NEP and Learning Outcome-based Curriculum Framework (LOCF)

For

Under Graduate Programme
B.Sc. (Honours) Chemistry
Academic Session (w.e.f. 2024-2025)

I & II SEMESTERS

DEPARTMENT OF CHEMISTRY
MAHARAJA SURAJMAL BRIJ UNIVERSITY
BHARATPUR

Dr. Farbat Singh
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(Dr. Nisha Chandra)

Dr. Rakhee Choudhary

Dr. Anshu Nandra

Scheme of Examination

The examination pattern comprises 20% internal assessment and 80% external assessment.

External Assessment

Theory Papers:

1. Each theory paper in the end-of-semester examination (EoSE) carries 80% marks.

2. The EoSE will be of 3 hours duration.

3. The questions will be designed in alignment with Bloom's Taxonomy.

Part A of the question paper shall contain 10 very short answer type questions covering the entire syllabus. Each question carries equal marks.

Part B of the question paper shall contain 04 descriptive type questions one from each unit with internal choice. Each question carries equal marks.

Value-Added Papers

1. Each theory paper in the end-of-semester examination (EoSE) carries 80% marks.

2. The EoSE will be of 2 hours duration.

3. Question paper shall contain 40 multiple choice questions covering the entire syllabus. Each question carries 1 mark.

Practical:

Internal: continuous evaluation (20%).

External: end term practical record (20%), written exam (40%) and viva-voce (20%).

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Scheme of Programme

B.Sc. (Honours) Chemistry

SEMESTER 1

Course Code	Course ID	Course Title	L	T	P	L	T	P	Total Credits	MARKS				
			(Hrs)			Credits				TI	TE	PI	PE	Total
Core Course(s)														
UCSC-01	Inorganic Chemistry-I	Atomic Structure & Chemical Bonding	3			3			3	15	60	-	-	75
UCSC-02	Organic Chemistry-I	Basic Concepts and Aliphatic Hydrocarbons	3			3			3	15	60	-	-	75
UCSC-03	Physical Chemistry-I	Gaseous and Liquid state	3			3			3	15	60	-	-	75
UCLAB-01L	Chemistry Lab-1				6			3	3			15	60	75
General Elective Courses: Student can choose any one														
UCGE-01	Chemistry General Elective-I	Conductance and Electrochemistry	2			2			2	10	40	-	-	50
UCGE-01L	Chemistry General Elective Lab-I	Conductance and Electrochemistry Lab			4			2	2			10	40	50
UCGE-02	Chemistry General Elective-II	Statistical Methods and Data Analysis-I	2			2				10	40			50
UCGE-02L	Chemistry General Elective Lab-II	Statistical Methods and Data Analysis-I Lab			4			2				10	40	50
Ability Enhancement Course														
UAEC-01	Environment Science-I	Environment Science and Sustainable Development-1	2			2			2	10	40			50
Skill Enhancement Course														
UCSEC-01	Lab Skill	Lab Testing and Quality Assurance	2			2			2	10	40	-	-	50
Value-added Course(s)														
UVAC-01	Societal Value of Science	Science and Society	2			2			2	10	40	-	-	50
Total Credits									22					550

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SEMESTER 2

Course Code	Course ID	Course Title	L	T	P	L	T	P	Total Credits	MARKS				
			(Hrs)			Credits				TI	TE	PI	PE	Total
Core Course(s)														
UCSC-04	Inorganic Chemistry-II	Chemistry of s- and p-Block Elements	3			3			3	15	60	-	-	75
UCSC-05	Organic Chemistry-II	Haloalkanes, Arenes, Haloarenes, Alcohols, Phenols, Ethers and Epoxides	3			3			3	15	60	-	-	75
UCSC-06	Physical Chemistry-II	Chemical Thermodynamics and its application	3			3			3	15	60	-	-	75
UCLAB-02	Chemistry Lab-2				6			3	3			15	60	75
General Elective Courses: Student can choose any one														
UCGE-03	General Elective-III	Coordination and Organometallic Compounds	2			2			2	10	40	-	-	50
UCGE-03L	General Elective-III Lab	Coordination and Organometallic Compounds Lab			4			2	2			10	40	50
UCGE-04	General Elective-IV	Statistical Methods and Data Analysis-II	2			2			2	10	40			50
UCGE-04L	General Elective-IV Lab	Statistical Methods and Data Analysis-II Lab			4			2	2			10	40	50
Ability Enhancement Course														
UAEC-02	Environment Science-II	Environment Science and Sustainable Development-2	2			2			2	10	40			50
Skill Enhancement Course														
UCSEC-02/UPGE-02	Physics-I	Engineering Materials	2			2			2	10	40			50
Value-added Course(s)														
UVAC-02		Indian Knowledge System	2			2			2	10	40	-	-	50
Total Credits									22					550

