Appendix-28
Resolution No. 5-12

INDEX

B.Sc. Analytical Chemistry

SEMESTER-V & VI

BSc. (Analytical Chemistry)
(Analytical and Chemistry Component)

Kirori Mal College

SEMESTER V

DISCIPLINE SPECIFIC CORE COURSE CHEM-DSC -13: Analytical Chemistry- V: Instrumental Methods Of Analysis-I

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		
Instrumental Methods of Analysis-I DSC-13: Analytical Chemistry-IV	**04**	**02**	**0**	**02**	**Class 12th with Physics, Chemistry, Mathematics**	**NIL**

Learning Objectives

This course is to make students understand the following concepts:

• Spectroscopic methods of analysis
• Principles of UV and Visible spectrophotometry and its applications
• Various components of UV and Visible spectrophotometry
• Single and double beam instruments
• IR spectroscopy and its applications

Learning Outcomes:

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

- Different types of spectroscopic methods of analysis.
- The instrumentation and the applications of the UV- Visible and IR spectrometry.

Syllabus of DSC-13

THEORY COMPONENT-

Unit 1: Basic Concepts of Spectroscopy (04 Hours)

An introduction to spectroscopic methods of analysis: Electromagnetic radiation, frequency, wavelength, Planck's equation, Electromagnetic spectrum, mathematical description of wave, superposition of waves, optical interferences, interaction of radiation with the matter, emission of radiation, absorption of radiation, scattering, line broadening.

Unit 2: UV- Visible Spectrophotometry: (12 Hours)

A. Lambert-Beer's law

B. Principles, Electronic transitions, Instrumentation, Single/double beam instrument

C. Industrial/Research Applications: Effect of solvent and conjugation on λ_{max}, Effect of cis-trans geometrical isomerism (e.g. stilbene, cinnamic acid, maleic and fumaric acid), calculation λ_{max} of different compounds (homo- and heteroannular dienes, unsaturated carbonyl compounds) (Woodward-Fieser Rule and Schott's Rule) and calculation of stoichiometric ratios of metal-ligand complex using Job's method.

Unit 3: IR Spectrophotometry: (10 Hours)

A. Principle, Modes of vibrations, Bands (Fundamental, overtones, etc)

B. Instrumentation: FT-IR, sample handling, special cautions during scanning.

C. Applications: Identification of the functional groups (mention the use of fingerprint region and functional group region) and simple organic molecules, Factors affecting the absorption frequency.

Unit 4: Raman spectroscopy: (04 Hours)

Introduction, basic principle, instrumentation, the difference between Raman and IR, Applications of Raman spectroscopy.

PRACTICAL COMPONENT (60 Hours)

1. Comparison of UV spectra of $K_2Cr_2O_7$ in aqueous and acidified medium (UV range 180-250 nm).
2. Determination of the pK_a of an indicator (methyl orange) using a spectrophotometer.
3. To find the stability constant and reaction stoichiometry of the complex formed between iron and 1,10-phenanthroline.

4. Identification of the structure of organic compounds using IR- spectroscopy (IR spectra should be provided).
5. Partial reduction of m-dinitrobenze to m-nitro aniline and its characterization using IR spectroscopy.
6. Synthesis of benzoic acid from benzamide and its characterization using IR spectrum.
7. Isolation of DNA from onion and its characterization using UV spectroscopy.
8. Extraction of carotene and xanthophyl from plants and recording its IR spectra.
9. Discuss the IR spectra of alcohols, carbonyl compounds, carboxylic acids and esters. (*Provide IR spectra*).
10. Oxidation of benzaldehyde to benzoic acid and compare the IR spectra of product with starting material.
11. Visit to Central Instrument Facility Centre- Delhi University and prepare a report.

References

- Kemp, W. (1991), Organic Spectroscopy, Palgrave Macmillan.
- Pavia, D.L., et al. (2015) Introduction to Spectroscopy, Cengage Learning India Private Limited.
- Banwell, C.N. (2006), Fundamentals of Molecular Spectroscopy,Tata McGraw-Hill Education.
- Kalsi, P.S. (2002) Spectroscopy of Organic Compounds, New Age International Publishers.
- Smith, B.C. (1998), Infrared Spectral Interpretations: A Systematic Approach, CRC Press.
- Plummer, D.T.(2001), Introduction to Practical Biochemistry, McGraw-Hill.
- B D Khosla, et al. (2018) Senior Practical Physical Chemistry, R Chand & Co.

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

DISCIPLINE SPECIFIC CORE COURSE CHEM-DSC -14: Chemistry- V: 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-14: Chemistry- V	**04**	**02**	**0**	**02**	**Class 12th with Physics, Chemistry, Mathematics**	**NIL**

Learning Objectives

- The course introduces the students to basics of coordination chemistry and organometallics which are of immense importance to biological systems, qualitative and quantitative analysis, catalysis, medicines, paints and pigments etc.
- Nomenclature, isomerism, bonding in coordination compounds has been dealt with in sufficient detail along with special emphasis on important coordination compounds in the biological system.
- In organometallic chemistry, the students are introduced to 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 the end of 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 of DSC-14

THEORY COMPONENT

Unit 1: Introduction to Coordination compounds (06 Hours)

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 (14 Hours)

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 (10 Hours)

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 (60 Hours)

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. Preparation of the following inorganic compounds and their characterization using appropriate analytical techniques:
   (i) Tetraamminecopper(II) sulphate
   (ii) Potassium trioxalatoferrate(III) trihydrate
   (iii) Chrome alum
   (iv) Cuprous chloride
   (v) Manganese(III)phosphate ($MnPO_4.H_2O$)
   (vi) Potash alum
   (vii) Acetylacetonate complex of Cu^{2+} and Fe^{3+}
   (viii) Tetraamminecarbonatocobalt(III)nitrate

References:

Theory:

- Huheey, J.E.; Keiter, E.A., Keiter; R. L.; Medhi, O.K. (2009), Inorganic Chemistry-Principles of Structure and Reactivity, Pearson Education
- Shriver, D.D.; Atkins, P.; Langford, C.H. (1994), Inorganic Chemistry 2nd Ed., Oxford University Press.
- 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.
- Cotton, F.A.; Wilkinson, G.; Gaus, P.L. Basic Inorganic Chemistry, 3rd Edition, Wiley India.
- Douglas, B.E.; McDaniel, D.H.; Alexander, J.J. (1994), Concepts and Models of Inorganic Chemistry, John Wiley & Sons.
- Greenwood, N.N.; Earnshaw, A. (1997), Chemistry of the Elements, 2nd Edition, Elsevier.

Practical:

- Jeffery, G.H.; Bassett, J.; Mendham, J.; Denney, R.C. (1989),Vogel's Textbook of Quantitative Chemical Analysis, John Wiley and Sons.
- Marr, G.; Rockett, B.W. (1972), Practical Inorganic Chemistry, Van Nostrand Reinhold.

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 CHEM-DSC -16: Analytical Chemistry- VI: Instrumental Methods of Analysis-II

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		
Instrumental Methods of Analysis-II DSC-16: Analytical Chemistry- VI	**04**	**02**	**0**	**02**	**Class 12th with Physics, Chemistry, Mathematics**	**Must have studied Instrumental Methods of Analysis-I**

Learning Objectives:

The Objective of this course is to make students aware of the following concepts:

•Atomic spectroscopy
• NMR spectroscopy and its applications
• ESR spectroscopy

Learning Outcomes:

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

- What are the different types of spectroscopic methods of analysis that can be used to analyze the samples.
- The instrumentation and the applications of the NMR and ESR spectroscopy.

