Appendix-19
Resolution No. 27 {27-1 (27-1-1)}

INDEX
DEPARTMENT OF CHEMISTRY
Semester -IV/V/VI
BSc. (Industrial Chemistry) - Chemistry Component

Bachelor of Sciences in Industrial Chemistry

Category II

Industrial Chemistry Course for Undergraduate Programme of study with Industrial Chemistry as one of the Core Disciplines

SEMESTER IV

DISCIPLINE SPECIFIC CORE COURSE – 10: (DSC-10) PHARMACEUTICALS, COSMETICS AND PESTICIDES

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Pharmaceuticals, Cosmetics and Pesticides (DSC-10: Industrial Chemistry -IV)	04	02	--	02	Physics, Chemistry, Mathematics, in Class XII	NIL

Learning Objectives

The Learning Objectives of this course are as follows:

- To imparts basic knowledge of chemistry of inorganic materials such as silicates, non-silicates, ceramics, and cement.
- To enrich students with the knowledge of various types of batteries like Pb acid Battery, Li-ion Battery, Fuel Cells, Solar cell and Polymer cell.
- To impart the theoretical and practical knowledge of estimation and determination of various industrially important chemicals.

Learning outcomes

By the end of this course, students will be able to:

- Establish an appreciation of the role of inorganic chemistry in the chemical sciences.

- Analyse inorganic materials like silicates, ceramics and cement.
- Familiarized with scientific method of planning, developing, conducting, reviewing and reporting experiments.
- Draw various concepts of industrial metallurgy which will help them to explore new innovative areas of research.
- Explain scientific methods employed in inorganic chemistry.

SYLLABUS OF DSC-10

Unit 1: Drugs and Pharmaceuticals Lectures: 12

Drug discovery, design and development. Synthesis of the representative drugs of the following classes: analgesics, antipyretics, antiinflammatory agents (Aspirin, Paracetamol.), antibiotics (Penicillin, Cephalosporin, Chloromycetin, Streptomycin and Chloramphenicol), antibacterial and antifungal agents (Sulphonamides, Sulfamethoxazole), antiviral agents (Acyclovir), Central Nervous System agents (Phenobarbital, Diazepam), Cardiovascular drugs (Glyceryl trinitrate), antileprosy drug (Dapsone).

Unit 2: Cosmetics Lectures: 08

Introduction to cosmetics and perfumes, preparation and uses of the following: Hair dye, hair spray. Shampoo. Sun-tan lotions, face powder, lipsticks. talcum powder, nail enamel, creams (cold, vanishing and shaving creams), antiperspirants.

Unit 3: Pesticides Lectures: 10

Introduction to pesticides (natural and synthetic), benefits and adverse effects, changing concepts of pesticides. Synthesis and technical manufacture, uses of representative pesticides in the following classes: Organochlorines (DDT, Gammaxene), Organophosphates (Malathion, Parathion), Carbamates (Carbofuran and carbaryl), Quinones (Chloranil), Anilides (Alachlor and Butachlor).

Practical

(Credits: 2, Laboratory periods: 60)

1. Preparation of talcum powder.
2. Preparation of shampoo.
3. Preparation of nail enamel
4. Preparation of hair remover.
5. Preparation of face cream.
6. Preparation of Aspirin and its analysis.
7. Preparation of nail polish and nail polish remover.
8. To calculate acidity in a given sample of pesticide formulations as per BIS specifications.
9. To calculate alkalinity in a given sample of pesticide formulations as per BIS specifications.
10. Preparation of Antacid.

11. Preparation of paracetamol.

References (Theory and practical):

1. Vermani, O. P.; Narula, A. K. (2004), **Industrial Chemistry**, Galgotia Publications Pvt. Ltd., New Delhi.
2. Bhatia, S. C. (2004), **Chemical Process Industries,** Vol. I & II, CBS Publishers, New Delhi.
3. Barel, A.O.; Paye, M.; Maibach, H.I.(2014), **Handbook of Cosmetic Science and Technology**, CRC Press.
4. Gupta, P.K.; Gupta, S.K.(2011),**Pharmaceutics and Cosmetics**, Pragati Prakashan
5. Butler, H. (2000),**Poucher's Perfumes, Cosmetic and Soap**, Springer.
6. Kumari,R.(2018),**Chemistry of Cosmetics**,Prestige Publisher.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

DISCIPLINE SPECIFIC CORE COURSE –DSC 11: Chemistry of Carboxylic acids & derivatives. Amines and Heterocvcles

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Chemistry of Carboxylic Acids & their Derivatives, Amines and Heterocycles DSC-10: Chemistry-IV	**04**	**02**	**-**	**02**	**Class 12th with Physics, Chemistry, Mathematics**	

Learning Objectives

The Learning Objectives of this course are as follows:

- To make students learn about the chemistry of carboxylic acids and their derivatives (aliphatic and aromatic)
- To give basic understanding of amines (aliphatic & aromatic), diazonium salts
- To provide basic understanding of heterocyclic systems.

Learning outcomes

By studying this course, students will be able to:

- Understand reactions of carboxylic acids, esters, amides, amines and diazonium salts
- Understand the concept of protection and deprotection.
- Use the synthetic chemistry learnt in this course to do functional group transformations.
- Gain theoretical understanding of chemistry of heterocyclic compounds.

Syllabus

Unit 1: Carboxylic Acids and their Derivatives (aliphatic and aromatic)
(Lectures: 13)

Preparation: Oxidation reactions of alcohols, aldehydes and ketones, Acidic and alkaline hydrolysis of esters; Reactions: Hell-Volhard Zelinsky reaction,

Carboxylic acid derivatives (aliphatic): Preparation: Acid chlorides, anhydrides, esters and amides from acids and their interconversion, Claisen condensation. Reactions: Relative reactivities of acid derivatives towards nucleophiles, Reformatsky reaction, Perkin condensation.

Active methylene compounds: Keto-enol tautomerism. Preparation and synthetic applicationsof ethyl acetoacetate

Unit 2: Amines (aliphatic & aromatic) and Diazonium Salts (Lectures:10)

Amines

Preparation: from alkyl halides, Gabriel's Phthalimide synthesis, Hoffmann bromamide reaction. Reactions: Hoffmann *vs* Saytzeff elimination, carbylamine test, Hinsberg test, reaction with HNO_2, Schotten-Baumann reaction. Electrophilic substitution (case aniline): nitration, bromination, sulphonation; basicity of amines.

Diazonium salt

Preparation: from aromatic amines; Reactions: conversion to benzene, phenol and dyes.

Unit 3: Heterocyclic Compounds (Lectures: 7)

Introduction, classification, structure, nomenclature and uses. Preparation and properties of the following heterocyclic compounds with reference to electrophilic and nucleophilic substitution: furan, pyrrole, thiophene, and pyridine.

Practical Component: **Credits: 02**

(Laboratory periods: 60)

1. Systematic qualitative analysis and preparation of suitable crystalline derivative (carboxylic acids, carbonyl, alcohols, phenols, amines (1°, 2°, 3°) and amides).
2. Preparation:
   a. Acetylation of Aniline and Phenols.
   b. Benzoylation of Aniline and phenols

The above derivatives should be prepared using 0.5-1g of the organic compound. The solidsamples must be collected and may be used for recrystallization and melting point.

References:

Theory:

1. Morrison, R. N.; Boyd, R. N. **Organic Chemistry**, Dorling Kindersley (India) Pvt. Ltd.(Pearson Education).
2. Finar, I. L. **Organic Chemistry** (Volume 1), Dorling Kindersley (India) Pvt. Ltd. (PearsonEducation).
3. Ahluwalia, V.K.; Bhagat, P.; Aggarwal, R.; Chandra, R. (2005), **Intermediate for OrganicSynthesis**, I.K. International.
4. Solomons, T. W. G.; Fryhle, C. B. ; Snyder, S. A. (2016), **Organic Chemistry**, 12th Ed.,Wiley.