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UCSC-01: INORGANIC CHEMISTRY–I
(Atomic Structure & Chemical Bonding)

Course Outcomes:

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

- Solve the conceptual questions using the knowledge gained by studying the quantum mechanical model of the atom, quantum numbers, electronic configuration, radial and angular distribution curves, shapes of s, p, and d orbitals, and periodicity in atomic radii, ionic radii, ionization enthalpy and electron affinity of elements.
- Draw the plausible structures and geometries of molecules using radius ratio rules, VSEPR theory and MO diagrams (homo- & hetero-nuclear diatomic molecules).
- Understand the concept of lattice energy using Born-Landé and Kapustinskii equation.
- Calibrate the apparatus used in titrimetric analysis and prepare standard solutions for titration
- Understand the theory and application of various acid-base and redox titrations.
- Comprehend the theory of acid-base indicators

Unit 1: Atomic Structure:

Recapitulation of concept of atom in ancient India, Bohr's theory & its limitations, atomic spectrum of hydrogen atom. De Broglie equation, Heisenberg's Uncertainty Principle and its significance. Postulates of wave mechanics, Time independent Schrödinger's wave equation, well behaved wave function, significance of ψ and $\psi 2$. Quantum mechanical treatment of H-atom, Quantum numbers and their significance. Normalized and orthogonal wave functions. Sign of wave functions. Radial and angular wave functions for hydrogen atom. Radial function plots, radial probability distribution plots, angular distribution curves. Shapes of s, p, and d orbitals, Relative energies of orbitals. Pauli's Exclusion Principle, Hund's rule of maximum spin multiplicity, Aufbau principle and its limitations.

Unit 2: Periodic properties of Elements & Periodic Trends

Brief discussion of the following properties of the elements, with reference to *s*- & *p*-block and their trends:

(a) Effective nuclear charge, shielding or screening effect and Slater's rules

(b) Atomic and ionic radii

(c) Ionization enthalpy (Successive ionization enthalpies)

(d) Electron gain enthalpy

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(e) Electronegativity, Pauling's scale of electronegativity. Variation of electronegativity with bond order and hybridization.

Unit 3: Ionic bond

General characteristics, types of ions, size effects, radius ratio rule and its limitations. Packing of ions in crystals. Lattice energy, Born-Landé equation with derivation, Madelung constant, importance of Kapustinskii equation for lattice energy. Born-Haber cycle and its applications.Covalent character in ionic compounds, polarizing power and polarizability. Fajan's rules and consequences of polarization

Unit 4: Covalent Bond

Valence Shell Electron Pair Repulsion (VSEPR) theory, shapes of simple molecules and ions containing lone pairs and bond pairs of electrons, including H_2O, NH_3, PCl_3, PCl_5, SF_6, ClF_3, I_3^-, BrF_2^+, PCl_6^-, ICl_2^-, ICl_4^-, and SO_4^{2-}. Application of VSEPR theory in predicting trends in bond lengths and bond angles. Valence Bond Theory (Heitler-London approach), hybridization, equivalent and nonequivalent hybrid orbitals, and Bent's rule. Ionic character in covalent compounds, bond moment and dipole moment, and determination of percentage ionic character from dipole moment and electronegativity difference. Molecular orbital diagrams of homo- and hetero-diatomic molecules such as N_2, O_2, C_2, B_2, F_2, CO, NO, and their ions, as well as HCl, with an emphasis on the concept of s-p mixing and orbital interaction.

