of the given sample, crystallization and determination of melting point.

Each student, during laboratory session, is required to carry out qualitative chemical tests for all the special elements and the functional groups with relevant derivatisation in known and unknown (at least six) organic compounds. *45 Hours*

B. ***Organic Preparations***

The following reactions are to be performed, noting the yield of the crude product with melting point:

1) Nitration of acetanilide
2) Condensation reactions: Synthesis of 7-hydroxy-4-methylcoumarin
3) Hydrolysis of amides/imides/esters
4) Acetylation of phenols/aromatic amines (using Zn-dust/Acetic Acid)
5) Benzoylation of phenols/aromatic amines
6) Side chain oxidation of toluene and p-nitrotoluene
7) Diazo coupling reactions of aromatic amines
8) Bromination of acetanilide using green approach (Bromate-Bromide method)
9) Selective reduction of m-dinitrobenzene to m-nitroaniline
10) Students must also calculate percentage yield, based upon isolated yield (crude) and theoretical yield.

Purification of the crude product is to be made by crystallisation from water/alcohol, crystallization after charcoal treatment, or sublimation, whichever is applicable.

30 Hours

Reference Books

1) Vogel, A. I. Elementary Practical Organic Chemistry, Part 2: Qualitative Organic Analysis, CBS Publishers and Distributors.

2) Furniss, B.S., Hannaford, A.J., Smith, P.W.G., Tatchell, A.R. Practical Organic Chemistry, 5th Ed.,Pearson (2012)

3) Clarke, H. T., A Handbook of Organic Analysis (Qualitative and Quantitative), Fourth Edition, CBS Publishers and Distributors (2007).

4) Ghoshal, A., Mahapatra, B., Nad, A. K. An Advanced Course in Practical Chemistry, New Central Book Agency (2007).

5) Bhattacharyya, R. C, A Manual of Practical Chemistry.

Chemistry MINOR

Paper code: CHEM4021

Paper title: General Chemistry-III

Credit: 3 + 1

Course objective

Discussion on several general aspects of inorganic, organic and physical chemistry

Course outcome

This course will help the students to develop advanced topics of chemistry, physics and biology. Students will learn to synthesize several coordination compounds. Students will also learn to estimate hardness of water by chemical analysis.

Theory Credit: 3

1. Liquid state

Definition of Surface tension, its dimension and principle of its determination using stalagmometer; Viscosity of a liquid and principle of determination of coefficient of viscosity using Ostwald viscometer; Effect of temperature on surface tension and coefficient of viscosity of a liquid (qualitative treatment only). *6 Hours*

2. Colligative properties

Raoult's law of relative lowering of vapour pressure, elevation of boiling point, depression of freezing point, osmosis and osmotic pressure, abnormal colligative property and vant Hoff factor, molecular weight determination of unknown solute *6 Hours*

3. Solutions

a. Ideal solutions and Raoult's law, deviations from Raoult's law – non-ideal solutions; Vapour pressure-composition and temperature-composition curves of ideal and non-ideal solutions; Distillation of solutions; Lever rule; Azeotropes

b. Critical solution temperature; effect of impurity on partial miscibility of liquids; Immiscibility of liquids- Principle of steam distillation; Nernst distribution law and its applications, solvent extraction *8 Hours*

4. Aromatic hydrocarbons

Benzene: Preparation: from phenol, by decarboxylation, from acetylene, from benzene sulphonic acid. Reactions: electrophilic substitution (general mechanism); nitration (with mechanism), halogenations (chlorination and bromination), sulphonation and Friedel-Craft's

reaction (alkylation and acylation) (up to 4 carbons on benzene); side chain oxidation of alkyl benzenes (up to 4 carbons on benzene). *6 Hours*

5. Synthetic uses of Grignard reagent & Active methylene compounds

Synthetic uses of Grignard reagent (GR), ethylacetoacetate (EAA) and diethylmalonate (DEM) *6 Hours*

6. Coordination chemistry

Double and complex salts, Warner's theory of coordination complexes, classification of ligands, chelates, coordination numbers, IUPAC nomenclature of coordination complexes (up to two metal centers), isomerism in coordination compounds, constitutional and stereo isomerism, geometrical and optical isomerism in square planar and octahedral complexes. *10 Hours*

7. Radioactivity

Characteristics, α, β and γ-rays, radioactive disintegration and equilibrium, decay constant, half-life and average life, artificial transmutation and artificial radioactivity, uses *3 Hours*

Reference Books

1) Lee, J. D. Concise Inorganic Chemistry ELBS, 1991.
2) Douglas, B.E. and McDaniel, D.H. Concepts & Models of Inorganic Chemistry Oxford, 1970.
3) Sharpe, A.G., Inorganic Chemistry, 4th Indian Reprint (Pearson Education) 2005.
4) Mingos, D.M.P., Essential trends in inorganic chemistry. Oxford University Press (1998).
5) Morrison, R. N. & Boyd, R. N. Organic Chemistry, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
6) Sarkar, R, General and inorganic chemistry, Volume II, New central book agency, (2012).
7) Rakshit, P. C., Physical Chemistry, Sarat Book House.
8) Rastogi, R. P. & Misra, R.R. An Introduction to Chemical Thermodynamics, Vikas Publishing House.

9) Sharma, K. K. & Sharma, L. K., A Textbook of Physical Chemistry, Vikas Publishing House.
10) Bajpai, D. N., Advanced Physical Chemistry, S. Chand Publication.
11) Kapoor, K.L., Textbook of Physical Chemistry (Volume 1 and Volume 2), McGraw Hill Education
12) Ghoshal, A. Numerical problems & short questions on Physical Chemistry, Books and Allied (P) Ltd.