Practical:

1. Ahluwalia, V.K.; Dhingra, S.; Gulati, A. (2005), **College Practical Chemistry**, UniversityPress (India) Ltd.
2. Ahluwalia, V.K.; Dhingra, S. (2004), **Comprehensive Practical Organic Chemistry:Qualitative Analysis**, University Press.
3. Pasricha, S., Chaudhary, A. (2021), **Practical Organic Chemistry: Volume I**, I KInternational Publishing House Pvt. Ltd., New Delhi.
4. Pasricha, S., Chaudhary, A. (2021), **Practical Organic Chemistry: Volume II**, I KInternational Publishing House Pvt. Ltd., New Delhi.
5. Vogel, A.I. (1972), **Textbook of Practical Organic Chemistry**, Prentice-Hall.
6. Jeffery, G.H.; Bassett, J.; Mendham, J.; Denney, R.C. (1989), **Vogel's Textbook ofQuantitative Chemical Analysis**, John Wiley and Sons.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

SEMESTER V

DISCIPLINE SPECIFIC CORE COURSE – 13: (DSC-13) INDUSTRIAL CATALYSTS

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Industrial Catalysts (DSC-13: Industrial Chemistry -V)	04	02	--	02	Physics, Chemistry, Mathematics, in Class XII	NIL

Learning Objectives:

The Learning Objectives of this course are as follows:

- To imparts basic knowledge of catalysis, properties of catalysts and mode of action of catalyst.
- To enrich students with the knowledge of various types of catalysts such as organometallic catalyst, biocatalyst, shape selective catalyst and photocatalysts.
- To impart the theoretical and practical knowledge of catalysts with the view of their industrial applications.

Learning Outcomes:

By the end of this course, students will be able to:

- Establish an appreciation of the role of catalyst in industrial applications.
- Gain sound knowledge of various types of catalyst.
- Get skilled in the scientific method of planning, developing, conducting, reviewing and reporting experiments.
- Get skilled concepts of industrial catalysis which will help them to explore new innovative areas of research.

Unit 1: Introduction of Catalyst Lectures: 8

General principles of catalysis, properties of catalysts, Mode of action of catalyst, Types of catalyst (homogeneous and heterogeneous catalysis), Deactivation and regeneration of catalysts, catalytic poison, Promoter, Turnover frequency, Turnover number, Specificity and selectivity

Unit 2: Catalysis by Organometallic Compounds Lectures: 6

Study of the following industrial processes, catalytic cycle and their mechanism:
Alkene hydrogenation (Wilkinson's Catalyst), Synthetic gasoline (Fischer Tropsch reaction), Polymerisation of ethene using Ziegler-Natta catalyst

Unit 3: Biocatalysis Lectures: 5

Introduction, Kinetics of enzyme–catalysed reactions, Industrial process with biocatalyst, Aspartame through enzymatic peptide synthesis, 4-Hydroxyphenoxypropionic acid as herbicide intermediate

Unit 4: Shape selective catalysis: Zeolites Lectures: 6

Composition and structure of Zeolites, Catalytic properties of Zeolites, Shape selectivity, Isomorphic substitution of Zeolites, Metal doped Zeolites, Applications of Zeolites

Unit 5: Photocatalysis Lectures: 5

Basic principle, Photoreduction and oxidation of water, Water reduction, Water oxidation, Photocleavage of water

Practical

(Credits: 2, Laboratory periods: 60)

1. Catalytic bromination of benzene. Catalyst: $FeCl_3/AlCl_3$
2. Catalytic chlorination of benzene. Catalyst: $FeCl_3/AlCl_3$
3. Catalytic Removal of Bromates from polluted Water: Synthesis of catalyst one lab, Removal of Bromates one lab.
4. Phase-Transfer Catalytic Reactions
5. Catalytic oxidation of ammonia using chromium(III) oxide as a catalyst. Catalytic Friedal-craft reaction using $AlCl_3$ and Lewis acid catalyst. Synthesis of toluene.
6. Synthesis of "Zeolite A" catalyst.
7. Zeolite Hydrogen-Y or dil.HCl/dil.H_2SO_4 as a Catalyst for the Preparation of an Ester.
8. Synthesis of biaryl using palladium catalyst.
9. Catalytic Transfer Hydrogenation of Castor Oil
10. Reduction of Nitrobenzene

References (Theory):

1. Huheey, J. E.; Keiter, E.A.; Keiter; R. L.; Medhi, O.K. (2009), **Inorganic Chemistry-Principles of Structure and Reactivity**, Pearson Education.
2. Cotton, F.A.; Wilkinson, G. (1999), **Advanced Inorganic Chemistry,** Wiley-VCH.
3. Jens Hagen (2015) **Industrial Catalysis: A Practical Approach** Wiley-VCH Verlag GmbH & Co

References (Practical):

1. Cerrillo, J. L.; López-Hernández, I.; Palomares, A. E. **Catalytic Removal of Bromates from Water: A Hands-On Laboratory Experiment to Solve a Water Pollution Problem through Catalysis** J. Chem. Educ. 2021, 98, 1726−1731.
2. Shabestary, N.; Khazaeli, S.; Hickman, R.; **Phase-Transfer Catalytic Reactions Journal of Chemical Education**, 1998, 75, 1470-1472.
3. Volkovich, V. A.; Griffiths, T. R.; **Catalytic Oxidation of Ammonia: A Sparkling Experiment** J. Chem. Educ. 2000, 77, 2, 177.

4. Williams, D. J.; Huck, B. E.; Wilkinson, A. P. **First-Year Undergraduate Laboratory Experiments with Zeolites Chem. Educator** 2002, 7, 33–36.
5. Coker, E. N.; Davis, P. J.; **Experiments with Zeolites at the Secondary-School Level: Experience from The Netherlands** Journal of Chemical Education 1999, 76, 10, 1417.
6. Hanson RW. **Catalytic transfer hydogenation reactions for undergraduate practical programs.** J Chem Educ. 2009, 74, 430.
7. Alwaseem H, Donahue CJ, Marincean S. **Catalytic transfer hydrogenation of castor oil.** J Chem Educ. 2014; 91, 575–8.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

DISCIPLINE SPECIFIC CORE COURSE –DSC 14: COORDINATION CHEMISTRY AND ORGANOMETALLICS

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Coordination Chemistry and Organometallics DSC-13: Chemistry- V	**04**	**02**	**-**	**02**	**Class 12th with Physics, Chemistry, Mathematics**	

Learning Objectives

The Learning Objectives of this course are as follows:

- To develop basic understanding of coordination chemistry and organometallics which are of immense importance to biological systems, qualitative quantitative analysis, catalysis, medicines, paints and pigments etc.
- The students learn nomenclature, isomerism and bonding in coordination compounds with special emphasis on important coordination compounds in the biological system.
- To understand classification of organometallic compounds, the concept of hapticity and the 18-electron rule governing the stability of a wide variety of organometallic species with special emphasis on metal carbonyls.

Learning outcomes

By studying this course, students will be able to:

- Understand terms: ligand, denticity of ligands, chelate, coordination number.

- Systematically name coordination compounds.
- Discuss the various types of isomerism possible in Octahedral and Tetrahedral coordination compounds.
- Use Valence Bond Theory to predict the structure and magnetic behaviour of metal complexes and understand the terms inner and outer orbital complexes.
- Explain the meaning of the terms Δo., Δt, pairing energy, CFSE, high spin and low spin and how CFSE affects thermodynamic properties like lattice enthalpy and hydration enthalpy.
- Explain magnetic properties and colour of complexes on basis of Crystal Field Theory
- Apply 18-electron rule to rationalize the stability of metal carbonyls and related species.
- Learn how IR data can be used to understand extent of back bonding in metal carbonyls.

Syllabus

Unit 1: Introduction to Coordination compounds (Lectures: 6)

Brief discussion with examples of types of ligands, denticity and concept of chelate. IUPAC system of nomenclature of coordination compounds (mononuclear and binuclear) involving simple monodentate and bidentate ligands. Structural and stereoisomerism in complexes with coordination numbers 4 and 6.

Unit 2: Bonding in Coordination Compounds (Lectures: 14)

Valence Bond Theory (VBT): Salient features of theory, concept of inner and outer orbital complexes, Drawbacks of VBT.

Crystal Field Theory: Splitting of d orbitals in octahedral symmetry. Crystal field effects for weak and strong fields, Crystal field stabilization energy (CFSE), concept of pairing energy, Factors affecting the magnitude of Δ, Spectrochemical series, Splitting of d orbitals in tetrahedral symmetry, Comparison of CFSE for octahedral and tetrahedral fields, tetragonal distortion of octahedral geometry, Jahn-Teller distortion

Unit 3: Organometallic Chemistry (Lectures: 10)

Definition and classification with appropriate examples based on nature of metal-carbon bond (ionic, sigma, pi and multicentre bonds), Structure and bonding of methyl lithium and Zeise's salt, Structure and bonding of ferrocene, mononuclear and polynuclear carbonyls of 3d metals, 18-electron rule as applied to carbonyls, π-acceptor behaviour of carbon monoxide (MO diagram of CO to be discussed), synergic effect and use of IR data to explain extent of back bonding.