Syllabus of DSC-16

THEORY COMPONENT-

Unit 1: Atomic Spectroscopy **(06 Hours)**

A. Basic principle and Bohr theory of hydrogen atom
B. Types
C. Atomizer
D. Atomic absorption and photoelectron spectroscopy
E. Applications of absorption and photoelectron spectroscopy

Unit 2: ^{1}H NMR Spectroscopy **(18 Hours)**

A. Principle
B. Instrumentation and sample handling
C. Spin-spin and spin-lattice relaxation
D. Chemical shift
E. Solvents, Internal and external reference compounds
F. Factors affecting chemical shift (Electronegativity, diamagnetic anisotropy, *etc*.)
G. Spin-spin coupling
H. Coupling constants and its applications in characterization of organic molecules including *cis*- and *trans*-isomers
I. Discussion on Chemical shift equivalent nuclei and Magnetic equivalent nuclei with suitable examples
J. Deuterium exchange, Effect of restricted rotation (*e.g.* DMF) and low temperature NMR.
K. Identification of simple organic compounds including tautomer's using ^{1}H NMR spectral data.

Unit 3: ESR spectroscopy: **(06 Hours)**

Basic principles, Relaxation and line width, zero-field splitting and Kramer's degeneracy, g-factor and factor affecting g-factor, Hyperfine coupling constants splitting in triplet spectra, ESR of simple radicals.

PRACTICAL COMPONENT **(60 Hours)**

1. Determination of sodium in ORS using atomic absorption spectroscopy.
2. Determination of copper in drinking water using atomic absorption spectroscopy.
3. Multi-step organic synthesis and characterization of compounds using ^{1}H NMR spectral data (^{1}H NMR spectra of the compounds will be provided to students)
   (**a**) Aniline to *p*-bromoacetanilde
   (**b**) Nitration of bromobenzene
   (**c**) Substitution (S_N2) reaction of 1-iodobutane and 2-naphthol
   (**d**) Synthesis of chalcones, coumarins and xanthenes
4. Separation and identification of organic mixtures containing up to ***two components*** (Use functional group test only).
5. ESR spectra of simple radicals should be discussed in detail with students.

References:

- Skoog, D.A. et al (2018) Principles of Instrumental Analysis, Cengage Learning India Private Limited.
- Kemp, W. (1991), Organic Spectroscopy, Palgrave Macmillan.
- Pavia, D.L., et al. (2015) Introduction to Spectroscopy, Cengage Learning India Private Limited.
- Silverstein, R.M. (2014) Spectrometric Identification of Organic Compounds. John Wiley & Sons.
- Kalsi, P.S. (2002) Spectroscopy of Organic Compounds, New Age International Publishers.
- Chang, R. (1971) Basic Principles of Spectroscopy, McGraw-Hill, New York.
- Ahluwalia, V.K.; Dhingra, S. (2000), Comprehensive Practical Organic Chemistry: Qualitative Analysis, Universities Press.
- Jeffery, G.H.; Bassett, J.; Mendham, J.; Denney, R.C. (1989), Vogel's Textbook of Quantitative Chemical Analysis, John Wiley and Sons.
- Mann F.G, and Saunders, B.C. (2009) Practical Organic Chemistry, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education Ltd.), Singapore.
- Vogel A.I. (2010) Elementary Practical Organic Chemistry, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education Ltd.), Singapore.

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

DISCIPLINE SPECIFIC CORE COURSE CHEM-DSC -17: Chemistry- VI: Quantum Chemistry and Spectroscopy

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-17: Chemistry- VI	**04**	**02**	**-**	**02**	**Class 12th with Physics, Chemistry, Mathematics**	**NIL**

Learning Objectives

The objective of this course is

- To introduce the students to the concepts and methodology of quantum mechanics,
- Its applications to spectroscopy
- To establish the relation between structure determination and spectra.

Learning Outcomes:

By the end of 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.
- Explain Lambert-Beer's law, quantum efficiency and photochemical processes.

Syllabus of DSC-17

THEORY COMPONENT

Unit 1: Quantum Chemistry (15 Hours)

Postulates of quantum mechanics, quantum mechanical operators.

Free particle. Particle in a 1-D box (complete solution), quantization, normalization of wave functions, concept of zero-point energy.

Schrodinger equation and its application to free particle and particle in a 1D box

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 (15 Hours)

Spectroscopy and its importance in chemistry. Wave-particle duality. Link between spectroscopy and quantum chemistry. Electromagnetic radiation and its interaction with matter.

Laws of photochemistry including Lambert-Beer’s law. Jablonski diagram, Fluorescence and phosphorescence.

Types of spectroscopy. Difference between atomic and molecular spectra. Born- Oppenheimer approximation: Separation of molecular energies into translational, rotational, vibrational and electronic components.

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 from vibrational spectra. Vibrations of polyatomic molecules. Group frequencies. 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. Colour and constitution, chromophores, auxochromes, bathochromic and hypsochromic shifts.

PRACTICAL COMPONENT **(60 Hours)**

1. Study the 200-500 nm absorbance spectra of $KMnO_4$ and K_2Cr2O_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 $K_2Cr_2O_7$ (*Use solutions of different pH*)
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.
4. Verify Lambert-Beer's law and determine the concentration of $K_2Cr_2O_7$ in a solution of unknown concentration.
5. Determine the concentrations of $KMnO_4$ and $K_2Cr_2O_7$ in a mixture.
6. Study the kinetics of iodination of propanone in acidic medium.
7. Determine the dissociation constant of an indicator (phenolphthalein).
8. Study the kinetics of interaction of phenolphthalein with sodium hydroxide.
9. Study the kinetics of interaction of crystal violet with sodium hydroxide.

References:

Theory

- Banwell, C.N.; McCash, E.M.(2006), Fundamentals of Molecular Spectroscopy, Tata McGraw- Hill.
- Kapoor, K.L.(2015),A Textbook of Physical Chemistry, McGraw Hill Education, ,Vol 4, 5th Edition, McGraw Hill Education.
- McQuarrie, D.A.(2016),Quantum Chemistry, Viva Books.
- Chandra, A. K.(2001),Introductory Quantum Chemistry, Tata McGraw-Hill.

Practical:

- Khosla, B.D.; Garg, V.C.; Gulati, A. (2015), Senior Practical Physical Chemistry, R. Chand & Co, New Delhi.
- Kapoor, K.L. (2019),A Textbook of Physical Chemistry, Vol.7, 1st Edition, McGraw Hill Education.

- Garland, C. W.; Nibler, J. W.; Shoemaker, D. P.(2003),Experiments in Physical Chemistry, 8th Edition, McGraw-Hill, New York.

Additional Resources:

- Castellan, G. W .(2004),Physical Chemistry, Narosa.
- Petrucci, R. H.(1989),General Chemistry: Principles and Applications, Macmillan Publishing

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

11.2. DISCIPLINE SPECIFIC ELECTIVES (DSE)

DISCIPLINE SPECIFIC ELECTIVE COURSE CHEM-DSE: Analytical Chemistry- I: Analytical Biochemistry

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		
Analytical Biochemistry DSE: Analytical Chemistry-I	**04**	**02**	**0**	**02**	**Class 12th with Physics, Chemistry, Mathematics**	**NIL**

Learning Objectives

The Objective of the course is

- To learn about proteins, enzymes, nucleic acids and lipids, using suitable examples, drug receptor interaction.
- Structure Activity Relation (SAR) studies along genetic code and concept of heredity.

Learning Outcomes:

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

- Learn about structures of carbohydrates and Proteins
- Learn about the molecules, macromolecules, polymers and their formations
- Learn about the metabolism of a few biomolecules.
- Know basic principles of drug-receptor interaction and structure activity relationship (SAR).
- Know biochemistry of diseases.