Practical Credit 1

A. *Inorganic preparations*

1) Tetraamminecarbonatocobalt(III) ion
2) Potassium tris(oxalato)ferrate(III)
3) Tris(ethylenediamine) nickel (II) chloride *10 Hours*

B. *Complexometric titration*

Determination of total hardness of water by using standard EDTA solution *5 Hours*

Reference Books

1) Bhattacharyya, R. C, A Manual of Practical Chemistry.
2) Nad, Mahapatra, Ghosal, An Advance course in Practical Chemistry, New Central Book Agency (P) Ltd.
3) K. S. Mukherjee, Textbook on Practical Chemistry, New Central Book Agency (P) Ltd.
4) Ghosh, Das Sharma, Majumdar, Manna, Chemistry in Laboratory, Santra Publication (P) Ltd.
5) Poddar and Ghosh, Degree Practical Chemistry, Book Syndicate (P) Ltd.

Semester-V

Chemistry MAJOR
Course code: CHEM5011 (3 and 4 Years)
Course title: Inorganic Chemistry
F.M. 75 (40+20+15)

Credit: 5

Course objective:
Development of knowledge for several basic and advanced topics of inorganicchemistry

Course outcome:
The course will help the students to develop a complete knowledge on radioactivity, co-ordination chemistry, transition elements, inorganic polymers as well as practical concept on chromatographic separation technique, gravimetric and spectrophotometric estimation

Theory (F.M. 40)
Credit 4

1. **Radioactivity**
   Nuclear stability and nuclear binding energy. Nuclear forces: meson exchange theory. Nuclear models (elementary idea): Concept of nuclear quantum number, magic numbers. Nuclear Reactions: Artificial radioactivity, transmutation of elements, fission, fusion and spallation. Nuclear energy and power generation. Separation and uses of isotopes.Radio chemical methods: principles of determination of age of rocks and minerals, radio carbon dating, hazards of radiation and safety measures. *12 hours*
2. **Co-ordination Chemistry-II**
   VB description and its limitations. Elementary Crystal Field Theory: splitting of dn configurations in octahedral, square planar and tetrahedral fields, crystal field stabilization energy (CFSE) in weak and strong fields; pairing energy. Spectrochemical series. Jahn- Teller distortion, Octahedral site stabilization energy (OSSE), spinel and inverted spinels, Metal-ligand bonding (MO concept, elementary idea), sigma- and pi-bonding in octahedral complexes (qualitative pictorial approach) and their effects on the oxidation states of transitional metals (examples). Magnetism and Colour: Orbital and spin magnetic moments, spin only moments of d^n ions and their correlation with effective magnetic moments, including orbital contribution; quenching of magnetic moment: super exchange and antiferromagnetic interactions (elementary idea with examples only); d-d transitions; L-S coupling; qualitative Orgel diagrams for $3d^1$ to $3d^9$ ions. Racah parameter. Selection rules for electronic spectral

transitions; spectrochemical series of ligands; charge transfer spectra (elementary idea). *24 hours*

3. **Chemistry of Transition Elements**
   General comparison of 3d, 4d and 5d elements in term of electronic configuration, oxidation states, redox properties, coordination chemistry *12 hours*
4. **Inorganic Polymers**
   Types of inorganic polymers, comparison with organic polymers, synthesis, structural aspects and applications of silicones and siloxanes. Borazines, silicates and phosphazenes. *12 hours*

Reference Books

1. Arnikar, H. J. Essentials of Nuclear Chemistry, New Age International, 1995.
2. Lee, J. D. Concise Inorganic Chemistry 5th Ed., John Wiley and sons 2008.
3. Huheey, J. E.; Keiter, E.A. & Keiter, R.L. Inorganic Chemistry, Principles of Structure and Reactivity 4th Ed., Harper Collins 1993, Pearson, 2006.
4. Douglas, B.E. and McDaniel, D.H. Concepts & Models of Inorganic Chemistry Oxford, 1970.
5. Cotton, F.A., Wilkinson, G., & Gaus, P.L. Basic Inorganic Chemistry 3rd Ed.; Wiley India.
6. Miessler, G. L., Fischer, P. J., Tarr, D. A., Inorganic Chemistry, Pearson, 5th Edition.
7. Banerjee, S. P., Comprehensive Coordination Chemistry,Books& Allied Pvt. Ltd., 2019
8. Mingos, D.M.P., Essential trends in inorganic chemistry. Oxford University Press (1998).
9. Atkins, P., Overton, T., Rourke, J., Weller, M., Armstrong, F,. Shriver & Atkins, Inorganic Chemistry, Fifth Edition, Oxford University Press.

Practical (F.M. 20)

Credit 1

I. Chromatographic separation of metal ions

Paper chromatographic separation of following metal ions:

1. Ni (II) and Co (II)

2. Fe (III) and Al (III)

II. Gravimetric estimation

1. Estimation of nickel (II) using Dimethylglyoxime (DMG).

2. Estimation of copper as CuSCN

3. Estimation of Al (III) by precipitating with oxine and weighing as $Al(oxine)_3$ (aluminiumoxinate)

4. Estimation of chloride

III. Spectrophotometry

1. Measurement of 10Dq of 3d metal complexes by spectrophotometric method.

2. Determination of λmax of $KMnO_4$ and $K_2Cr_2O_7$.

Reference Books

1. Mendham, R.C., Denney, J.D., Baines, M. Thomas and Siva Sankar, B. Vogel's Text Book on Quantitative Chemical Analysis, 6/e, Pearson.
2. Nad, A.K., Mahapatra, B. & Ghosal, A. An Advanced Course in Practical Chemistry, New Central Book Agency, 2007.
3. Das, S.C. Advanced Practical Chemistry, The World Press Pvt. Ltd., 4th Ed. 2010.
4. Mukhopadhyay, R. & Chattejee, P. Advanced Practical Chemistry, Books & Allied(P) Ltd., 3rd Ed., 2007.