Practical Component **Credits:02**

(Laboratory periods:60)

1. Estimation of Mg^{2+} by direct complexometric titrations using EDTA.
2. Estimation of Zn^{2+} by direct complexometric titrations using EDTA.
3. Estimation of Ca^{2+} by direct complexometric titrations using EDTA.
4. Estimation of total hardness of a given sample of water by complexometric titration.
5. Determination of the composition of the Fe^{3+} - salicylic acid complex / Fe^{2+}-1, 10- phenanthroline complex in solution by Job's method.
6. Determination of the composition of the Fe^{3+} - salicylic acid complex / Fe^{2+}-1,10-phenanthroline complex in solution by mole ratio method
7. Preparation of the following inorganic compounds:
   a). Tetraamminecopper(II) sulphate
   b). Potassium trioxalatoferrate(III) trihydrate
   c). Chrome alum
   d). *Cis*- and *trans*-Potassium diaquadioxalatochromate(III)

8. Any suitable experiment (other than the listed ones) based upon complexation reactions.

References:

Theory:

1. Huheey, J.E.; Keiter, E.A., Keiter; R. L.; Medhi, O.K. (2009), **Inorganic Chemistry- Principles of Structure and Reactivity**, Pearson Education.
2. Shriver, D.D.; Atkins, P.; Langford, C.H. (1994), **Inorganic Chemistry** 2nd Ed., Oxford University Press.
3. Atkins, P.W.; Overton, T.L.; Rourke, J.P.; Weller, M.T.; Armstrong, F.A. (2010), **Inorganic *Chemistry***, 5th Edition, W. H. Freeman and Company.
4. Cotton, F.A.; Wilkinson, G.; Gaus, P.L. **Basic Inorganic Chemistry**, 3rd Edition, Wiley India.
5. Douglas, B.E.; McDaniel, D.H.; Alexander, J.J. (1994), **Concepts and Models of Inorganic Chemistry**, John Wiley & Sons.
6. Greenwood, N.N.; Earnshaw, A. (1997), **Chemistry of the Elements**, 2nd Edition, Elsevier.
7. Lee, J.D.; (2010), **Concise Inorganic Chemistry**, Wiley India.

Practicals:

1. Jeffery, G.H.; Bassett, J.; Mendham, J.; Denney, R.C. (1989),Vogel's Textbook of Quantitative Chemical Analysis, John Wiley and Sons.
2. Marr, G.; Rockett, B.W. (1972), Practical Inorganic Chemistry, Van Nostrand Reinhold.
3. Dua A, Manav N, **Practical Inorganic Chemistry,** (2017), Manakin Press.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

SEMESTER VI

DISCIPLINE SPECIFIC CORE COURSE – 16: (DSC-16) FOOD ADDITIVES, CONTAMINATION AND SAFETY

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Food Additives, Contamination and Safety (DSC-16: Industrial Chemistry - VI)	04	02	--	02	Physics, Chemistry, Mathematics, in Class XII	NIL

Learning Objectives

The Learning Objectives of this course are as follows:

- To understand the chemistry of food additives and their applications.
- To impart theoretical and practical knowledge on common food additives, contaminants and adulterants.
- To enhance the understanding of safety measures of food and evaluation techniques to determine toxicity of additives.
- To enhance knowledge about regulations and monitoring agencies of food.

Learning Outcomes:

By the end of this course, students will be able to:

- Understand and describe applications of various food additives in food processing and preservation.
- Know the merits and demerits of synthetic and natural colouring, flavouring and sweetening agents as food additives.
- Identify and prevent potential sources of food contamination
- Know Safety measures of food additives, regulations and monitoring agencies and toxicological evaluation of additives.

Unit 1: Food Additives Lectures: 12

Introduction, need of food additives in food processing and preservation. Characteristics and classification of food additives.
Antimicrobial agents. -Nitrites, sulphides, sulphur dioxide, sodium chloride, hydrogen peroxide.

Antioxidants - Introduction, mechanism of action, natural and synthetic antioxidants, technological aspect of antioxidants.
Sweeteners- Introduction, importance, classification- natural and artificial, chemistry, technology and toxicology, consideration for choosing sweetening agents.
Colors- Introduction, importance, classification- natural, artificial, and natural identical, FD&C Dyes and Lakes. polymeric colors.

Unit 2: Food Contamination & adulterants Lectures: 12

Contamination in Food: Physical, chemical contaminants- heavy metals, pesticide residues, agrochemicals, Antibiotics and Veterinary Drug residues, environmental pollutants, radionuclides, solvent residues, NOTS (Naturally Occurring Toxic Substances)
Contaminants formed during processing & packaging – nitrosamines, acrylamide, alloys, benzene, dioxins, furans, persistent organic pollutants, polymers, PAH (Polycyclic Aromatic Hydrocarbons) in smoked foods, food. fumigants, autoxidation products.
Food adulteration - Common adulterants in foods and tests to detect common adulterants.

Unit 3: Food Safety, Risks and hazards Lectures: 6

Food related hazards, regulations and monitoring agencies, interaction of additives with food ingredients and their toxicological aspects, quality evaluation of additives and contaminants, Acute and chronic studies, NOEL, ADI, LD50

Practical

Credits: 02, Laboratory periods: 60)

1. Determination of moisture content of foods by oven drying.
2. Determination of reducing and total sugar content in foods.
3. Chromatographic Separation and identification of sugars and amino acids.
4. Testing of turmeric powder, milk and mustard oil for adulterants.
5. Extraction of natural coloring and flavoring agent from flowers and fruits
6. Inspection of various food grains- cereals and coarse cereals
7. Determination of quality standards and inspection of spices and condiments.
8. Qualitative tests for hydrogenated fats, butter, and ghee.
9. Estimation of sulphur dioxide in beverages.
10. Qualitative estimation of benzoic acid in ketchup and sauces.
11. Chromatographic estimation of colour.
12. Study the effect of aerial oxidation of food.

References (Theory):

1. DeMan. (2007). **Principles of Food Chemistry**. Springer, 3rdedition
2. Emerton, V, (2008). **Food Colours**. Blackwell Publishing.
3. Wilson, R. (2007).**Sweeteners**. Blackwell Publishing.
4. Fennema OR.(1996). **Food Chemistry**. Marcel Dekker.
5. Pieternel A, Luning. & Willem, J. Marcelis. (2009). **Food Quality Management Technological and Managerial principles and practices**. Wageningen.

References (Practical):

1. Ranganna, S., & Ranganna, S. (2003). **Handbook of analysis and quality control for fruit and vegetable products**. New Delhi: Tata McGraw-Hill
2. Nielsen, S. S. (2017). **Food analysis**.
3. Vogel, Arthur I. (Arthur Israel). (1989). **Vogel's textbook of quantitative chemical analysis**. Harlow, Essex, England : New York :Longman Scientific & Technical ; Wiley,

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Quantum Chemistry and Spectroscopy DSC-16: Chemistry- VI	**04**	**02**	**--**	**02**	**Class 12th with Physics, Chemistry, Mathematics**	**NA**

Learning Objectives

The Learning Objectives of this course are as follows:

- To introduce the concepts and methodology of quantum mechanics
- Application of Quantum chemistry to spectroscopy
- To establish the relation between structure determination and spectra.

Learning outcomes

By studying this course, students will be able to:

- Understand basic principles of quantum mechanics: operators, eigen values, averages, probability distributions.
- Understand and use basic concepts of microwave, IR and UV-VIS spectroscopy for interpretation of spectra.

Syllabus

Unit 1: Quantum Chemistry **(Lectures: 16)**

Postulates of quantum mechanics, quantum mechanical operators.

Schrodinger equation and its application to free particle and particle in a 1-D box (complete solution), quantization, normalization of wave functions, concept of zero-point energy.

Qualitative treatment of H and H like atoms. Setting up of Schrodinger equation for many electron atoms.