Syllabus of DSE-AC1

THEORY COMPONENT

Unit 1: Carbohydrates and Proteins: (16 Hours)

Basic understanding of the structures and properties of carbohydrates, biological importance of Carbohydrates.
Monosaccharides: Constitution and absolute configuration of glucose and fructose, epimers and anomers, mutarotation, Haworth projections and conformational structures; Structure elucidation of glucose and fructose (Fischer's proof), Interconversions of aldoses and ketoses; Killiani-Fischer synthesis and Ruff degradation;
Disaccharides – Structure elucidation of maltose, lactose and sucrose.
Polysaccharides – Elementary treatment of starch, cellulose and glycogen.
Amino Acids, Peptides and Proteins:
α-Amino Acids - Classification and characterization, Zwitterions, pKa values, isoelectric point and electrophoresis;
Proteins: Classification, Primary, secondary and tertiary structures of proteins, test for proteins, isolation, characterization, biological importance; denaturation of proteins.

Enzymes: Introduction, classification and characteristics of enzymes. Salient features of active site of enzymes. Mechanism of enzyme action (taking trypsin as an example), factors affecting enzyme action, coenzymes and cofactors (ATP, NAD, FAD), specificity of enzyme action (including stereospecificity).

Unit 2: Lipids (06 Hours)
Introduction to oils and fats; common fatty acids present in oils and fats, Hydrogenation of fats and oils, Classification. Biological importance of triglycerides and phosphoglycerides and cholesterol; Liposomes and their biological functions and underlying applications. Lipoproteins. Properties, functions and biochemical functions of steroid hormones and peptide hormones.

Unit 3: Clinical Biochemistry: (08 Hours)
A diagnostic approach by blood/ urine analysis. **Blood:** Composition and functions of blood, blood coagulation. Blood collection and preservation of samples. Anemia: Causes and symptoms.
Urine: Collection and preservation of samples. Formation of urine. Composition and estimation of constituents of normal and pathological urine.

Regulation, estimation and interpretation of data for blood sugar, urea, creatinine, cholesterol and bilirubin.

PRACTICAL COMPONENT (60 Hours)

1. Carbohydrate- qualitative and quantitative both.
2. Proteins-qualitative tests
4. Determination of the iodine number of oil.

5. Determination of the saponification value of an oil.
6. Determination of acid value of fats and oils.
7. Determination of cholesterol using Liebermann- Burchard reaction.
8. Estimation of DNA by diphenylamine reaction
9. Isolation and characterization of DNA from Onion/cauliflower.
10.Determination of amount of protein using Lowry's method/ Biuret method.
11. To study the activity of α-amylase.
12. To study the effect of temperature and pH on the activity of α-amylase.

References:

- Devlin, T. M. (2010), Textbook of Biochemistry with Clinical Correlations, John Wiley & Sons.
- Berg, J.M., Tymoczko, J.L.; Stryer, L. (2010), Loose-leaf Version for Biochemistry, W.H.Freeman.
- Lehninger, A.L., Nelson, D.L.;Cox, M. (2004), Principle of Biochemistry, W.H.Freeman.
- Morrison, R. N.; Boyd, R. N. (2016) Organic Chemistry, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
- Finar, I. L. (2015) Organic Chemistry (Volume 1& 2), Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).

Additional References:

- Swahney, S.K.; Singh, R. (2001), Introductory Practical Biochemistry, Narosa Publishing House.
- Cooper, T.G. (2011),The Tools of Biochemistry, Wiley India Pvt Ltd.
- Wilson, K.; Walker, J. (2000), Principles and Techniques of Practical Biochemistry, Cambridge University Press.

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

DISCIPLINE SPECIFIC ELECTIVE COURSE CHEM-DSE: Analytical Chemistry- II: Polymers

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		
Polymers DSE: Analytical Chemistry-II	**04**	**02**	**0**	**02**	**Class 12th with Physics, Chemistry, Mathematics**	**NIL**

Learning Objectives

The objective of the course is:

- To study and develop understanding of molecules and macromolecules.
- To study about molecular weight determination and the solution properties of polymers.

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

- Learn about the molecules, macromolecules and polymers
- Learn about properties of polymer solutions.
- Learn about the differentiation between molecule and polymer.
- Learn about the properties of polymers and their industrial applications.

Syllabus of DSE-AC2

THEORY COMPONENT

Unit 1: Introduction to Polymers (04 Hours)
Introduction of polymeric materials, classification of polymers, Various structures of copolymers such as linear branched and cross-linked polymers and their types, Molecular forces and chemical bonding in polymers

Unit 2: Polymerization (04 Hours)
Criteria for synthetic polymer formation, Types of polymerizations, Relationships between functionality, extent of reaction and degree of polymerization.

Unit 3: Molecular Weight of Polymers (10 Hours)
Nature and structure of polymers: structure-property relationships, molecular weight of polymers (M_n, M_w), molecular weight distribution, polydispersity, and determination of molecular weight by viscosity, end group analysis, cryoscopy, ebulliometry, osmometry, light scattering & ultracentrifugation method

Unit 4: Solution Properties of Polymers (12 Hours)

Criteria for polymer solubility, Polymer solution – solubility parameter, properties of dilute solutions and their criteria, Thermodynamics of polymer solutions, entropy, enthalpy, and free energy change. Flory- Huggins theory.
Glass Transition Behaviour of Polymers
Glass transition temperature (T_g), factors affecting the glass transition temperature, WLF equation.

PRACTICAL COMPONENT (60 Hours)

1. Free radical solution polymerization of

   (i) Styrene (St) (ii)Methyl Methacrylate (MMA) (iii) MethylAcrylate (MA).

2. IR , ^{1}H NMR studies of polymers (PSt, PMMA, PMA, PEG, PVOH)

3. Thermal studies of polymers (PSt, PMMA, PMA, PEG, PVOH)

4. To check the solubility of the given polymeric sample in different solvents.

5. Preparation of nylon-6,6

6. Determination of the viscosity-average molecular weight of poly(vinyl alcohol).

7. Determination of the fraction of head-to-head monomer linkages in of poly(vinyl alcohol)

9. Determination of molecular weight by end group analysis.

10. Chemical identification of polymers- (i) Unsaturation (ii) Testing of functional groups (associated with polymers).

11. Determination of hydroxyl number of a polymer using colorimetric method.

12. i) Preparation of urea-formaldehyde resin

ii) Separation of monomers from polymers by solvation-technique.

References:

- Harry R. Allcock, Frederick W. Lampe and James E. Mark ((2003) Contemporary Polymer Chemistry, 3rd ed. Prentice-Hall
- Fred W. Billmeyer (1984) Textbook of Polymer Science, 3rd ed. Wiley-Interscience,
- L. H. Sperling (2005) Introduction to Physical Polymer Science, 4th ed. John Wiley & Sons (2005)
- Malcolm P. Stevens (2005) Polymer Chemistry: An Introduction, 3rd ed. Oxford University Press.
- Gowarikar V.R., (2010) Polymer Science, New Age International Publishers Ltd.
- Ghosh P., (2010) Polymer Science and Technology: Plastics, Rubbers, Blends and Composites, Tata McGraw Hill.

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

DISCIPLINE SPECIFIC ELECTIVE COURSE CHEM-DSE: Analytical Chemistry- III: Food Chemistry, Nutrition and Additives

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 Chemistry, Nutrition and Additives DSE: Analytical Chemistry-III	**04**	**02**	**0**	**02**	**Class 12th with Physics, Chemistry, Mathematics**	**NIL**

Learning Objectives

The introductory course on food chemistry, nutrition and additives is designed:

- To develop a basic understanding of the sources, importance, stability.
- To study about transformations of food components during handling and processing.

Learning Outcomes:

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

- Build a strong understanding of fundamentals of food chemistry.
- Understand how alterations /transformations during processing and handling affect the quality and stability of food
- Learn about the nature and importance of additives in food chemistry

Syllabus of DSE-AC3

THEORY COMPONENT

Unit 1: Introduction **(03 Hours)**

Introduction of food chemistry; An overview of the following: alterations during handling or processing (texture, flavour and colour), chemical and biochemical reactions leading to alteration in food quality (browning, oxidation, hydrolysis, protein denaturation), cause and effect relationship pertaining to food handling; Factors governing stability of food (chemical and environmental factors) and role of food chemists.