Chemistry MAJOR
Course code: CHEM5012 (3 and 4 Years)
Course title: Organic Chemistry
F.M 75 (40+20+15)

Credit: 5

Course objective:
Development of knowledge for several basic and advanced topics of organic chemistry

Course outcome:
The course will help the students to develop a complete knowledge on pericyclic reactions, retrosynthesis, polynuclear hydrocarbons and study of biomolecules as well as practical concept of volumetric estimation and chromatographic separation of organic sample

Theory (F.M. 40): Credit: 4

1. Pericyclic Reactions

Mechanism, stereochemistry, regioselectivity in case of

(i) Electrocyclic reactions: FMO approach involving 4π- and 6π-electrons (thermal and photochemical) and corresponding cycloreversion reactions.

(ii) Cycloaddition reactions: FMO approach, Diels-Alder reaction, photochemical [2+2] cycloadditions.

(iii) Sigmatropic reactions: FMO approach, sigmatropic shifts and their order; [1,3]- and [1,5]-H shifts and [3,3]-shifts with reference to Claisen and Cope rearrangements.

10 hours

2. The Logic of Organic Synthesis

(i) Retrosynthetic analysis: disconnections; synthons, donor and acceptor synthons; natural reactivity and umpolung; latent polarity in bifunctional compounds: consonant and dissonant polarity; illogical electrophiles and nucleophiles; synthetic equivalents; functional group interconversion and addition (FGI and FGA); C-C disconnections and synthesis: one-group and two group (1,2- to 1,6-diocarbonyl compounds), reconnection; protection and deprotection strategy (alcohol, amine, carbonyl, acid).

(ii) Strategy of ring synthesis: thermodynamic and kinetic factors; synthesis of large rings, application of high dilution technique.

(ii) Asymmetric synthesis: stereoselective and stereospecific reactions; diastereoselectivity and enantioselectivity (only definition); enantioselectivity: kinetically controlled MPV reduction; diastereoselectivity: addition of nucleophiles to C=O adjacent to a stereogenic centre: Cram's rule, Felkin-Anh model.

10 hours

3. Polynuclear aromatic hydrocarbons

Polynuclear hydrocarbons and their derivatives: synthetic methods include Haworth, Bardhan-Sengupta and other useful syntheses (with mechanistic details); fixation of double bonds and Fries rule; reactions (with mechanism) of naphthalene, anthracene, phenanthrene and their derivatives.

6 hours

4. Carbohydrates

Monosaccharides: Aldoses up to 6 carbons; structure of D-glucose & D-fructose (configuration & conformation); ring structure of monosaccharides (furanose and pyranose forms): Haworth representations and non-planar conformations; anomeric effect (including stereoelectronic explanation); mutarotation; epimerization; reactions

(mechanisms in relevant cases): Fischer glycosidation, osazone formation, bromine-water oxidation, HNO_3 oxidation, selective oxidation of terminal $–CH_2OH$ of aldoses, reduction to alditols, *Lobry de Bruyn-van Ekenstein* rearrangement; stepping–up (Kiliani-Fischer method) and stepping–down (Ruff's & Wohl's methods) of aldoses; acetonide (isopropylidene) and benzylidene protections; ring-size determination; Fischer's proof of configuration of (+)-glucose.

12 hours

5. **Biomolecules**

(i) *Amino acids*: synthesis with mechanistic details: Strecker, Gabriel, acetamido malonic ester, azlactone, Bücherer hydantoin synthesis, synthesis involving diketopiperazine; isoelectric point, zwitterions; electrophoresis, reaction (with mechanism): ninhydrin reaction; resolution of racemic amino acids.

(ii) *Peptides*: peptide linkage and its geometry; syntheses (with mechanistic details) of peptides using N-protection & C-protection, solid-phase (Merrifield) synthesis; peptide sequence: C-terminal and N-terminal unit determination (Edman, Sanger & '*dansyl*' methods); partial hydrolysis; specific cleavage of peptides: use of CNBr.

(iii) *Nucleic acids*: pyrimidine and purine bases (only structure & nomenclature); nucleosides and nucleotides corresponding to DNA and RNA; elementary idea of double helical structure of DNA (Watson-Crick model); complimentary base–pairing in DNA.

12 hours

6. **Alkaloids and Terpenoids**

General studies of terpenenoids and alkaloids; biosynthesis of terpenes; determination of structures of citral, nerol, α-terpineol, piperin, ephedrine and coniine 10 *hours*

Reference Books

1. Warren, S, Organic Synthesis:The Disconnection approach, Wiley student Ed., 2013.
2. Fleming, I. Molecular Orbitals and Organic Chemical reactions, Reference/Student Edition, Wiley, 2009.
3. Fleming, I. Pericyclic Reactions, Oxford Chemistry Primer, Oxford University Press.
4. Gilchrist, T. L. & Storr, R. C. Organic Reactions and Orbital symmetry, Cambridge University Press.
5. Nasipuri, D, Stereochemistry of organic compounds, New Age International Publishers, , 2014.

6. Sen Gupta, S, basic Stereochemistry of Organic molecules, Oxford University press, 2014.
7. Singh, S & Singh, J, Photochemistry and Pericyclic Reactions, New Age International Publishers, 3rd Ed., 2010.
8. Finar, I. L. Organic Chemistry (Volume 1), Dorling Kindersley (India) Pvt. Ltd.(Pearson Education).
9. Finar, I. L. Organic Chemistry (Volume 2), Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
10. Morrison, R. T. & Boyd, R. N. Organic Chemistry, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
11. Loudon, G. M. Organic Chemistry, Fourth edition, Oxford University Press.
12. Davis, B. G., Fairbanks, A. J., Carbohydrate Chemistry, Oxford Chemistry Primer, Oxford University Press.
13. Kar, R. K. Fundamentals of Organic Synthesis: The Retrosynthetic Analysis, New Central Book Agency, 2007.
14.