Rotational Motion: Schrödinger equation of a rigid rotator and brief discussion of its results (solution not required). Quantization of rotational energy levels.

Vibrational Motion: Schrödinger equation of a linear harmonic oscillator and brief discussion of its results (solution not required). Quantization of vibrational energy levels.

Unit 2: Spectroscopy (Lectures: 14)

Electromagnetic radiation and its interaction with matter. Lambert-Beer's law, Jablonski's diagram. Florescence and Phosphorescence.
Difference between atomic and molecular spectra. Born- Oppenheimer approximation: Separation of molecular energies into translational, rotational, vibrational and electronic components.

Microwave Spectroscopy: Microwave (pure rotational) spectra of diatomic molecules. Selection rules.
Structural information derived from rotational spectroscopy.

IR Spectroscopy: Selection rules, IR spectra of diatomic molecules. Structural information derived fromvibrational spectra. Effect of hydrogen bonding (inter- and intramolecular) and substitution on vibrational frequencies.

Electronic Spectroscopy: Electronic excited states. Free electron model and its application to electronic spectra of polyenes. chromophores, auxochromes, bathochromic and hypsochromic shifts.

Practical component Credits:02

(Laboratory

Periods: 60)

UV/Visible

spectroscop

y

1. Study the 200-500 nm absorbance spectra of $KMnO_4$ and $K_2Cr_2O_7$ (in 0.1 M H_2SO_4) and
   determine the λ_{max} values. Calculate the energies of the two transitions in different units (J molecule^{-1}, kJ mol^{-1}, cm^{-1}, eV).
2. Study the pH-dependence of the UV-Vis spectrum (200-500 nm) of $K_2Cr_2O_7$
3. Record the 200-350 nm UV spectra of the given compounds (acetone, acetaldehyde, 2- propanol, acetic acid) in water. Comment on the effect of

structure on the UV spectra of organic compounds.

Colorimetry

4. Verify Lambert-Beer's law and determine the concentration of $CuSO_4$/ $KMnO_4$/ $K_2Cr_2O_7$/$CoCl_2$ in a solution of unknown concentration
5. Determine the concentrations of KMnO4 and $K_2Cr_2O_7$ in a mixture.
6. Study the kinetics of iodination of propanone in acidic medium.
7. Determine the amount of iron present in a sample using 1, 10-phenanthroline.
8. Determine the dissociation constant of an indicator (phenolphthalein).
9. Study the kinetics of interaction of crystal violet/ phenolphthalein with sodium hydroxide.

References:

Theory:

1. Banwell, C.N.; McCash, E.M.(2006), **Fundamentals of Molecular Spectroscopy**,Tata McGraw- Hill.
2. Kapoor, K.L.(2015),**A Textbook of Physical Chemistry**, McGraw Hill Education,
   ,Vol 4, 5th Edition, McGraw Hill Education.
3. McQuarrie, D.A.(2016),**Quantum Chemistry**, Viva Books.
4. Chandra, A. K.(2001),**Introductory Quantum Chemistry**, Tata McGraw-Hill.
5. Dua A and Tyagi P, **Molecular Spectroscopy: Quantum to Spectrum**, (2022)Atlantic Publishers & Distributors Pvt Ltd.
6. Dua A, Singh C, **Quantum Chemistry: Classical to Computational** (2015) ManakinPress.

Practical:

1. Khosla, B.D.; Garg, V.C.; Gulati, A. (2015),**Senior Practical Physical Chemistry**,
   R. Chand & Co, New Delhi.
2. Kapoor, K.L. (2019),**A Textbook of Physical Chemistry**,
   Vol.7, 1st Edition,McGraw Hill Education.
3. Garland, C. W.; Nibler, J. W.; Shoemaker, D. P.(
   2003),**Experiments in PhysicalChemistry**, 8th Edition, McGraw-Hill, New York.

Additional Resources:

1. Castellan, G. W .(2004),**Physical Chemistry**, Narosa.
2. Petrucci, R. H.(1989),**General Chemistry: Principles and Applications**, MacmillanPublishing

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

Pool of Discipline Specific Elective Courses (DSE)

11.2.1 Course Code: Industrial Chemistry DSE-1
Course Title: Green Chemistry
Total Credits: 04 (Credits: Theory-02, Practical-02)
Total Lectures: Theory- 30, Practical-60

Learning Objectives

The Learning Objectives of this course are as follows:

- To make the society to become more and more environmentally conscious by knowing huge rise in environmental pollution, depleting resources, climate change, ozone depletion, heaps and heaps of landfills piling up has forced.
- To improve the creative and innovative thinking in undergraduate students towards sustainable practices of Green Chemistry. has arisen from these concerns.
- To know the Green chemistry in a way to boost profits, increase productivity and ensure sustainability with absolute zero waste. To trained them to practice chemistry in the safest way in the laboratories as well as the chemical industry and extends to society in a sustainable future for the planet.

Learning Outcomes:

By the end of this course, students will be able to:

- Understand the twelve principles of green chemistry and also build the basic understanding of toxicity, hazard and risk related to chemical substances.
- Calculate atom economy, E-factor and relate them in all organic synthesis
- Appreciate the use of catalyst over stoichiometric reagents
- Learn to use green solvents, renewable feedstock and renewable energy sources for carrying out safer chemistry
- Appreciate the use of green chemistry in problem solving skills and critical thinking to innovate and find solutions to environmental problems.
- Learn to design safer processes, chemicals and products through understanding of inherently safer design (ISD)
- Appreciate the success stories and real-world cases as motivation for them to practice green chemistry

Unit 1: Introduction — Lectures:08

Definition of green chemistry and how it is different from conventional chemistry and environmental chemistry.

• Need of green chemistry

• Importance of green chemistry in- daily life, Industries and solving human health problems (four examples each).

• A brief study of Green Chemistry Challenge Awards (Introduction, award categories and study about five last recent awards).

Unit 2: Twelve Principles of Green Chemistry Lectures: 12

The twelve principles of the Green Chemistry with their explanations, Special emphasis on the following:

• Prevention of waste / byproducts, pollution prevention hierarchy.

• Green metrics to assess greenness of a reaction: environmental impact factor, atom economy and calculation of atom economy.

• Green solvents-supercritical fluids, water as a solvent for organic reactions, ionic liquids, solvent less reactions, solvents obtained from renewable sources.

• Catalysis and green chemistry- comparison of heterogeneous and homogeneous catalysis, biocatalysis, asymmetric catalysis and photocatalysis.

• Green energy and sustainability.

• Real-time analysis for pollution prevention.

• Prevention of chemical accidents, designing greener processes, inherent safer design, principle of ISD "What you don't have cannot harm you", greener alternative to Bhopal Gas Tragedy (safer route to carcarbaryl) and Flixiborough accident (safer route to cyclohexanol) subdivision of ISD, minimization, simplification, substitution, moderation and limitation

Unit 3: Lectures: 10

The following Real-world Cases in green chemistry should be discussed: Surfactants for carbon dioxide – replacing smog producing and ozone depleting solvents with CO_2 for precision cleaning and dry cleaning of garments. Designing of environmentally safe marine antifoulant. Rightfit pigment: Synthetic azo pigments to replace toxic organic and inorganic pigments. An efficient, green synthesis of a compostable and widely applicable plastic (polylactic acid) made from corn.

Practical
(Credits: 02, Laboratory periods: 60)

Characterization by melting point, UV-Visible spectroscopy, IR spectroscopy and any other specific method should be done (wherever applicable).

1. Preparation and characterization of nanoparticles of gold using tea leaves/silver nanoparticles using plant extracts.

2. Preparation of biodiesel from waste cooking oil and characterization (TLC, pH, solubility, combustion test, density, viscosity, gel formation at low temperature and IR can be provided).
4. Benzoin condensation using thiamine hydrochloride as a catalyst instead of cyanide.
5. Extraction of D-limonene from orange peel using liquid CO_2 prepared from dry ice.
6. Mechanochemical solvent free, solid-solid synthesis of azomethine using *p*-toluidine and *o*-vanillin/*p*-vanillin.
8. 6 Microwave-assisted Knoevenagel reaction using anisaldehyde, ethylcyanoacetate and ammonium formate.
7. Photoreduction of benzophenone to benzopinacol in the presence of sunlight.
8. Photochemical conversion of dimethyl maleate to dimethyl fumarate (*cis-trans* isomerisation)
9. Benzil- Benzilic acid rearrangement: Preparation of benzilic acid in solid state under solvent-free condition.