Unit 2: Water: **(09 Hours)**

Definition of water in food, Structure of water and ice, Types of water, Sorption phenomenon, Water activity and packaging, Water activity and shelf-life.

Carbohydrates: Introduction, Sources, Functions, Deficiencies, Structure and importance of Polysaccharides in food chemistry (Agar and Agarose, Pectin, Hemicellulose, Cyclodextrins, Gums, Alginate, Starches, Modified starches), Non Enzymic Browning and its prevention, Caramelisation, Formation of acrylamide in food, Role of carbohydrates as sweeteners in food.

Unit 3: Vitamins and Minerals. **(06 Hours)**

Vitamins: Introduction, Sources, Classification: Water Soluble and Water insoluble Vitamins, Essential Vitamins, Physiological function, deficiencies, Causes of variation and loss in foods, Vitamin like compounds, Effect of food processing. Minerals: Introduction, Sources, Classification: Major minerals and trace elements, Physiological function, Deficiencies, Factors affecting mineral content of food, Fortification and enrichment of foods with minerals, Effect of food processing

Unit 4: Food additives: **(12 Hours)**

Additives: Introduction, Importance, Classification, Antioxidants, Emulsifiers, Stabilizers, Gelling agents, Gums, Thickeners, Sweeteners, Acidulants, Preservatives, Humectants, Food toxins.

Colouring Agents and Pigments: Introduction, Natural food colourants: Anthocyanins, Carotenoids, Chlorophyll, Caramel, Betalains; Examples of Pigments in common food; Nature-identical colourants: β -Carotene, Canthaxanthin and Riboflavin. Artificial colouring agents; Artificial/synthetic colourants: Azo dyes (e.g. amaranth dye, tatrazine, citrous red, Allura red); Quinoline (e.g. quinoline yellow); Phthalein (e.g. erythrosine); Triarylmethanes and indigoid (e.g. indigo carmine), FD&C Dyes and Lakes; Properties of certified dyes, Colours exempt from certification.

Food Flavours: Sensation of taste and odour, Chemical Dimension of basic types of taste (Salty, Sweet, Bitter, Sour, Umami taste), other sensations like astringency, coolness, pungency/pungency); Non-Nutritive Sweeteners (aspartame, saccharin, sucralose, Cyclamate) and Nutritive Sweeteners, Molecular mechanism of flavour perception, Biogenesis of fruits and vegetable flavours, Taste Inhibition, Modification and Enhancement, Common Vegetable and Spice Flavours.

PRACTICAL COMPONENT (60 Hours)

1. Determination of Moisture in different Food Products by hot air oven-drying method.
2. Paper chromatography of synthetic food dyes (*ascending and circular both*).
3. Quantitative determination of Food dyes in Powdered drink mixes by Spectrophotometric method.
4. Colorimetric determination of Iron in vitamin / dietary tablets.
5. Determination of rancidity of edible oils by Kriess Test.
6. Estimation of Vitamin C in a given solution/ Lemon Juice/ Chilies by 2, 6-dichlorophenol Indophenol Method.
7. Isolation of Casein from milk.
8. Qualitative test for Amino acids and proteins (Biuret Test, Xanthoproteic Test, Ninhydrin Test, Millon's Test, Nitroprusside Test, etc).
9. Determination of total fat by acid hydrolysis method.

References:

Theory:

- DeMan, J.M., Finley, J.W., Hurst, W.J., Lee, C.Y. (2018), Principles of Food Chemistry, 4th Edition, Springer.
- Msagati, T.A.M. (2013), Chemistry of Food Additives and Preservatives, WileyBlackwell.
- Fennema, O.R. (2017), Food Chemistry, 5th Edition, CRC Press.
- Attokaran, M. (2017), Natural Food Flavors and Colorants, 2nd Ed., Wiley-Blackwell.
- Potter, N.N., Hotchkiss, J.H, (1995) Food Science, 5 th Ed., Chapman & Hall.
- Brannen, D., Davidsin, P.M., Salminen, T. Thorngate III, J.H. (2002), Food Additives, 2 nd Edition, CRC Press.
- Coultate, T. (2016), Food: The Chemistry of its Components, 6th Edn., Royal Society of Chemistry. 8. Belitz, H. D.; Grosch, W. (2009), Food Chemistry, Springer.

Practicals:

1. Ranganna, S. (2017). Handbook of analysis and quality control for fruits and vegetable products, 2nd Edn., McGraw Hill Education.
2. Sawhney, S.K., Singh, R. (2001), Introductory Practical Biochemistry, Narosa Publishing House.

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

DISCIPLINE SPECIFIC ELECTIVE COURSE CHEM-DSE: Analytical Chemistry- IV: Industrial Chemicals and Environment

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 Chemicals and Environment DSE: Analytical Chemistry-IV	**04**	**02**	**-**	**02**	**Class 12th with Physics, Chemistry, Mathematics**	**NIL**

Learning Objectives

The objective of this course is

- To teach students about various processes being used in industry
- To learn basis properties of gases and their industrial production, uses, storage and hazards. Manufacturing, applications, analysis and hazards of the Inorganic Chemicals,
- Preparation of Ultra-Pure metals for semiconducting technology, Air and Water pollution, control measures for Air and Water Pollutants,
- Catalyst and Biocatalyst,
- Energy and Environment.

Learning Outcomes:

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

- The different toxic gases and their toxicity hazards
- Safe design systems for large scale production of industrial gases.
- Manufacturing processes, handling and storage of inorganic chemicals.
- Hazardous effects of the inorganic chemicals on human beings and vegetation.
- The requirement of ultra-pure metals for the semiconducting technologies
- Composition of air, various air pollutants, effects and control measures of air pollutants.
- Different sources of water, water quality parameters, impacts of water pollution, water treatment.

Syllabus of DSE-AC4

THEORY COMPONENT

Unit 1: Chemical Technology (08 Hours)

Basic principles of distillation, solvent extraction, solid-liquid leaching and liquid-liquid extraction. An introduction into the scope of different types of equipment needed in chemical technology, including reactors, distillation columns, extruders, pumps, mills, emulgators. Introduction to clean technology.

Unit 2: Industrial Gases and Inorganic Chemicals (10 Hours)

(a) Industrial Gases: Large scale production, uses, storage and hazards in handling of the following gases: oxygen, nitrogen, argon, helium, hydrogen, acetylene, chlorine, fluorine, sulphur dioxide and phosgene.
(b) Inorganic Chemicals: Manufacture, application, analysis and hazards in handling the following chemicals: hydrochloric acid, nitric acid, sulphuric acid, caustic soda, common salt, borax, bleaching powder, hydrogen peroxide, potash alum, potassium dichromate and potassium permanganate. Preparation of metals (ferrous and nonferrous) and ultra-pure metals for semiconductor technology.

Unit 3. Environment (12 Hours)

(a) Air Pollution: Pollutants and their sources, pollution by SO_2, CO_2, CO, NOx, H_2S and other foul-smelling gases. Green House effect and Global warming, Ozone depletion by oxides of nitrogen, chlorofluorocarbons and Halogens, removal of sulphur from coal. Control of particulates.
(b) Water pollution and Water Quality Standards: Pollutants and their sources, Effluent treatment plants (primary, secondary and tertiary treatment). Industrial effluent from the following industries and their treatment: electroplating, textile, tannery, dairy, petroleum and petrochemicals, agro, fertilizer, *etc.* Industrial waste management, incineration of waste. Water

treatment and purification (reverse osmosis, electro dialysis, ion exchange). Water quality parameters for waste water, industrial water and domestic water.
(c) Energy & Environment: Sources of energy: Coal, petrol and natural gas. Nuclear fusion / fission, solar, hydrogen, geothermal, tidal and hydel.