Practical (F.M. 20)
Credit:1

I. Volumetric Estimation:

(i) Estimation of Glucose using Fehling's solution
(ii) Estimation of Ascorbic acid (Vitamin-C) in reduced form
(iii) Estimation of Aniline using $KBrO_3$-KBr mixture
(iv) Estimation of Phenol using $KBrO_3$-KBr mixture
(v) Estimation of saponification value of oil/fat/ester

II. Chromatographic Separations

(i) TLC separation of a mixture containing 2/3 amino acids
(ii) TLC separation of a mixture of dyes (fluorescein & methylene blue)
(iii) Column chromatographic separation of mixture of dyes
(iv) Paper chromatographic separation of a mixture containing 2/3 amino acids

Reference Books:

1. Mendham, J., A. I. Vogel's Quantitative Chemical Analysis 6th Ed., Pearson.
2. Harris, D. C. Quantitative Chemical Analysis. 6th Ed., Freeman (2007).

3. University Hand Book of Undergraduate Chemistry Experiments, edited by Mukherjee, G. N., University of Calcutta.
4. Gurtu, J. N., Kapoor, R., Advanced Experimental Chemistry S. Chand & Co. Ltd.
5. Mukhopadhyay, R & Chatterjee, P, Advanced Practical Chemistry, Books & Allied (P) Ltd., 3rd Ed., 2007.
6. Manna, A.K., Practical Organic Chemistry, Books & Allied (P) Ltd., 2nd Ed., 2020.

Chemistry MAJOR
Course code: CHEM5013 (3 and 4 Years)
Course title: Physical Chemistry

Credit: 5

F.M. 75 (40+20+15)

Course objective:
Development of theoretical and practical knowledge for several basic and advanced topics of physical chemistry
Course outcome:
The course will help the students to develop a complete knowledge on crystal structure, polymers, dipole moment, polarizability, applications of quantum mechanics, statistical thermodynamics and surface phenomena

Theory (F.M. 40) Credit 4

1. Crystal Structure

Bravais Lattice and Laws of Crystallography: Types of solid, Bragg's law of diffraction; Laws of crystallography (Haüy's law and Steno's law); Permissible symmetry axes in crystals; Lattice, space lattice, unit cell, crystal planes, Bravais lattice. Packing of uniform hard sphere, close packed arrangements (fcc and hcp); Tetrahedral and octahedral voids.

Crystal planes: Distance between consecutive planes [cubic, tetragonal and orthorhombic lattices]; Indexing of planes, Miller indices; calculation of d_{hkl}; Relation between molar mass and unit cell dimension for cubic system; Bragg's law (derivation)

Determination of crystal structure: Powder method; Structure of NaCl and KCl crystals

10 hours

2. Polymers

Classification of polymers, Polymer nomenclature, Molecular forces and chemical bonding in polymers, Texture of Polymers, Criteria for synthetic polymer formation; classification of

polymerization processes, Functionality, Extent of reaction and Degree of polymerization – relationship.

Kinetics of Polymerization – Condensation and free-radical Addition Polymerization (only), Molecular weights of polymers, Determination of molecular weights by viscometry and osmometry methods, Molecular weight distribution and its significance. Polydispersity index

Preparation, Structures, Properties of few polymers (Physical, Thermal, Flow & Mechanical Properties) - polyolefins, polystyrene and styrene copolymers, poly(vinyl chloride), Polyamides, Phenol formaldehyde resins (Bakelite, Novalac)

8 hours

3. Dipole moment and Polarizability

Polarizability of atoms and molecules, dielectric constant and polarisation, molar polarisation for polar and non-polar molecules; Clausius-Mosotti equation and Debye equation (both without derivation) and their application; Determination of dipole moments

6 hours

4. Surface phenomena

Adsorption: Physical and chemical adsorption; Freundlich and Langmuir adsorption isotherms; multilayer adsorption and BET isotherm (no derivation required); Gibbs adsorption isotherm and surface excess; Heterogenous catalysis (single reactant); Zero order and fractional order reactions

Colloids: Lyophobic and lyophilic sols, Origin of charge and stability of lyophobic colloids, Coagulation and Schultz-Hardy rule, Zeta potential and Stern double layer (qualitative idea), Tyndall effect; Electrokinetic phenomena (qualitative idea only); Determination of Avogadro number by Perrin's method; Stability of colloids and zeta potential; Micelle, surfactants, reverse micelleand emulsions

12 hours

5. Quantum mechanics-II

Particle in a box: setting up of Schrödinger equation for one-dimensional particle in box and its solution; comparison with free particle eigenfunctions and eigenvalues. properties of PB wave functions (normalisation, orthogonality, probability distribution); expectation values of x, x^2, p_x and p_x^2 and their significance in relation to the uncertainty principle; extension of the problem to two and three dimensions and the concept of degenerate energy levels.

Simple Harmonic Oscillator: setting up of the Schrödinger stationary equation, energy expression (without derivation), expression of wave function for n = 0 and n = 1 (without derivation) and their characteristic features

Angular momentum: Commutation rules, quantization of square of total angular momentum and z-component

Rigid rotor model of diatomic molecule: Schrödinger equation, transformation to spherical polar coordinates, Separation of variables, Spherical harmonics, Discussion of solutions

Qualitative treatment of hydrogen atom and hydrogen-like ions: Setting up of Schrödinger equation in spherical polar coordinates, radial part, quantization of energy (only final energy expression); Average and most probable distances of electron from nucleus; Setting up of Schrödinger equation for many-electron atoms (He, Li)

16 hours

6. Statistical Thermodynamics

Configuration: Macrostates, microstates and configuration; calculation with harmonic oscillator; variation of W with E, equilibrium configuration, Boltzmann distribution, thermodynamic probability, entropy and probability, Boltzmann distribution formula (with derivation), applications to barometric distribution; concept of ensemble - canonical ensemble; Partition function, molecular partition function and thermodynamic properties, Maxwell's speed distribution; Gibbs' paradox