References (Theory):

1. Anastas, P.T., Warner, J.C. (2014), **Green Chemistry, Theory and Practice**, Oxford University Press.
2. Lancaster, M. (2016), **Green Chemistry: An Introductory Text**, 3rd Edition, RSC Publishing.
3. Cann, M. C., Connely, M.E. (2000), **Real-World cases in Green Chemistry, American Chemical Society**, Washington.
4. Matlack, A.S. (2010), **Introduction to Green Chemistry**, 2nd Edition, Boca Raton: CRC Press/Taylor & Francis Group publisher.
5. Alhuwalia, V.K., Kidwai, M.R. (2005), **New Trends in Green chemistry**, Anamalaya Publishers.
6. Sidhwani, I.T, Sharma, R.K. (2020), **An Introductory Text on Green Chemistry**, Wiley India Pvt Ltd.

References (Practical):

1. Kirchoff, M.; Ryan, M.A. (2002), **Greener approaches to undergraduate chemistry experiment**, American Chemical Society, Washington DC.
2. Sharma, R.K.; Sidhwani, I.T.; Chaudhari, M.K. (2013), **Green Chemistry Experiments: A monograph**, I.K. International Publishing House Pvt Ltd. New Delhi.
3. Pavia, D.L.; Lamponam, G.H.; Kriz, G.S.W. B. (2012), **Introduction to organic Laboratory Technique- A Microscale approach**, 4th Edition, Brooks-Cole Laboratory Series for Organic chemistry.
4. Sidhwani I.T. (2015), Wealth from Waste: A green method to produce biodiesel from waste cooking oil and generation of useful products from waste further generated. **DU Journal of Undergraduate Research and Innovation**, 1(1),131-151. ISSN: 2395-2334.
5. Sidhwani, I.T; Sharma, R.K. (2020), **An Introductory Text on Green Chemistry**, Wiley India Pvt Ltd.
6. **Monograph on Green Chemistry Laboratory Experiments**, Green Chemistry Task Force Committee, Department of Science and Technology, Government of India.

11.2.2 Course Code: Industrial Chemistry DSE-2
Course Title: Analytical Methods in Chemistry
Total Credits: 04 (Credits: Theory-02, Practical-02)
Total Lectures: Theory- 30, Practical-60

Learning Objectives

The Learning Objectives of this course are as follows:

- To make the students aware of the concept of sampling, accuracy, precision, statistical test data-F, Q and t test.
- To learn the laws of spectroscopy and selection rules governing the possible transitions in the different regions of the electromagnetic spectrum, Thermal and electroanalytical methods of analysis.
- To learn important separation methods like solvent extraction and chromatography. The practical exposure to the latest instrumentation and to detect analytes in a mixture.

Learning Outcomes:

By the end of this course, students will be able to:

- Perform experiments with accuracy and precision.
- Develop methods of analysis for different samples independently.
- Test contaminated water samples.
- Understand basic principles of instruments like Flame Photometer, UV-vis spectrophotometer.
- Learn separation of analytes by chromatography.
- Apply knowledge of geometrical isomers and keto-enol tautomers to analysis.
- Determine composition of soil.
- Estimate macronutrients using Flame photometry.

Unit 1: Qualitative and quantitative aspects of analysis Lectures: 04

Sampling, evaluation of analytical data, errors, accuracy and precision, methods of their expression. Normal law of distribution of indeterminate errors, statistical test of data; F, Q and t test, rejection of data, and confidence intervals.

Unit 2: Optical methods of analysis Lectures:10

Origin of spectra, interaction of radiation with matter, fundamental laws of spectroscopy and selection rules. UV-Visible Spectrometry: Basic principles of instrumentation (choice of source, monochromator and detector) for single and double beam instrument; Transmittance. Absorbance and Beer-Lambert law. Absorption and Emission Spectrometry: Basic principles

of instrumentation (choice of source, monochromator, detector, choice of flame and Burner designs).

Unit 3: Thermal methods of analysis Lectures:04

Theory of thermogravimetry (TG) and basic principle of instrumentation of thermal analyser. Techniques for quantitative estimation of Ca and Mg from their mixture.

Unit 4: Electroanalytical methods Lectures:04

Classification of electroanalytical methods, basic principle of pH metric, potentiometric and conductometric titrations. Techniques used for the determination of equivalence points. Techniques used for the determination of pKa values.

Unit 5: Separation techniques Lectures:08

Solvent extraction: Classification, principle and efficiency of the technique. Qualitative and quantitative aspects of solvent extraction: extraction of metal ions from aqueous solution, extraction of organic species from the aqueous and nonaqueous media. Chromatography: Classification, principle and efficiency of the technique, Mechanism of separation: adsorption, partition &ion-exchange, Development of chromatograms: frontal, elution and displacement methods.

Practical
(Credits: 02, Laboratory periods: 60)

1. Separation of mixtures by paper chromatography and reporting the Rf values:
   (i) Co^{2+} and Ni^{2+}.
   (ii) Amino acids present in the given mixture.
2. Solvent Extractions

To separate a mixture of Ni^{2+} & Fe^{2+} by complexation with DMG and extracting the Ni^{2+} DMG complex in chloroform, and determine its concentration by spectrophotometry.

3. Analysis of soil:
   (i) Determination of pH of soil.
   (ii) Total soluble salt
   (iii) Estimation of calcium and magnesium
   (iv) Qualitative detection of nitrate and phosphate
4. Ion exchange:
   (i) Determination of exchange capacity of cation exchange resins and anion exchange resins.
   (ii) Separation of amino acids from organic acids by ion exchange chromatography.
5. Spectrophotometry
   (i) Verification of Lambert-Beer's law and determination of concentration of a coloured species ($CuSO_4$, $KMnO_4$, $CoCl_2$, $CoSO_4$)
   (ii) Determination of concentration of coloured species via following methods;

(a) Graphical method
(b) Epsilon method
(c) Ratio method
(d) Standard addition method

References (Theory):

1. Willard, H.H.(1988),**Instrumental Methods of Analysis**, 7th Edition, Wardsworth Publishing Company.
2. Christian, G.D.(2004),**Analytical Chemistry**, 7th Edition, John Wiley & Sons, New York.
3. Harris, D. C.(2007),**Quantitative Chemical Analysis**,7th Edition, Freeman.
4. Khopkar, S.M. (2008), **Basic Concepts of Analytical Chemistry**, New Age International Publisher.
5. Skoog, D.A.; Holler F.J.; Nieman, T.A. (2017), **Principles of Instrumental Analysis,** Thomson Asia Pvt. Ltd.

References (Practical):

1. Jeffery, G.H.; Bassett, J.; Mendham, J.; Denney, R.C.(1989),**Vogel's Textbook of Quantitative Chemical Analysis**, John Wiley and Sons.

11.2.3 Course Code: Industrial Chemistry DSE-3
Course Title: Basics of Polymer Chemistry
Total Credits: 04 (Credits: Theory-02, Practical-02)
Total Lectures: Theory- 30, Practical-60

Learning Objectives

The Learning Objectives of this course are as follows:

- To help the student to know about the synthesis, properties and applications of polymers.
- To give glimpse of polymer industry to the student and help them to choose their career in the field of polymer chemistry.

Learning Outcomes:

By the end of this course, students will be able to:

- Know about history of polymeric materials and their classification
- Learn about different mechanisms of polymerization and polymerization techniques
- Learn about different methods of finding out average molecular weight of polymers
- Differentiate between glass transition temperature (Tg) and crystalline melting point (Tm)

- Determine Tg and Tm
- Learn properties and applications of various useful polymers in our daily life.

Unit 1: Introduction to Polymeric Materials Lectures:10

History of polymeric materials, Different schemes of classification of polymers, Polymer nomenclature
Molecular forces and chemical bonding in polymers, Physical and chemical properties of polymers
Solubility and Criteria for polymer solubility, Texture of Polymers, modification of polymers, Structure and property relationships, Introduction to conducting and biodegradable polymers.

Unit 2: Characterization of Polymers: Lectures:10

Thermal characterisation of polymer: Glass transition temperature (Tg), thermal stability and decomposition of polymers, Molecular weight of polymers (Mn, Mw, etc.) by end group analysis, viscometry, light scattering technique and osmotic pressure methods.
Structural characterisation of polymers by IR and NMR spectroscopy.