PRACTICAL COMPONENT (60 Hours)

1. Percentage of available chlorine in bleaching powder.
2. Measurement of chloride, sulphate and salinity of water samples by simple titration method. ($AgNO_3$ and potassium chromate)
3. Estimation of total alkalinity of water samples (CO_3^{-2}, HCO_3^-) using double titration method.
4. Measurement of dissolved CO_2 in water.
5. Determination of hexavalent Chromium Cr(VI) concentration in tannery wastes/waste water sample using UV-Vis spectrophotometry technique.
6. Study of some of the common bio-indicators of pollution.
7. Estimation of SPM in air samples.
8. Preparation of borax/ boric acid.
9. Detection of constituents of Ammonium Sulphate fertilizer (Ammonium and Sulphate ions) by qualitative analysis and determine its free acidity.
10. Detection of constituents of CAN fertilizer (Calcium, Ammonium and Nitrate ions) fertilizer and estimation of Calcium content.
11. Detection of constituents of Superphosphate fertilizer (Calcium and Phosphate ions) and estimation of phosphoric acid content.
12. Detection of constituents of Dolomite (Calcium, Magnesium and carbonate ions) and determination of composition of Dolomite (Complexometric titration).

References:

Theory

- Manahan, S. E. (2017), Environmental Chemistry, CRC Press.
- Buchel, K. H.; Moretto, H. H.; Woditsch, P. (2003), Industrial Inorganic Chemistry, Wiley-VCH.
- De, A. K. (2012), Environmental Chemistry, New Age International Pvt., Ltd.
- Khopkar, S. M. (2010), Environmental Pollution Analysis, New Age International Publisher.
- Stocchi E. (1990) Industrial Chemistry, Vol-I, Ellis Horwood Ltd. UK.
- Felder, R. M.; Rousseau, R. W. (2008) Elementary Principles of Chemical Processes, Wiley Publishers, New Delhi.

- Kent, J. A. (2007) Riegel's Handbook of Industrial Chemistry, CBS Publishers, New Delhi.

Practicals

- Vowles, P. D.; Connell, D. W. (1980), Experiments in Environmental Chemistry: A Laboratory Manual, Vol. 4, Pergamon Series in Environmental Science.
- Gopalan, R.; Anand, A.; Sugumar R. W. (2008), A Laboratory Manual for Environmental Chemistry, I. K. International.
- Svehla, G. (1996), Vogel's Qualitative Inorganic Analysis, Prentice Hall.
- Banewicz, J. J.; Kenner, C.T. Determination of Calcium and Magnesium in Limestones and Dolomites, Anal. Chem., 1952, 24 (7), 1186–1187.

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

DISCIPLINE SPECIFIC ELECTIVE COURSE CHEM-DSE: Analytical Chemistry- V: Python Programming for Analytical Chemists

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		
Python Programming for Analytical Chemists DSE: Analytical Chemistry-V	**04**	**03**	**0**	**01**	**Class 12th with Physics, Chemistry, Mathematics**	

Learning Objectives

This course aims

- To teach students the fundamental building blocks and syntax of coding in Python
- To apply python programming to solve simple Chemistry problems by thinking algorithmically and coding structurally.

Learning Outcomes:

By studying this course, the students will be able to:

• Understand the importance of python programming in chemistry and its applications in the field of AI and ML

• Perform simple computations in python after learning the basic syntax, loop structure, string data manipulation etc.
• Solve chemistry problems such as finding pK_a of a weak acid, solving Schrodinger's equation etc.
• Plot experimental data and perform regression analysis

Syllabus of DSE-AC5

THEORY COMPONENT

Unit 1: Introduction to Python (04 Hours)
Python coding environment setup, Python as an interpreted language, Brief history of Python, Uses of Python (including artificial intelligence and machine learning), Applications of Python in Chemistry

Unit 2: Coding in Python (16 Hours)
(i) Basic syntax including constants and variables, Operators, Data Types, Declaring and using Numeric data types: int, float, string etc. (ii) Program Flow Control Conditional blocks: if, else and else if, simple FOR loops, FOR loop using ranges, string, list and dictionaries. Use of while loops, Loop manipulation using pass, continue, break and else. (iii) Complex data types: String, List, Arrays, Tuples and Dictionary, String operations and manipulation methods, List operations including slicing, in-built Python Functions. (iv) Python packages - usage of numpy and scipy for mathematical computations.

Unit 3: Plotting graphs (10 Hours)
Matplotlib for Plotting - Simple plots, formatting of plots, multiple plots, histograms, bar graphs, distributions, curve fitting – linear regression.

Unit IV: Numerical Methods in Chemistry (15 Hours)
Solution of quadratic equation, polynomial equations (formula, iteration, Newton – Raphson methods and binary bisection) with examples of polynomial equations used in chemistry; Numerical differentiation – finite difference method (backward, central and forward), Numerical integration - Trapezoidal and Simpson's rule to calculate area under the curves for chemistry problems, e.g., entropy calculations, Simultaneous equations, Statistical analysis-mean, variance, standard deviation, error, Curve fitting – linear regression, Solving Schrödinger's equation using Python packages.

PRACTICAL COMPONENT (30 Hours)

1. Writing simple programs using scipy and numpy
a. syntax, data types
b. loop structure, conditional loops
c. To learn string data manipulation
d. Array and lists
e. Sorting, matrix manipulations

2. Plotting graphs using matplotlib a. Planck's distribution law
b. Maxwell-Boltzmann distribution curves as a function of temperature and mass
c. Radial distribution curves for hydrogenic orbitals

d. Gas law Isotherms – Ideal and Real
e. Data from phase equilibria studies
f. Wavefunctions and Probabilities as multiplots
g. Kinetics data with linear fitting

3. Numerical Methods in Chemistry

a. Solving equations involved in chemical equilibria such as pH of a weak acid at a given concentration, cubic equation obtained from solving van der Waals equation of real gases using Iteration, Newton-Raphson, and Binary Bisection Method
b. Numerical Differentiation – finding equivalence point given pH metric and potentiometric titrations data by finding the first and the second derivative using the finite difference method
c. Numerical Integration – Trapezoidal and Simpson's 1/3 rule to calculate enthalpy and entropy of an ideal gas
d. Statistical Analysis – Calculating Mean, Variance, Standard Deviation
e. Solving Schrodinger's Equation

References:

1. Dr. M. Kanagasabapathy(2023), Python for Chemistry: An introduction to Python algorithms, Simulations, and Programing for Chemistry (English Edition), BPB Publications

2. Robert Johansson (2021), Numerical Python: Scientific Computing and Data Science Applications with NumPy, SciPy and Matplotlib, 2nd Edition, Apress

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

DISCIPLINE SPECIFIC ELECTIVE COURSE CHEM-DSE: Chemistry- I: Green Chemistry

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		
Green Chemistry DSE: Chemistry-I	**04**	**02**	**0**	**02**	**Class 12th with Physics, Chemistry, Mathematics**	**NIL**

Learning Objectives

This course is designed

- To become more and more environmentally conscious and work towards sustainable practices.
- To practice chemistry in the safest way possible is key towards safe working conditions in the laboratories as well as the chemical industry
- To extend the same 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

Syllabus of DSC-C1

THEORY COMPONENT

Unit 1: Introduction **(08 Hours)**

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 **(12 Hours)**

The twelve principles of the Green Chemistry with their explanation, 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: **(10 Hours)**

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 COMPONENT **(60 Hours)**

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).
3. Benzoin condensation using thiamine hydrochloride as a catalyst instead of cyanide.
4. Extraction of D-limonene from orange peel using liquid CO_2 prepared from dry ice.
5. Mechanochemical solvent free, solid-solid synthesis of azomethine using *p*-toluidine and *o*-vanillin/*p*-vanillin.
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.

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.