8 hours

Reference Books

1. Rakshit, P.C., Physical Chemistry, Sarat Book Distributors, 7th Ed.
2. Kapoor, K. L., A Textbook of Physical Chemistry, Volume-4, McGraw Hill Education (India) Pvt. Ltd., 5th Ed.
3. Kapoor, K., A Textbook of Physical Chemistry, Volume-5, McGraw Hill Education (India) Pvt. Ltd., 5th Ed.
4. Castellan, G. W. Physical Chemistry, Narosa
5. Atkins, P. W. & Paula, J. de Atkins', Physical Chemistry, Oxford University Press.
6. McQuarrie, D. A. & Simons, J. D. Physical Chemistry: A Molecular Approach, Viva Press.
7. Levine, I. N. Physical Chemistry, Tata McGraw-Hill.
8. Moore, W. J. Physical Chemistry, Orient Longman.
9. Mortimer, R. G. Physical Chemistry, Elsevier.

10. Engel, T. & Reid, P. Physical Chemistry, Pearson.
11. Maron, S.H., Prutton, C. F., Principles of Physical Chemistry, McMillan.
12. Puri, B.R., Sharma, L.R., and Pathania, M.S., Principles of Physical Chemistry, Vishal Publishing Co.
13. Levine, I. N. Quantum Chemistry, PHI.
14. Atkins, P.W. Molecular Quantum Mechanics, Oxford.

Practical (F.M. 20) Credit 1

1. Conductometric titration with standardization of
   (i) Strong acid-strong base
   (ii) Weak acid-strong base
   (iii) Precipitation reaction
2. Kinetics of saponification of ester by conductometric method
3. Conductometric verification of Ostwald dilution law and determination K_a for a weak acid
4. Determination of solubility product of a sparingly soluble salt by titrimetric method
5. Determination of Equilibrium constant (K_c) of the reaction $KI + I_2 = KI_3$ by partition method
6. Determination of partition co-efficient (K_d) of a solute in two immiscible solvents

Reference Books

1. Nad, A.K., Mahapatra, B. &Ghosal, A.An Advanced Course in Practical Chemistry, New Central Book Agency, 2007.
2. Das, S.C. Advanced Practical Chemistry, The World Press Pvt. Ltd., 4th Ed. 2010.
3. Mukhopadhyay, R. & Chatterjee, P. Advanced Practical Chemistry, Books &Allied (P) Ltd., 3rd Ed., 2007.
4. Maity, S. K. & Ghosh, N. K. Physical Chemistry Practical, New Central Book Agency (P) Ltd. 2012

Semester-VI

Chemistry MAJOR
Course code: CHEM6011 (3 and 4 Years)
Course title: Inorganic Chemistry (Theory)

Credit: 4

Course objective:
Development of knowledge for several basic and advanced topics of inorganic chemistry

Course outcome:
The course will help the students to develop a complete knowledge on metallurgy, lanthanides & actinides, bio-inorganic chemistry, organometallic chemistry as well as reaction kinetics & mechanism

1. General Principles of Metallurgy

Chief modes of occurrence of metals based on standard electrode potentials. Ellingham diagrams for reduction of metal oxides using carbon and carbon monoxide as reducing agent, electrolytic reduction, hydrometallurgy, methods of purification of metals: electrolytic Kroll process, Parting process, van Arkel-de Boer process and Mond's process, zone refining.

10 hours

2. Lanthanoids and Actinoids

General comparison on electronic configuration, oxidation states, colour, spectral and magnetic properties; lanthanide contraction, separation of lanthanides (ion-exchange method only). *8 hours*

3. Bioinorganic Chemistry

Elements of life: essential and beneficial elements, major, trace and ultratrace elements. Role of metal ions (specially Na^+, K^+, Mg^{2+}, $Ca^{2+,}$ $Fe^{3+/2+}$, $Cu^{2+/+}$, and Zn^{2+}) in biological systems. Metal ion transport across biological membrane Na^+/K^+-ion pump, Oxygen transport in biological systems: haemoglobin, myoglobin, hemocyanine and hemerythrin. Electron transfer proteins: Cytochromes and ferredoxins, hydrolytic enzymes: carbonate bicarbonate buffering system, carbonic anhydrase and carboxyanhydrase A, biological nitrogen fixation, photosynthesis: photosystem-I and photosystem-II, toxic metal ions and their effects, chelation therapy (examples only), Pt

and Au complexes as drugs (examples only), metal dependent diseases (examples only).

10 hours

4. Organometallic Chemistry

(i) Definition and classification of organometallic compounds on the basis of bond type, concept of hapticity of organic ligands, 18-electron and 16-electron rules (pictorial MO approach), applications of 18-electron rule to metal carbonyls, nitrosyls, cyanides. General methods of preparation of mono and binuclear carbonyls of 3d series. Structures of mononuclear and binuclear carbonyls, π-acceptor properties of CO, synergic effect and use of IR data to explain extent of back bonding, Zeise's salt: Preparation, structure, evidences of synergic effect, Ferrocene: Preparation and reactions (acetylation, alkylation, metallation, Mannich Condensation), Reactions of organometallic complexes: substitution, oxidative addition, reductive elimination and insertion reactions.

(ii) *Catalysis by Organometallic Compounds*

Study of the following industrial processes

1. Alkene hydrogenation (*Wilkinson's Catalyst*)
2. Hydroformylation
3. Wacker Process
4. Synthetic gasoline (Fischer Tropsch reaction)
5. *Ziegler-Natta* catalysis for olefin polymerization.