Unit 3: Preparation, Properties and Uses of Polymers: Lectures:10

Brief introduction to polymerisation, mechanism, properties and application of the following polymers: polyolefins, polystyrene, poly(vinyl chloride), poly(vinyl acetate), polyurethanes, acrylic polymers and polyamides. Phenol formaldehyde and urea formaldehyde, Silicone polymers, Conducting Polymers: polyacetylene, polyaniline, polypyrrole, polythiophene., Biopolymer: Cellulose and Chitosan.

Practical:
(Credits: 2, Laboratory periods: 60)

1. Preparation of nylon 6,6.
2. Redox polymerization of acrylamide.
3. polymerization of acrylonitrile.
4. Preparation of urea-formaldehyde resin.
5. Preparations of phenol-formaldehyde resin.
6. Determination of molecular weight of different polymers in water by viscometry.
7. Estimation of the amount of HCHO in the given solution by sodium sulphite method.
8. Demonstration for chemical structure and functional group in polymers using IR spectroscopy.
9. Purification of monomer and polymerisation of Styrene and Polymethylmethacrylate using BPO (Benzoyl Peroxide).
10. Polymerization of aniline and pyrrole by chemical polymerisation method.
11. Preparation of poly methylacrylate by emulsion and bulk polymerisation and compare the results.

12. Characterisation of polymers by IR spectroscopy.

References (Theory):

1. Ahluwalia V.K. & Mishra A**. Polymer Science :A Textbook**(2009) Anne Books.
2. Odian, G. (2004), **Principles of Polymerization**, John Wiley.
3. Billmeyer, F.W. (1984),**Text Book of Polymer Science**,3rd Ed., John Wiley.
4. Ghosh, P. (2001),**Polymer Science & Technology**, Tata Mcgraw-Hill.
5. Lenz, R.W. (1967),**Organic Chemistry of Synthetic High Polymers**, Interscience (Wiley).

References (Practical):

1. Hundiwale ,D.G.,Athawale V.D ,Kapadi, U.R.& Gite V.V, **Experiments in Polymer Science ,**New Age International Publishers .
2. Allcock, H.R.; Lampe, F. W.; Mark, J. E. (2003), **Contemporary Polymer Chemistry**, Prentice-Hall.
3. Fried, J.R. (2003), **Polymer Science and Technology**, 2nd Ed, Prentice-Hall.
4. Munk, P.; Aminabhavi , T. M. (2002), **Introduction to Macromolecular Science,** John Wiley & Sons.
6. Sperling, L.H. (2005), **Introduction to Physical Polymer Science**, John Wiley & Sons.

11.2.4 Course Code: Industrial Chemistry DSE-4
Course Title: Molecules of Life
Total Credits: 04 (Credits: Theory-02, Practical-02)
Total Lectures: Theory- 30, Practical-60

Learning Objectives

The Learning Objectives of this course are as follows:

- To deliver information about the chemistry of carbohydrates, proteins & enzymes and its relevance in the biological system using suitable examples.
- To understand the structural principles that govern reactivity/physical /biological properties of biomolecules as opposed to learning structural details.

Learning Outcomes:

By the end of the course, the students will be able to:

- Learn and demonstrate how the structure of biomolecules determines their chemical properties, reactivity and biological uses.
- Gain an insight into the mechanism of enzyme action and inhibition.
- Understand the basic principles of drug-receptor interaction and SAR.

Unit 1: Carbohydrates Lectures: 12

Classification of carbohydrates, reducing and non-reducing sugars, biological functions, general properties and reactions of glucose and fructose, their open chain structure, epimers, mutarotation and anomers, reactions of monosaccharides, determination of configuration of glucose (Fischer proof), cyclic structure of glucose. Haworth projections. Cyclic structure of fructose. Linkage between monosaccharides: structure of disaccharides (sucrose, maltose, lactose) and polysaccharides (starch and cellulose) excluding their structure elucidation.

Unit 2: Amino Acids, Peptides and Proteins Lectures: 10

Classification of amino acids and biological uses of amino Acids, peptides and proteins. Zwitterion structure, isoelectric point and correlation to acidity and basicity of amino acids. Determination of primary structure of peptides, determination of N-terminal amino acid (by Edman method) and C– terminal amino acid (with carboxypeptidase enzyme). Synthesis of simple peptides (up to dipeptides) by N-protection (t-butyloxycarbonyl) & C-activating groups (only DCC) and Merrifield solid phase synthesis, Overview of primary, secondary, tertiary and quaternary structure of proteins, denaturation of proteins.

Unit 3: Enzymes Lectures: 04

Classification of enzymes and their uses (mention Ribozymes). Mechanism of enzyme action, factors affecting enzyme action, Coenzymes and cofactors and their role in enzyme action, specificity of enzyme action (including stereospecificity).

Unit 4: Nucleosides, Nucleotides and Nucleic acids Lectures: 04

Components of Nucleic acids: Adenine, guanine, thymine, cytosine and uracil (structure only), other components of nucleic acids, nucleosides and nucleotides (nomenclature), structure of polynucleotides; structure of DNA (Watson-Crick model) and RNA (types of RNA), difference between DNA and RNA

Practical
(Credits: 02, Laboratory periods: 60)

1. Estimation of glucose by Fehling's solution.
2. Determination of total sugar content by ferricyanide method (volumetric/colorimetric method).
3. Study of the titration curve of glycine and determine the isoelectic point of glycine.
4. Estimation of proteins by Lowry's method.

5. Qualitative tests for amino acids, proteins and carbohydrates.
6. Separation and identification of mixture of sugars by paper chromatography.
7. Separation and identification of mixture of Amino acids by paper chromatography.
8. Study of the action of salivary amylase on starch under optimum conditions and find the enzyme activity.
9. Study the effect of temperature on activity of salivary amylase.
10. Extraction of DNA from onion/cauliflower.

References (Theory):

1. Finar, I. L. **Organic Chemistry** (Volume 1 & 2), Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
2. Morrison, R. N.; Boyd, R. N., Bhattacharjee, S.K. (2010), **Organic Chemistry**, 7th Edition, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
3. Berg, J. M.; Tymoczko, J. L.; Stryer, L. (2019), **Biochemistry**, 9th Ed., W. H. Freeman Co Ltd.

References (Practical):

1. Furniss, B.S.; Hannaford, A.J.; Smith, P.W.G.; Tatchell, A.R. (2012), **Vogel's Textbook of Practical Organic Chemistry**, Pearson.
2. **Manual of Biochemistry Workshop**, 2012, Department of Chemistry, University of Delhi.

11.2.5 Course Code: Chemistry DSE-5
Course Title: Main Group Chemistry
Total Credits: 04 (Credits: Theory-02, Practical-02)
Total Lectures: Theory- 30, Practical-60

Learning Objectives

The Learning Objectives of this course are as follows:

- To provide basic understanding of the fundamental principles of metallurgy through study of the different methods of extraction and refining of metals.
- To illustrate the diversity and fascination of inorganic chemistry through the study of structure, properties and utilities of s- and p-block elements and their compounds

Learning Outcomes:

By the end of the course, the students will be able to:

- Understand the basis of occurrence of metals in nature and the methods that can be applied on minerals to extract the metals from them.
- Explain the importance of free energy of formation of oxides with the choice of reducing agent for extracting the metals.
- Understand and explain the importance of refining of metals and the choice of a refining procedure
- Explain the group trends observed for different properties of s and p block elements
- Explain the structures and the bonding basis of compounds of s- and p- block elements
- Explain the uniqueness observed in alkali metals and some other main group elements
- Understand and explain the polymerization of inorganic ions to generate inorganic polymers and the difference between organic and inorganic polymers.

Unit 1: General Principles of Metallurgy — Lectures: 06

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 with reference to cyanide process for silver and gold. Methods of purification of metals: Electrolytic process, Van Arkel-De Boer process, Zone refining.