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

DISCIPLINE SPECIFIC ELECTIVE COURSE CHEM-DSE: Chemistry- II: Conductance, Electrochemistry and Chemical Kinetics

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		
Conductance, Electrochemistry and Chemical Kinetics DSE: Chemistry- II	**04**	**02**	**0**	**02**	**Class 12th with Physics, Chemistry, Mathematics**	**NIL**

Learning Objectives

This course is aimed at

- To learn about electrolytic and galvanic cells,
- To measure conductance and learn its applications,
- To measure emf and its applications.
- To learn about the reaction rate, order, activation energy and theories of reaction rates.

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

- Explain the factors that affect conductance, migration of ions and application of conductance measurement.
- Understand the importance of Nernst equation, measurement of emf, calculations of thermodynamic properties and other parameters from the emf measurements.
- Understand rate law and rate of reaction, theories of reaction rates and catalysts; both chemical and enzymatic.

Syllabus of DSE-C2

THEORY COMPONENT

Unit 1: Conductance (08 Hours)

Conductivity, equivalent and molar conductivity and their variation with dilution for weak and strong electrolytes, Kohlrausch Law of independent migration of ions, Ionic velocity, mobility and their determination, transference number and its relation to ionic mobility, Conductometric titrations (only acid-base).

Unit 2: Electrochemistry (12 Hours)

Concept of reversible and irreversible cells, standard electrode potential, concept of EMF of a cell, measurement of EMF of a cell, Nernst equation and its importance, types of electrodes, electrochemical series. Thermodynamics of a reversible cell, calculation of thermodynamic properties: G, H and S from EMF data. Calculation of equilibrium constant from EMF data. Concentration cells, liquid junction potential and salt bridge, pH determination using hydrogen electrode and quinhydrone electrode, Potentiometric titrations-qualitative treatment (acid-base and oxidation-reduction only).

Unit 3: Chemical Kinetics and Catalysis (10 Hours)

The concept of reaction rates, effect of temperature, pressure, catalyst and other factors on reaction rates. Order and molecularity of a reaction, derivation of integrated rate equations for zero, first and second order reactions (both for equal and unequal concentrations of reactants), half–life of a reaction, general methods for determination of order of a reaction, Concept of activation energy and its calculation from Arrhenius equation. Theories of reaction rates: Collision theory and activated complex theory of bi-molecular reactions. Comparison of the two theories (qualitative treatment only) Catalysis: Types of catalyst, specificity and

selectivity, mechanisms of catalyzed reactions at solid surfaces. Enzyme catalysis, Michaelis-Menten mechanism, acid-base catalysis.

PRACTICAL COMPONENT (60 Hours)

Conductance

1. Determination of molar conductance, degree of dissociation and dissociation constant of a weak acid.
2. Perform the following conductometric titrations: **a**) Strong acid *vs* strong base **b**) Weak acid *vs* strong base. **c**) Mixture of strong acid and weak acid *vs.* strong base.

Potentiometry

3. Perform the potentiometric titrations of
   a) Strong acid vs strong base
   b) Weak acid vs strong base.
   c) Potassium dichromate vs. Mohr's salt Chemical Kinetics
4. Study the kinetics of acid hydrolysis of methyl acetate with hydrochloric acid.
5. Study the kinetics of Iodide-persulphate reaction by Initial rate method or integrated rate law method.
6. Effect of substrate concentration on acid phosphatase activity and determination of its K_m, V_{max} and K_i (with respect to inorganic phosphate).

References:

Theory:

- Castellan, G. W .(2004),P hysical Chemistry, Narosa.
- Kapoor, K.L. (2015), A Textbook of Physical Chemistry, Vol.1, 6th Edition, McGraw Hill Education.
- Kapoor, K.L. (2015), A Textbook of Physical Chemistry, Vol.5, 3rd Edition, McGraw Hill Education.
- Puri, B.R., Sharma, L.R. and Pathania M.S. (2020), Principles of Physical Chemistry, Vishal Publishing Co.

Practical:

- Khosla, B.D.; Garg, V.C.; Gulati, A.(2015), Senior Practical Physical Chemistry, R. Chand & Co.
- Kapoor, K.L. (2019), A Textbook of Physical Chemistry, Vol 7, 1st Edition, McGraw Hill Education.
- Batra, S.K., Kapoor, V and Gulati, S. (2017) 1 st Edition, Experiments in Physical Chemistry, Book Age series.

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

DISCIPLINE SPECIFIC ELECTIVE COURSE CHEM-DSE: Chemistry- III: Novel Inorganic Solids

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		
Novel Inorganic Solids DSE: Chemistry-III	**04**	**03**	**0**	**01**	**Class 12th with Physics, Chemistry, Mathematics**	**NIL**

Learning Objectives

This course will

- To know about Novel inorganic solids and their applications in both industrial and research arenas.
- To utilize them as catalysts, as a nano reactor to host reactants for synthesis and for the controlled release of biomolecules.

Learning Outcomes:

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

- Understand the mechanism of solid-state synthesis.
- Explain about the different characterization techniques and their principles.
- Understand the concept of nanomaterials, their synthesis and properties.
- Explain the mechanism of growth of self-assembled nanostructures.
- Understand the real-world importance of bioinorganic nanomaterials.
- Explain the importance of composites and their applications.
- Understand the importance and real-life application of solid materials

Syllabus of DSE-C3

THEORY COMPONENT

Unit 1: Synthesis of Inorganic solids (05 Hours)

Conventional heat and beat method, Co-precipitation method, Sol-gel method, Hydrothermal method, Chemical vapor deposition (CVD), Ion-exchange and Intercalation method.

Unit 2: Characterization techniques of inorganic solids (10 Hours)

Powder X-ray Diffraction, UV-visible spectroscopy, Scanning Electron Microscopy (SEM), Transmission Electron Microscopy (TEM), Fourier-Transform Infrared (FTIR) spectroscopy, Brunauer–Emmett–Teller (BET) surface area analyser, Dynamic Light Scattering (DLS).

Unit 3: Solid Electrolytes (10 Hours)

Cationic, anionic and mixed solid electrolytes and their applications. Inorganic pigments – coloured, white and black pigments. One-dimensional metals, molecular magnets, inorganic liquid crystals.

Unit 4: Nanomaterials (10 Hours)

Overview of nanostructures and nanomaterials, classification, preparation and optical properties of gold and silver metallic nanoparticles, concept of surface plasmon resonance, carbon nanotubes, inorganic nanowires, Bioinorganic nanomaterials, DNA and its nanomaterials, natural and artificial nanomaterials, self-assembled nanostructures, control of nanoarchitecture, one dimensional control.

Unit 4: Composite Materials (10 Hours)

Introduction, limitations of conventional engineering materials, role of matrix in composites, classification, matrix materials, reinforcements, metal-matrix composites, polymer-matrix composites, fibre-reinforced composites, bio-nanocomposites, environmental effects on composites, applications of composites.

PRACTICAL COMPONENT (30 Hours)

1. Synthesis of silver nanoparticles by chemical methods / green approach and characterization using UV-visible spectrophotometer.
2. Synthesis of metal sulphide nanoparticles (MnS, CdS, ZnS & CuS) and their characterization using UV-visible spectrophotometer.
3. Intercalation of hydrogen in tungsten trioxide and its conductivity measurement using conductometer.
4. Synthesis of inorganic pigments ($PbCrO_4$, $ZnCrO_4$, Prussian Blue, Malachite).
5. Synthesis of pure ZnO and Cu doped ZnO nanoparticles.
6. Preparation of zeolite A and removal of Mg and Ca ions from water samples quantitatively using zeolite.

References:

Theory:

- West, A. R. (2014), Solid State Chemistry and Its Application, Wiley.
- Smart, L. E.; Moore, E. A., (2012), Solid State Chemistry: An Introduction CRC Press Taylor & Francis.
- Rao, C. N. R.; Gopalakrishnan, J. (1997), New Direction in Solid State Chemistry, Cambridge University Press.
- Poole Jr.; Charles P.; Owens, Frank J. (2003), Introduction to Nanotechnology, John Wiley and Sons.