20 hours

5. Reaction Kinetics and Mechanism

Introduction to inorganic reaction mechanisms, substitution reactions in square planar complexes, trans- effect and its application in complex synthesis, theories of trans effect, mechanism of nucleophilic substitution in square planar complexes, thermodynamic and kinetic stability, kinetics of octahedral substitution reactions, ligand field effects and reaction rates, mechanism of substitution in octahedral complexes. *12 hours*

Reference Books

1. Arnikar, H. J. Essentials of Nuclear Chemistry, New Age International, 1995.
2. Lee, J. D. Concise Inorganic Chemistry 5th Ed., John Wiley and sons 2008.

3. Huheey, J. E.; Keiter, E.A. & Keiter, R.L. Inorganic Chemistry, Principles of Structure and Reactivity 4th Ed., Harper Collins 1993, Pearson, 2006.
4. Douglas, B.E. and McDaniel, D.H. Concepts & Models of Inorganic Chemistry Oxford, 1970.
5. Cotton, F.A., Wilkinson, G., & Gaus, P.L. Basic Inorganic Chemistry 3rd Ed.; Wiley India.
6. Miessler, G. L., Fischer, P. J., Tarr, D. A., Inorganic Chemistry, Pearson, 5th Edition.
7. Banerjee, S. P., Comprehensive Coordination Chemistry, Books & Allied Pvt. Ltd., 2019
8. Mingos, D.M.P., Essential trends in inorganic chemistry. Oxford University Press (1998).
9. Atkins, P., Overton, T., Rourke, J., Weller, M., Armstrong, F,. Shriver & Atkins, Inorganic Chemistry, Fifth Edition, Oxford University Press.

Chemistry MAJOR
Course code: CHEM6012 (3 and 4 Years)
Course title: Organic Chemistry (Theory)

Credit: 4

Course objective:
Development of knowledge for several basic and advanced topics of organic chemistry

Course outcome:
The course will help the students to develop a complete knowledge on organic spectroscopy, cyclic stereochemistry, heterocyclic chemistry as well as introductory concept on green chemistry

1. Organic Spectroscopy

(i) *UV Spectroscopy*: introduction; types of electronic transitions, end absorption; transition dipole moment and allowed/forbidden transitions; chromophores and auxochromes; bathochromic and hypsochromic shifts; intensity of absorptions (Hyper-/Hypochromic effects); application of Woodward's Rules for calculation of λ_{max} for the following systems: conjugated diene, α,β-unsaturated aldehydes and ketones (alicyclic, homoannular and heteroannular); extended conjugated systems (dienes, aldehydes and ketones); relative positions of λmax considering conjugative effect, steric effect, solvent effect, effect of pH; effective chromophore concentration: keto-enol systems; benzenoid transitions.

(ii) *IR Spectroscopy*: introduction; modes of molecular vibrations (fundamental and nonfundamental); IR active molecules; application of Hooke's law, force constant; fingerprint region and its significance; effect of deuteration; overtone bands; vibrational coupling in IR; characteristic and diagnostic stretching frequencies of C-H, N-H, O-H, C-O, C-N, C-X, C=C (including skeletal vibrations of aromatic compounds), C=O, C=N, N=O, C≡C, C≡N; characteristic/diagnostic bending vibrations are included; factors affecting stretching frequencies: effect of conjugation, electronic effects, mass effect, bond multiplicity, ring-size, solvent effect, H-bonding on IR absorptions; application in functional group analysis.

(iii) *NMR Spectroscopy*: introduction; nuclear spin; NMR active molecules; basic principles of Proton Magnetic Resonance; equivalent and non-equivalent protons; chemical shift and factors influencing it; ring current effect, anisotropic effects in alkene, alkyne, aldehydes and aromatics;; significance of the terms: up-/downfield, shielded and deshielded protons; spin coupling and coupling constant (1st order spectra); relative intensities offirst-order multiplets: Pascal's triangle; chemical and magnetic equivalence in NMR; elementary idea about non-first-order splitting; NMR peak area, integration; relative peak positions with coupling patterns of common organic compounds (both aliphatic and benzenoid-aromatic); rapid proton exchange; interpretation of NMR spectra of simple compounds.

(iv) Applications of IR, UV and NMR spectroscopy for identification of simple organic molecules. *30 hours*

2. Cyclic Stereochemistry

Alicyclic compounds: concept of I-strain; conformational analysis: cyclohexane, mono and disubstituted cyclohexane; symmetry properties and optical activity; ring-size and ease of cyclisation; conformation & reactivity in cyclohexane system: consideration of steric and stereoelectronic requirements; elimination (E2, E1), nucleophilic substitution (S_N1, S_N2, S_Ni, NGP), merged substitution-elimination; rearrangements; oxidation of cyclohexanol, esterification, saponification, lactonisation, epoxidation, pyrolytic syn elimination and fragmentation reactions.

10 hours

3. Heterocyclic chemistry

5- and 6-membered rings with one heteroatom; reactivity, orientation and important reactions (with mechanism) of furan, pyrrole, thiophene and pyridine;synthesis (including retrosynthetic approach and mechanistic details): pyrrole: Knorr synthesis,Paal-Knorr synthesis, Hantzsch; furan: Paal-Knorr synthesis, Feist-Benary synthesis and itsvariation; thiophenes: Paal-Knorr synthesis, Hinsberg synthesis; pyridine: Hantzsch synthesis;benzo-

fused 5- and 6-membered rings with one heteroatom: reactivity, orientation and importantreactions (with mechanistic details) of indole, quinoline and isoquinoline; synthesis (includingretrosynthetic approach and mechanistic details): indole: Fischer, Madelung and Reissert;quinoline: Skraup, Doebner- Miller, Friedlander; isoquinoline: Bischler-Napieralski synthesis. *10 hours*

4. Green Chemistry

Twelve principles and goals of green chemistry:

Designing greener processes: Prevention of waste/ by-products; maximum incorporation of the materials used in the process into the final products, atom Economy, calculation of atom economy of the rearrangement, addition, substitution and elimination reactions.