Unit 2: General Properties — Lectures: 05

General group trends of s- and p-block elements with special reference to melting and boiling points, flame colour, metallic character and complex formation tendency, diagonal relationship and anomalous behaviour of first member of each group, Alkali metal solutions in liquid ammonia

Unit 3: Structure, Bonding, Properties and Applications Lectures: 15

Structure, bonding, properties (Acidic/Basic nature, stability, ionic/covalent nature, oxidation/reduction, hydrolysis, thermal stability) and applications of the following:
Crown Ethers and cryptates of Alkali metals
Hydrides: hydrides of Group 13 (only diborane), Group 14, Group 15 (EH_3 where E = N, P, As, Sb, Bi), Group 16 and Group 17.
Oxides: Oxides of nitrogen, phosphorus and sulphur.
Oxoacids: oxoacids of phosphorus, sulphur and chlorine
Halides of phosphorus

Unit 4: Inorganic Polymers Lectures:04

Preparation, properties, structure and uses of the following:

Borazine, Silicates and Silicones

Practical
(Credits: 02, Laboratory periods: 60)

Qualitative semi-micro analysis of mixtures containing 2 anions and 2 cations (preferably 7-8 mixtures). Emphasis should be given to the understanding of the chemistry of different reactions. The following radicals are suggested:

CO_3^{2-}, NO_2^- , S^{2-}, SO_3^{2-}, SO_4^{2-} , $S_2O_3^{2-}$, CH_3COO^-, F^-, Cl^-, Br^-, I^-, NO_3^- , BO_3^{3-}, $C_2O_4^{2-}$, PO_4^{3-}, NH_4^+, K^+, Pb^{2+}, Cu^{2+}, Cd^{2+}, Bi^{3+}, Sn^{2+}, Sb^{3+}, Fe^{3+}, Al^{3+}, Cr^{3+}, Zn^{2+}, Mn^{2+}, Co^{2+}, Ni^{2+}, Ba^{2+}, Sr^{2+}, Ca^{2+}, Mg^{2+}

The mixtures may contain combination of anions/one interfering anion.

Spot tests should be preferred wherever applicable.

References (Theory):

1. Lee, J.D.; (2010), **Concise Inorganic Chemistry**, Wiley India.
2. Huheey, J.E.; Keiter, E.A.; Keiter; R. L.; Medhi, O.K. (2009), **Inorganic Chemistry-Principles of Structure and Reactivity**, Pearson Education.
3. Douglas, B.E.; McDaniel, D.H.; Alexander, J.J. (1994), **Concepts and Models of Inorganic Chemistry**, John Wiley & Sons.
4. Atkins, P.W.; Overton, T.L.; Rourke, J.P.; Weller, M.T.; Armstrong, F.A. (2010), **Shriver and Atkins Inorganic Chemistry**, 5th Edition, Oxford University Press.
5. Housecraft, E. H.; Sharpe, A.G. (2018), **Inorganic Chemistry**, 5th Edition, Pearson.

6. F.A. Cotton & G. Wilkinson (1999), **Advanced Inorganic Chemistry**, 6th Edition, John Wiley & Sons.

References (Practical):

1. Vogel, A.I. (1972), **Qualitative Inorganic Analysis**, Longman.

2. Svehla, G. (1996), **Vogel's Qualitative Inorganic Analysis**, Prentice Hall.

11.2.6 Course Code: Chemistry DSE-6
Course Title: Nanoscale Materials and their Applications
Total Credits: 04 (Credits: Theory-02, Practical-02)
Total Lectures: Theory- 30, Practical-60

Learning Objectives

The Learning Objectives of this course are as follows:

- To provide an introduction to nanoscale materials and their applications.
- To provides an insight into bottom-up and top-down-approach, the methods of synthesis of nanoparticles, simple characterization techniques and applications of nanomaterials.

Learning Outcomes:

By the end of the course, the students will be able to:

- Understand the concept of nano dimensions.
- Know the various methods of preparation of nanomaterials.
- Understand the principles of optical and electron microscopy techniques of characterizing nanomaterials.
- Understand the Appreciate the real life applications of nanomaterials.

Unit 1: Introduction to Nanodimensions Lectures: 12

0D, 1D, 2D nanomaterials, Quantum Dots, Nanoparticles, Nanostructures (nanowires, thin films, nanorods), carbon nanostructures (carbon nanotubes, carbon nanofibers, fullerenes), Size Effects in nano systems, Quantum confinement and its consequences, Semiconductors. Band structure and band gap. Optical Properties Surface plasmon resonance

Unit 2: Preparation of Nanomaterials Lectures: 10

Top down and Bottom up approach, Photolithography. Ball milling. Vacuum deposition. Physical vapor deposition (PVD), Chemical vapor deposition (CVD), Thermal decomposition, Chemical reduction, Sol-Gel synthesis, Hydrothermal synthesis, Spray pyrolysis, Electrochemical deposition, Pulsed Laser deposition. Characterization of nanomaterials: Basic principle of optical methods and electron microscopy.

Unit 3: Applications of Nanomaterials Lectures: 8

Nanomaterials as Catalysts, semiconductor nanomaterials as photocatalysts, Nanocomposites as catalysts. Carbon nanostructures as catalytic nanoreactors, metal and metal oxides confined inside carbon nanostructures, Nanowires and thin films for photonic devices (LEDs, solar cells, transistors).

Practical
(Credits: 02, Laboratory periods: 60)

1. Synthesis of silver nanoparticles by chemical methods and characterization using UV-visible spectrophotometer.
   a. Turkevich Method
   b. Burst Method
2. Synthesis of silver nanoparticles by green approach methods (using soluble starch, glucose or cinnamon bark) and characterization using UV-visible spectrophotometer.
3. Synthesis of metal sulphide nanoparticles and characterization using UV-visible spectrophotometer and determination of Band gap.
   a. MnS
   b. ZnS
   c. CuS
4. Intercalation of hydrogen in tungsten trioxide and its conductivity measurement using conductometer.
5. Synthesis of pure ZnO and Cu doped ZnO nanoparticles.
6. Phytochemicals mediated synthesis of gold nanoparticles (AuNPs) using tea leaves and to study the effect of size on color of gold/silver nanoparticles.
7. Preparation of magnetic nanoparticles (MNPs) of Fe_3O_4 using green tea leaf extract.
8. Any suitable experiment (other than the listed ones) based upon complexation reactions.

References (Theory):

1. West, A. R. (2014), **Solid State Chemistry and Its Application**, Wiley.
2. Smart, L. E.; Moore, E. A., (2012), **Solid State Chemistry: An Introduction**, CRC Press Taylor & Francis.
3. Rao, C. N. R.; Gopalakrishnan, J. (1997), **New Direction in Solid State Chemistry**, Cambridge University Press.

4. Poole Jr.; Charles P.; Owens, Frank J. (2003), **Introduction to Nanotechnology**, John Wiley and Sons. Harris, D. C. (2007), **Quantitative Chemical Analysis**,6th Edition, Freeman.
5. Chattopadhyay, K.K.; Banerjee, A. N. (2009), **Introduction to Nanoscience and Technology**, PHI.

References (Practicals):

1. Orbaek, W.; McHale, M.M.; Barron, A. R.; **Synthesis and Characterization of Silver Nanoparticles for An Undergraduate Laboratory**,J. Chem. Educ. 2015, 92, 339−344.
2. MacDiarmid, G.; Chiang, J.C.; Richter, A.F.; Somasiri, N.L.D.(1987), **Polyaniline: Synthesis and Characterization of the Emeraldine Oxidation State by Elemental Analysis**, L. Alcaeer (ed.), Conducting Polymers, 105-120, D. Reidel Publishing.
3. Cheng, K.H.; Jacobson, A.J.; Whittingham, M.S. (1981),**Hexagonal Tungsten Trioxide and Its Intercalation Chemistry, Solid State Ionics**, 5, 1981, 355-358.
4. Ghorbani H.R.; Mehr, F.P; Pazoki, H; Rahmani, B.M.; **Synthesis of ZnO Nanoparticles by Precipitation Method**, Orient J Chem 2015, 31(2).

11.2.7 Course Code: Chemistry DSE-7
Course Title: Chemistry of Polymers, Dyes and Natural Products
Total Credits: 04 (Credits: Theory-02, Practical-02)
Total Lectures: Theory- 30, Practical-60

Learning Objectives

The Learning Objectives of this course are as follows:

- Introducing the students to the process of converting knowledge of chemistry into marketable products for commercial gain**.**
- To learn the applications of chemistry in small industries.
- To give knowledge for business opportunities for small and medium enterprises through chemistry.