Practicals:

- Orbaek, W.; McHale, M.M.; Barron, A. R.; Synthesis and Characterization of Silver Nanoparticles for An Undergraduate Laboratory, J. Chem. Educ. 92, 2015, 339−344.
- Cheng, K.H.; Jacobson, A.J.; Whittingham, M.S. (1981), Hexagonal Tungsten Trioxide and Its Intercalation Chemistry, Solid State Ionics, 5, 1981, 355-358.
- Ghorbani H.R.; Mehr, F.P; Pazoki, H; Rahmani, B.M.; Synthesis of ZnO Nanoparticles by Precipitation Method, Orient J Chem 2015, 31(2).

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

DISCIPLINE SPECIFIC ELECTIVE COURSE CHEM-DSE: Chemistry- IV: Phase Equilibria and Solutions

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		
Phase Equilibria and Solutions DSE: Chemistry - IV	**04**	**02**	**0**	**02**	**Class 12th with Physics, Chemistry, Mathematics**	**NIL**

Learning Objectives

The course is designed

- To understand phase, co- existence of phases, phase diagram, CST
- To know about distribution law and its applications.

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

- Understand phase equilibrium, criteria, CST, Gibbs-Duhem-Margules equation.
- Apply the concepts of phase and its applications in purification etc.
- Learn about distribution law and its importance in solvent extraction.

Syllabus of DSE-C4
THEORY COMPONENT

Unit 1: Phase Equilibria **(15 Hours)**

Concept of phases, components and degrees of freedom, derivation of Gibbs Phase Rule for nonreactive and reactive systems; Clausius-Clapeyron equation and its applications to solid-liquid, liquid-vapour and solid-vapour equilibria,
Phase diagram for one component systems (H_2O, CO_2 and S), with applications. Phase diagrams for systems of solid-liquid equilibria involving eutectic, congruent and incongruent melting points. Phase diagram of three component system, Triangular plots, water-chloroform-acetic acid system.
Application of phase in explaining phenomenon in everyday life.

Unit 2: Solution **(15 Hours)**

Concentration term, lowering of vapour pressure, Raoult's law. Thermodynamic basis of the colligative properties - lowering of vapour pressure, elevation of Boiling Point, Depression of Freezing point and Osmotic pressure and derivation of expressions for these using chemical potential. Concept of activity and activity coefficients. Binary solutions: Gibbs-Duhem-Margules equation, its derivation and applications to fractional distillation of binary miscible liquids (ideal and non-ideal), azeotropes, lever rule, partial miscibility of liquids, CST (both upper and lower) and effect of impurities on CST, miscible pairs, steam distillation. Nernst distribution law: its derivation and applications.

PRACTICAL COMPONENT **(60 Hours)**

Phase Equilibrium
1. Determination of critical solution temperature and composition at CST of the phenol water system
2. To study the effect of impurities of sodium chloride and succinic acid on the CST of phenol-water system.
3. Construction of the phase diagram using cooling curves:
   (i) simple eutectic
   (ii) congruently melting systems.
4. Distribution of I_2/acetic/ benzoic acid between water and chloroform/CCl_4 or cyclohexane.
5. Study of equilibrium of any one of the following reactions by distribution method:
(i) I_2 (aq) + I^- (aq) ⇌ I_3^-(aq)
(ii) Cu^{2+} (aq) + nNH_3 ⇌ $[Cu(NH_3)_n]^{2+}$

References:

Theory:

- Atkins, P.W.; Paula, J.de. (2014), Atkin's Physical Chemistry Ed., 10th Edition, Oxford University Press.
- Ball, D. W. (2017), Physical Chemistry, 2 nd Edition, Cengage Learning, India.

- Castellan, G. W. (2004), Physical Chemistry, 4 th Edition, Narosa.
- Kapoor, K.L. (2015), A Textbook of Physical Chemistry, Vol 1, 6 th Edition, McGraw Hill Education.
- Kapoor, K.L. (2020) A Textbook of Physical Chemistry, Vol 3, 5th Edition, McGraw Hill Education.

Practical:

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

Additional Resources:

- Moore, W.J. (1972), Physical Chemistry, 5th Edition, Longmans Green & Co. Ltd.
- Glasstone, S. (1948), Textbook of Physical Chemistry, D. Van Nostrand company, New York.

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

DISCIPLINE SPECIFIC ELECTIVE COURSE CHEM-DSE: Chemistry- V: Main Group Chemistry

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		
Main Group Chemistry DSE: Chemistry -V	**04**	**02**	**0**	**02**	**Class 12th with Physics, Chemistry, Mathematics**	**NIL**

Learning Objectives

The objective of this paper is

- To provide basic understanding of the fundamental principles of metallurgy through study of the different methods of extraction and refining of metals.

- To illustrates 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 this course, 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.

Syllabus of DSE-C5

THEORY COMPONENT

Unit 1: General Principles of Metallurgy (06 Hours)

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 (05 Hours)

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 (15 Hours)

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 **(04 Hours)**

Preparation, properties, structure and uses of the following:

Borazine, Silicates and Silicones

PRACTICAL COMPONENT **(60 Hours)**

Qualitative semi-micro analysis of mixtures containing 2 anions and 2 cations including interfering radicals and water insoluble. 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+} (*At least 10 combinations of mixture to be prepared*).

References:

Theory:

- Lee, J.D.; (2010), Concise Inorganic Chemistry, Wiley India.
- Huheey, J.E.; Keiter, E.A.; Keiter; R. L.; Medhi, O.K. (2009), Inorganic Chemistry-Principles of Structure and Reactivity, Pearson Education.
- Douglas, B.E.; McDaniel, D.H.; Alexander, J.J. (1994), Concepts and Models of Inorganic Chemistry, John Wiley & Sons.
- 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.
- Housecraft, E. H.; Sharpe, A.G. (2018), Inorganic Chemistry, 5th Edition, Pearson.
- F.A. Cotton & G. Wilkinson (1999), Advanced Inorganic Chemistry, 6th Edition, John Wiley & Sons.

Practicals:

- Vogel, A.I. (1972), Qualitative Inorganic Analysis, Longman.
- Svehla, G. (1996), Vogel's Qualitative Inorganic Analysis, Prentice Hall.

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

DISCIPLINE SPECIFIC ELECTIVE COURSE CHEM-DSE: Chemistry- VI: Active Methylene Compounds, Polynuclear Hydrocarbons and Heterocyclic

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		
Active Methylene Compounds, Polynuclear Hydrocarbons and Heterocyclic Compounds DSE: Chemistry -VI	**04**	**02**	**0**	**02**	**Class 12th with Physics, Chemistry, Mathematics**	**NIL**

Learning Objectives

The purpose of this course is

- to introduce the chemistry and applications of polynuclear hydrocarbons,
- To know about active methylene and heterocyclic compounds.

Learning Outcomes:

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

- Understand the fundamentals of functional group chemistry, polynuclear hydrocarbons and heterocyclic compounds through the study of methods of preparation, properties and chemical reactions with underlying mechanism.
- Become familiar with their particular properties, chemical reactions, criterion of aromaticity with reference to polynuclear hydrocarbons and heterocyclic compounds, trends in basicity of amines and heterocyclic compounds and their behaviour at different pH.
- Understand the Synthetic applications of these compounds including their medicinal applications through their reaction chemistry.

Unit 1: Active methylene compounds **(08 Hours)**

Preparation and reactions, Claisen ester condensation, Keto-enol tautomerism. Reactions: Synthetic uses of ethylacetoacetate and malonic esters (preparation of non-heteromolecules having up to 6 carbons).