Green solvents– supercritical carbon dioxide, water as green solvent, ionic liquids, fluorous biphasic solvent, PEG, solventless processes, immobilized solvents.

Examples of Green Synthesis / Reactions and some real-world cases

Green synthesis of adipic acid, Hofmann Elimination, oxidation of toluene and alcohols; Diels-Alder reaction and Decarboxylation reaction, Simmons-Smith reaction, Aldol condensation reaction, Friedel-Crafts, Michael, Knoevenagel, Cannizzaro, Benzoin condensation and Dieckmann condensation.

10 hours

Reference Books

1. Eliel, E. L. & Wilen, S. H. Stereochemistry of Organic Compounds, Wiley, London.
2. Nasipuri, D. Stereochemistry of Organic Compounds, Wiley Eastern Limited.
3. Sengupta, S., Basic Stereochemistry of Organic Molecules, Oxford University Press, 2014.
4. Kalsi, P. S. Stereochemistry Conformation and Mechanism, Eighth edition, New Age International, 2014.
5. Joule, J. A. & Mills, K. Heterocyclic Chemistry, Blackwell Science.
6. Gilchrist, T. L. Heterocyclic Chemistry, 3rd edition, Pearson.
7. Bansal, R. K. Heterocyclic Chemistry, New Age International Publishers.
8. Davies, D. T., Heterocyclic Chemistry, Oxford Chemistry Primer, Oxford University Press.
9. Ahluwalia, V.K., Heterocyclic Chemistry, Narosa Publishing House, 2012.

10. Anastas, P.T. & Warner, J.K., Green Chemistry-Theory and Practical, Oxford University Press (1998).
11. Ryan, M.A. & Tinnesand, M. Introduction to Green Chemistry, American Chemical Society, Washington, 2002.
12. Lancaster, M. Green Chemistry: An Introductory Text RSC Publishing, 2nd Edition, 2010.
13. Ahluwalia, V.K., Green Chemistry: A Textbook, 1st Ed., Narosa Publishing House, 2013
14. Jag Mohan, Organic Spectroscopy: Principles and Applications, 2nd Ed., Narosa Publishing House, 2010.
15. Sharma, YY.R., Elementary Organic Spectroscopy: Principles and Chemical Applications, S. Chand & Company Ltd.
16. Manna, A.K., Organic Molecular Spectroscopy, Books & Allied (P) Ltd.2nd Ed., 2020.
17. Kalsi, P.S., Spectroscopy of Organic Compounds, New Age International Publisher

Chemistry MAJOR
Course code: CHEM6013 (3 and 4 Years)
Course title: Physical Chemistry (Theory)

Credit: 4

Course objective:
Development of knowledge for several basic and advanced topics of physical chemistry

Course outcome:
The course will help the students to develop a complete knowledge on thermodynamic applications, electrical properties of molecules, molecular spectroscopy and photochemistry

1. Applications of Thermodynamics

Condensed phase: Chemical potential of pure solid and pure liquids, ideal solution – definition, Raoult's law; mixing properties of ideal solutions, chemical potential of a component in an ideal solution; choice of standard states of solids and liquids.

Colligative properties: Vapour pressure of solution; ideal solutions, ideally diluted solutions and colligative properties; Raoult's law; thermodynamic derivation using chemical potential for the four colligative properties, relative lowering of vapour pressure, elevation of boiling point, depression of freezing point and osmotic pressure; applications

in calculating molar masses of solutes; abnormal colligative properties for dissociated and associated solutes in solution.

Heterogenous equilibria: Definitions of phase, component and degrees of freedom; phase rule and its derivations; phase diagram for water, CO_2, sulphur

1st order phase transition and Clapeyron equation; Clausius-Clapeyron equation - derivation and use; liquid vapour equilibrium for two component systems.

Binary solutions: ideal solution at fixed temperature and pressure; Nernst distribution law and its applications, principle of fractional distillation; Duhem-Margules equation; Henry's law; Konowaloff's rule; positive and negative deviations from ideal behavior; azeotropic solution; liquid-liquid phase diagram using phenol-water system; solid-liquid phase diagram; eutectic mixture.

Three-component systems: water-chloroform-acetic acid system, triangular plots

18 Hours

2. Electrical Properties of Molecules

Ionic equilibria: Chemical potential of an ion in solution; activity and activity coefficients of ions in solution; Debye-Hückel limiting law-brief qualitative description of the postulates involved, qualitative idea of the model, the equation (without derivation) for ion-ion atmosphere interaction potential; calculation of activity coefficient for electrolytes using Debye-Hückel limiting law; derivation of mean ionic activity coefficient from the expression of ion-atmosphere interaction potential; applications of the equation and its limitations.

Electromotive Force: Quantitative aspects of Faraday's laws of electrolysis, rules of oxidation/reduction of ions based on half-cell potentials, applications of electrolysis in metallurgy and industry; chemical cells, reversible and irreversible cells with examples; Electromotive force of a cell and its measurement, Nernst equation; standard electrode (reduction) potential and its application to different kinds of half-cells. application of EMF measurements in determining (a) free energy, enthalpy and entropy of a cell reaction, (b) equilibrium constants, and (c) pH values, using hydrogen, quinone-hydroquinone and glass electrodes.

Concentration cells with and without transference: liquid junction potential; determination of activity coefficients and transference numbers; qualitative discussion of potentiometric titrations (acid-base, redox, precipitation).

18 hours

3. Molecular Spectroscopy

Interaction of electromagnetic radiation with molecules and various types of spectra; Born-Oppenheimer approximation

Rotation spectroscopy: Selection rules, intensities of spectral lines, determination of bond lengths of diatomic and linear triatomic molecules, isotopic substitution

Vibrational spectroscopy: Classical equation of vibration, computation of force constant, amplitude of diatomic molecular vibrations, anharmonicity, Morse potential, dissociation energies, fundamental frequencies, overtones, hot bands, degrees of freedom for polyatomic molecules, modes of vibration.