Learning Outcomes:

By the end of this course the students will be able to:

- Learn about the chemistry of natural and synthetic polymers including fabrics and rubbers.
- Understand the chemistry of biodegradable and conducting polymers and appreciate the need of biodegradable polymers with emphasis on basic principles.
- Comprehend the theory of colour and constitution as well as the chemistry of dyeing.

- Know applications of various types of dyes including those in foods and textiles.
- Understand the chemistry and applications of natural products like terpenoids and alkaloids.

Unit-1: Polymers Lectures:12

Introduction and classification based on origin, monomer units, thermal response, mode of formation, structure, application and tacticity; di-block, tri-block and amphiphilic polymers; Weight average molecular weight, number average molecular weight, glass transition temperature (Tg) of polymers; Polymerisation Reactions-Addition and condensation. Mechanism of cationic, anionic and free radical addition polymerization; Ziegler-Natta polymerisation of alkenes.

Preparation and applications of: Plastics -thermosetting (phenol-formaldehyde, polyurethanes) and thermosoftening (PVC, polythene); Fabrics -natural (cellulose and synthetic derivatives of cellulose like rayon and viscose); synthetic (acrylic, polyamide, polyester); Rubbers-natural and synthetic: Buna-N, Buna-S, Neoprene, silicon rubber; Vulcanization; Polymer additives; Introduction to Specialty Polymers: electroluminescent (Organic light emitting diodes), conducting, biodegradable polymers and liquid crystals.

Unit-2: Dyes Lectures: 08

Classification, Colour and constitution; Mordant and Vat Dyes; Chemistry of dyeing. Synthesis and applications of Azo dyes – Methyl orange, Congo red; Triphenyl methane dyes- Crystal violet; Phthalein Dyes – Phenolphthalein; Natural dyes –Structure elucidation and synthesis of Alizarin and Indigotin; Edible Dyes with examples.

Unit 3: Natural Product Chemistry- An Introduction to Terpenoids and Alkaloids Lectures: 10

Terpenes: Introduction, occurrence, classification, uses, isoprene and special isoprene rule; structure elucidation, synthesis and industrial application of citral.

Alkaloids: Introduction, occurrence, classification, uses, general structural features, general methods for structure elucidation including Hoffmann's exhaustive methylation and Emde's method. Structure elucidation, synthesis and physiological action of Nicotine.

Practical
(Credits: 02, Laboratory periods: 60)

1. Preparation of Methyl Orange.
2. Preparation of Malachite Green.
3. Recycling of Plastic: Moulding of plastic or Cracking of plastic.
4. Preparation of Urea-formaldehyde resin.
5. (a) Dyeing of different fabrics (cotton, wool, silk) using Alizarin or any other dye.
   (b) Preparation of azo dye on the surface of the fabric.

6. Qualitative test for identification of alkaloids (Dragendorff Reagent and Mayer's reagent test) and terpenoids (Salkowski test).
7. Preparation of perichromic dye using p-amino Phenol and p-nitro benzaldehyde.

References (Theory):

1. Finar, I.L. (2008), **Organic Chemistry**, Volume 2, 5th Edition, Pearson Education
2. Saunders, K. J. (1988), **Organic Polymer Chemistry**,2nd Edition Chapman & Hall, London
3. Campbell, Ian M., (2000), **Introduction to Synthetic Polymers**, 2nd Edition Oxford University Press, USA.
4. Bahadur, P. and Sastry, N.V. (2002) **Principles of Polymer Science** Narosa, New Delhi
5. Patrick, G. **An Introduction to Medicinal Chemistry** (2013), 4th Edition, Oxford University Press.
6. Priscilla Abarca, Patricia Silva, Iriux Almodovar and Marcos Caroli ezende*Quim. Nova, Vol. 37, No. 4, 745-747, 2014. http://dx.doi.org/10.5935/0100-4042.20140120

11.2.8 Course Code: Chemistry DSE-8
Course Title: Chemistry: IT Skills and Molecular Modelling
Total Credits: 04 (Credits: Theory-02, Practical-02)
Total Lectures: Theory- 30, Practical-60

Learning Objectives

The Learning Objectives of this course are as follows:

- To introduce the students to basic computer skills that are a must for a new age chemist.
- To acquaints the students with data tabulation, calculation, graph plotting, data analysis and document. Preparation using various software (preferably open-source).
- To learn about molecular modelling, its applications to various molecular systems, energy minimization techniques, analysis of Mulliken Charge and ESP Plots.

Learning Outcomes:

By the end of the course, the students will be able to:

- Become familiar with the use of computers
- Use software for tabulating data, plotting graphs and charts, carry out statistical analysis of the data.
- Solve chemistry problems and simulate graphs.
- Prepare documents that will incorporate chemical structure, chemical equations, mathematical expressions from chemistry.
- Understand theoretical background of computational techniques and selective application to various molecular systems.
- Learn ESP Plots by suitable software, electron rich and electron deficient sites.
- Compare computational and experimental results and explain deviations.
- Perform Optimization of geometry parameters of a molecule (such as shape, bond length and bond angle) through use of software like Chem Sketch and Argus Lab in interesting hands-on exercises.

Unit 1: Introduction to important software in chemistry Lectures:10

Introduction to different software available for drawing chemical structures (Proprietary and Open-source) like ACD Chemsketch and 3-D viewer, ChemDraw.
Carrying out simple calculations on anyone of the following software: ArgusLab, Pymol, Avogadro, Molview, MarvinSketch.

Draw structures of various compounds (aliphatic, aromatic, heterocyclic with different functional groups) using software. Save the structures in various file formats. Incorporate the structures in word document and powerpoint presentation. SMILES notation for the chemical structures. PDB Files.

Unit 2: Handling of Numerical Data Lectures:10

Using a spreadsheet software: applying basic functions and formulae to the data, drawing charts, tables and graphs, displaying the equation of graph along with the R^2 value, incorporating tables and graphs in Word files, graphical solution of equations, plotting pressure-volume curves of van der Waals gases, Maxwell-Boltzmann distribution, concentration versus time graphs, spectral data, titration curves, etc.

Unit 3: Molecular Modelling Lectures: 10

Introduction to molecular modelling, overview of classical and quantum mechanical methods (semi empirical, ab initio and DFT) and molecular mechanics method

Intrinsic Reaction Coordinates, Stationary points, Equilibrium points – Local and Global minima, concept of transition state with examples.

Practical
(Credits: 02, Laboratory periods: 60)

Plotting graphs using a spreadsheet

1. van der Waals isotherms
2. Maxwell-Boltzmann distribution curves as function of temperature and molecular weight
3. Plot the conductometric titration curve for

   a) strong acid vs strong base and b) weak acid vs strong base

4. Plot the pH metric titration curve for

   a) strong acid vs strong base and b) weak acid vs strong base

5. Plot the graphs for the kinetics of first order reaction.

Molecular Modelling

6. Optimise and compare the geometry parameters of H_2O and H_2S using Argus Lab.
7. Compare the basicities of ammonia, methylamine, dimethylamine and trimethylamine using Argus Lab by comparing Mulliken charges and ESP maps.
8. Compare C-C bond lengths and bond order in ethane, ethene and ethyne using Argus Lab.

9. Determine enthalpy of isomerization of cis and trans-2-butene in Argus Lab.
10. Compare the HAH bond angles for the second row hydrides (BeH_2, CH_4, NH_3, H_2O) and compare with the results from qualitative MO theory.

References (Theory):

1. Levie, R. de. (2001), **How to use Excel in analytical chemistry and in general scientific data analysis**, Cambridge Univ. Press.
2. Lewars, E. (2003), **Computational Chemistry,** Kluwer academic Publisher.
3. Cramer, C.J.(2004), **Essentials of Computational Chemistry,** John Wiley & Sons.
4. Hinchcliffe, A. (1996), **Modelling Molecular Structures,** John Wiley & Sons.
5. Leach, A.R.(2001), **Molecular Modelling,** Prentice-Hall.

References (Practical):

1. Lewars, E. **(2003), Computational Chemistry,** Kluwer academic Publisher.
2. Cramer, C.J. **(2004), Essentials of Computational Chemistry,** John Wiley & Sons.
3. Hinchcliffe, A. **(1996), Modelling Molecular Structures,** John Wiley & Sons.

Note: Some of the papers are same as in B Sc (H) Chemistry and B Sc Physical Sciences.