Unit 2: Polynuclear Aromatic compounds: **(09 Hours)**

Introduction, Classification, Structure, Nomenclature and uses. Aromaticity of polynuclear hydrocarbons, structure elucidation of Naphthalene and general methods of preparation of naphthalene, phenanthrene and anthracene (including Haworth method, Friedel Craft acylation, Diels Alder reaction and Pschorr Synthesis).
Relative reactivity of naphthalene, phenanthrene and anthracene in comparison to benzene.
Properties: Physical properties, discussion on the following reaction (with mechanism) for Naphthalene, Anthracene and Phenanthrene: Addition reactions, Oxidation, Electrophilic substitution- Friedel Craft reaction, Chloromethylation, Halogenation, Formylation, Nitration and sulphonation. Reduction reaction and Diels Alder reaction.

UNIT-3: Heterocyclic Compounds **(13 Hours)**

Introduction, importance, classification and nomenclature of heterocyclic compounds (containing only one hetero atom). General discussion on the following aspects of heterocyclic compounds: Structure, aromaticity in 5-membered and 6-membered rings containing one heteroatom; Basicity and relative reactivity towards electrophilic substitution reactions (amongst five membered and six membered rings)

General methods of synthesis for: Furan, Pyrrole (Paal-Knorr synthesis, Hantzsch synthesis), Thiophene, Pyridine (Hantzsch synthesis), Properties: Physical properties, discussion on the following reaction (with mechanism) for Furan, Pyrrole, thiophene, Pyridine- Electrophilic substitution- Nitration, sulphonation, halogenation, Formylation, acylation, mercuration and carboxylation. Oxidation, Reduction, Addition, Reactions showing acidic /basic character. Reaction with diazonium salts, Ring opening, Ring expansion and Nucleophilic substitution reaction wherever applicable should be discussed

PRACTICAL COMPONENT **(60 Hours)**

1. Nitration of simple compounds like Chlorobenzene/Bromobenzene.
2. Benzoylation of p-toluidine (or any other compound).
3. Oxidation of toluene to benzoic acid.
4. Detection of Nitrogen/sulphur/halogens in the given organic compound.
5. Systematic identification of bifunctional compounds (Salicylic Acid, Cinnamic acid and nitro phenols) and preparation of their derivatives.
6. Systematic identification of Aromatic hydrocarbons and aryl halides.
7. Multistep synthesis: (a) Cyclohexanone to caprolactam (b) Aniline to p-bromo aniline

References:

- Morrison, R. T.; Boyd, R. N. (2010) Organic Chemistry, Dorling Kindersley (India) Pvt. Ltd.(Pearson Education).
- Finar, I. L.(2002) Organic Chemistry (Volume 1& 2), Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
- Solomons, T. W. G.; Fryhle, C. B. ; Snyder, S. A. (2016),Organic Chemistry, 12th Edition, Wiley.

- Clayden, J.; Greeves, N.; Warren, S.; Wothers, P. (2013),Organic Chemistry, Oxford University Press.
- Gilchrist, T.L. (1997),Heterocyclic Chemistry, Pearson Education.
- Ram V. J.; Sethi, A.; Nath, M.; Pratap, R.; (2019), The Chemistry of Heterocycles (Chemistry of six to eight membered N, O, S, P and Se heterocycles), Elsevier publication.
- Ahluwalia, V.K.; Dhingra, S. (2000), Comprehensive Practical Organic Chemistry: Qualitative Analysis, Universities Press.
- Jeffery, G.H.; Bassett, J.; Mendham, J.; Denney, R.C. (1989),Vogel's Textbook of Quantitative Chemical Analysis, John Wiley and Sons.
- Mann F.G, and Saunders, B.C. (2009) Practical Organic Chemistry, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education Ltd.), Singapore.
- Vogel A.I. (2012) Elementary Practical Organic Chemistry, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education Ltd.), Singapore.

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DISCIPLINE SPECIFIC ELECTIVE COURSE: DSE-RM: Research Methodology for Chemists

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		
Research Methodology for Chemists DSE-RM	**04**	**03**	**0**	**01**	**Class 12th with Physics, Chemistry, Mathematics**	**NIL**

Learning Objectives

The course is designed

- To make the students aware of fundamental but mandatory ethical practices in chemistry.
- To make the students aware of data analysis.
- To make the students aware of literature survey in different modes.
- To make the students aware of safety handling and safe storage of chemicals.
- This paper will help student to learn to avoid plagiarism. To learn different e-resources.

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

- Ethical practices in chemistry
- Data analysis
- Literature survey in different modes
- Three R (recovery, recycling and reuse of laboratory chemicals).
- e-resources.
- Plagiarism, consequences

Syllabus of DSE-RM
THEORY COMPONENT

Unit 1: Literature Survey **(20 Hours)**

Print: Sources of information: Primary, secondary, tertiary sources; Journals: Journal abbreviations, abstracts, current titles, reviews, monographs, dictionaries, text-books, current contents, Introduction to Chemical Abstracts and Beilstein, Subject Index, Substance Index, Author Index, Formula Index, and other Indices with examples.
Digital: Web resources, E-journals, Journal access, TOC alerts, Hot articles, Citation index, Impact factor, H-index, E-consortium, UGC infonet, E-books, Internet discussion groups and communities, Blogs, Preprint servers, Search engines, Scirus, Google Scholar, ChemIndustry, Wiki- Databases, ChemSpider, Science Direct, SciFinder, Scopus.
Information Technology and Library Resources: The Internet and World Wide Web. Internet resources for chemistry. Finding and citing published information. publications of scientific work. Writing ethics. Avoiding plagiarism.

Unit 2: Chemical Safety and Ethical Handling of Chemicals **(12 Hours)**

Safe working procedure and protective environment, protective apparel, emergency, procedure and first aid, laboratory ventilation. Safe storage and use of hazardous chemicals, procedure for working with substances that pose hazards, flammable or explosive hazards, procedures for working with gases at pressures above or below atmospheric – safe storage and disposal of waste chemicals, recovery, recycling and reuse of laboratory chemicals, procedure for laboratory disposal of explosives, identification, verification and segregation of laboratory waste, disposal of chemicals in the sanitary sewer system, incineration and transportation of hazardous chemicals.

Unit 3: Data Analysis **(13 Hours)**

The Investigative Approach: Making and Recording Measurements. SI Units and their use. Scientific method and design of experiments. Analysis and Presentation of Data: Descriptive statistics. Choosing and using statistical tests. Curve fitting, fitting of linear equations, simple linear cases, weighted linear case, analysis of residuals, General polynomial fitting, linearizing transformations, exponential function fit, r and its abuse. Basic aspects of multiple linear regression analysis.

PRACTICAL COMPONENT (30 Hours)

1. Collection of journal articles on a particular topic using Google Scholar and creating a database.
2. Collection of journal articles on a particular topic using Science Direct and creating a database.
3. Collection of journal articles on a particular topic using Scopus and creating a database.
4. Collection of chemical structure using ChemSpider and creating a database.
5. Collection of chemical structure using SciFinder and creating a database.
6. Curve fitting using freely available softwares/apps (any one)
7. Making of power point presentation
8. Experimental learning of safe storage hazardous chemicals
9. Experimental learning of handling of hazardous chemicals

References:

- Dean, J. R., Jones, A. M., Holmes, D., Reed, R., Weyers, J. & Jones, A. (2011) Practical skills in chemistry. 2nd Ed. Prentice-Hall, Harlow.
- Hibbert, D. B. & Gooding, J. J. (2006) Data analysis for chemistry. Oxford University Press.
- Topping, J. (1984) Errors of observation and their treatment. Fourth Ed., Chapman Hall, London.
- Harris, D. C. Quantitative chemical analysis. 6th Ed., Freeman (2007) Chapters 3-5.
- Levie, R. de, how to use Excel in analytical chemistry and in general scientific data analysis. Cambridge Univ. Press (2001) 487 pages.
- Chemical safety matters – IUPAC – IPCS, Cambridge University Press, 1992.
- OSU safety manual 1.01.

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