Raman spectroscopy: Qualitative treatment of Rotational Raman effect; Effect of nuclear spin, Vibrational Raman spectra, Stokes and anti-Stokes lines; their intensity difference, rule of mutual exclusion

Nuclear Magnetic Resonance (NMR) spectroscopy: Principles of NMR spectroscopy, Larmor precession, chemical shift and lowresolution spectra, different scales, spin-spin coupling and high-resolution spectra

14 hours

4. Photochemistry

Lambert-Beer's law: Characteristics of electromagnetic radiation, Lambert-Beer's law and its limitations, physical significance of absorption coefficients; Laws of photochemistry, StarkEinstein law of photochemical equivalence quantum yield, actinometry, examples of low and high quantum yields Photochemical Processes: Potential energy curves (diatomic molecules), Frank-Condon principle and vibrational structure of electronic spectra; Bond dissociation and principle of determination of dissociation energy (ground state); Decay of excited states by radiative and non-radiative paths; Pre-dissociation; Fluorescence and phosphorescence, Jablonski diagram

Rate of Photochemical processes: Photochemical equilibrium and the differential rate of photochemical reactions, Photostationary state; HI decomposition, H_2-Br_2 reaction, dimerisation of anthracene; photosensitised reactions, quenching; Role of photochemical reactions in biochemical processes, photostationary states, chemiluminescence

10 hours

Reference Books

1. Castellan, G. W. Physical Chemistry, Narosa

2. Atkins, P. W. & Paula, J. de Atkins', Physical Chemistry, Oxford University Press.

3. McQuarrie, D. A. & Simons, J. D. Physical Chemistry: A Molecular Approach, Viva Press.

4. Levine, I. N. Physical Chemistry, Tata McGraw-Hill.

5. Moore, W. J. Physical Chemistry, Orient Longman.

6. Mortimer, R. G. Physical Chemistry, Elsevier.

7. Engel, T. & Reid, P. Physical Chemistry, Pearson.

8. Maron, S.H., Prutton, C. F., Principles of Physical Chemistry, McMillan.

9. Klotz, I.M., Rosenberg, R. M. Chemical Thermodynamics: Basic Concepts and Method, Wiley.

10. Rastogi, R. P. & Misra, R.R. An Introduction to Chemical Thermodynamics, Vikas Publishing House.

11. Glasstone, S. An Introduction to Electrochemistry, East-West Press.

12. Rakshit, P.C., Physical Chemistry, Sarat Book Distributors, 7th Ed.

13. Kapoor, K.., A Textbook of Physical Chemistry, Volume-4, McGraw Hill Education (India) Pvt. Ltd., 5th Ed.

14. Kapoor, K.., A Textbook of Physical Chemistry, Volume-5, McGraw Hill Education (India) Pvt. Ltd., 5th Ed.

Chemistry MAJOR
Course code: CHEM6014 (3 and 4 Years)
Course title: Inorganic & Physical Chemistry (Practical)

Credit: 4

F.M. 75 (60+ 15)

Course objective:
Development of practical knowledge for several basic and advanced topics of inorganic and physical chemistry
Course outcome:
The course will help the students to develop a complete practical knowledge oninorganic as well as physical chemistry

Inorganic Chemistry experiments (F.M. 30) *60 hours*

I. Volumetric estimation using redox titration:

(a) Estimation of Mohr's salt with standard $KMnO_4$ and $K_2Cr_2O_7$ solution

(b) Estimation of Fe^{+2} and Fe^{+3} (total iron) with standard $KMnO_4$ and $K_2Cr_2O_7$ solution

(c) Estimation of one of the metal ions such as iron, copper, chromium and manganese in a binary

mixture using dichromometry/permanganometry/iodometry as applicable

II. Volumetric estimation using complexometric titration:

Complexometric titration using EDTA for estimation of (a) Ca(II) or Mg(II) in a mixture and (b) total hardness of water sample

III. Colorimetric analysis of (i) Mn(II) in permanganate solution and (ii) Cr(III) in dichromate solution

Physical Chemistry Experiments (F.M. 30) *60 hours*

a. Verification of Beer-Lambert's law for aqueous $KMnO_4$ and $K_2Cr_2O_7$ solutions.

b. Determination of Indicator Constant (K_{In}) of an acid-base indicator colorimetrically.

c. Potentiometric titration of a solution of strong acid with a solution of strong alkali using quinhydrone electrode.

d. Potentiometric titration of a solution of weak acid with a solution of strong alkali and determination of pKa of the weak acid.

e. Potentiometric titration of Mohr's salt solution against standard $K_2Cr_2O_7$ solution

f. Determination of hydrolytic constant (K_h) of ammonium chloride solution pH-metrically.

g. Study the phase diagram of a binary system (phenol-water) and the effect of impurities (e.g., NaCl)

Reference Books

1. Mendham, R.C., Denney, J.D., Baines, M. Thomas and Siva Sankar, B. Vogel's Text Book on Quantitative Chemical Analysis, 6/e, Pearson.

2. Nad, A. K., Mahapatra, B. & Ghosal, A. An Advanced Course in Practical Chemistry, New Central Book Agency, 2007.

3. Das, S.C. Advanced Practical Chemistry, The World Press Pvt. Ltd., 4th Ed. 2010

4. Mukhopadhyay, R. & Chattejee, P. Advanced Practical Chemistry, Books & Allied (P) Ltd., 3rd Ed., 2007.

5. Maity, S. K. & Ghosh, N. K. Physical Chemistry Practical, New Central Book Agency (P) Ltd. 2012