References:

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. Pfennig, B. W. (2015), Principles of Inorganic Chemistry. John Wiley & Sons.
6. Housecraft, C. E.; Sharpe, A. G., (2018), Inorganic Chemistry, 5th Edition, Pearson.
7. Wulfsberg, G (2002), Inorganic Chemistry, Viva Books Private Limited.
8. Miessler, G.L.; Fischer P.J.; Tarr, D. A. (2014), Inorganic Chemistry, 5th Edition, Pearson.
9. Shiver, D.; Weller, M.; Overton, T.; Rourke, J.; Armstrong, F. (2014), Inorganic Chemistry, 6th Edition, Freeman & Company
10. Das, A. K.; Das, M. (2014), Fundamental Concepts of Inorganic Chemistry, 1st Edition, Volume CBS Publishers & Distributors Pvt. Ltd.

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UCSC - 02: ORGANIC CHEMISTRY - I
(Basic Concepts and Aliphatic Hydrocarbons)

Course Outcomes:

On completion of the course, the student will be able to:

- Understand and explain the electronic displacements and reactive intermediates and their applications in basic concepts.
- Formulate the mechanistic route of organic reactions by recalling and correlating the fundamental concepts.
- Identify and comprehend mechanism for free radical substitution, electrophilic addition, nucleophilic substitution and elimination reactions.
- Understand the fundamental concepts of stereochemistry.
- Understand and suitably use the chemistry of hydrocarbons

Unit I: Basic Concepts of Organic Chemistry

Electronic displacements and their applications: inductive, electromeric, resonance and mesomeric effects and hyperconjugation. Dipole moment, acidity and basicity.

Homolytic and heterolytic fissions with suitable examples. Types, shape and relative stability of carbocations, carbanions, carbenes and free radicals.

Electrophiles & nucleophiles, and introduction to types of organic reactions: addition, elimination and substitution reactions.

Unit II: Stereochemistry-I

Stereoisomerism: Optical activity and optical isomerism, asymmetry, chirality, enantiomers, diastereomers. specific rotation; Configuration and projection formulae: Newman, Sawhorse, Fischer and their interconversion. Chirality in molecules with one and two stereocentres; meso configuration. Racemic mixture and their resolution. Relative and absolute configuration: D/L and R/S designations (CIP rules).

Unit III: Stereochemistry-II

Geometrical isomerism: *cis-trans*, *syn-anti* and *E/Z* notations.Conformational Isomerism: Alkanes (Conformations, relative stability and energy diagrams of Ethane, Propane and butane). Relative stability of cycloalkanes (Baeyer strain theory), Cyclohexane conformations with energy diagram. Conformations of monosubstituted cyclohexanes.

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Unit IV: Aliphatic Hydrocarbons

Alkanes: Preparation, Halogenation of alkanes, Concept of relative reactivity v/s selectivity.

Alkenes and Alkynes: Methods of preparation of alkenes using Mechanisms of E_1, E_2, E_1cb reactions, Saytzeff and Hoffmann eliminations. Electrophilic additions, mechanism with

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suitable examples, (Markownikoff/Anti-markownikoff addition), *syn* and *anti*-addition; addition of H_2, X_2, oxymercuration- demercuration, hydroboration-oxidation, ozonolysis, hydroxylation, Reactions of alkynes; acidity, Alkylation of terminal alkynes, electrophilic addition: hydration to form carbonyl compounds, Relative reactivity of alkenes and alkynes, 1,2-and 1,4-addition reactions in conjugated dienes, Diels Alder reaction (excluding stereochemistry)

References:

1. Morrison, R.N., Boyd, R.N., Bhattacharjee, S.K. (2010), **Organic Chemistry**, 7th Edition, Dorling Kindersley (India) Pvt. Ltd., Pearson Education.
2. Finar, I.L. (2002), **Organic Chemistry**, Volume 1, 6th Edition, Dorling Kindersley (India) Pvt. Ltd., Pearson Education.
3. Eliel, E.L., Wilen, S.H. (1994), **Stereochemistry of Organic Compounds**; Wiley: London.

Additional Resources:

1. Solomons, T.W.G., Fryhle, C.B., Snyder, S.A. (2017), **Organic Chemistry**, 12th Edition, Wiley.
2. Bruice, P.Y. (2020), **Organic Chemistry**, 8th Edition, Pearson.
3. Clayden, J., Greeves, N., Warren, S. (2014), **Organic Chemistry**, Oxford.
4. Nasipuri, D. (2018), **Stereochemistry of Organic Compounds: Principles and Applications**, 4th Edition, New Age International.
5. Gunstone, F.D. (1975), **Guidebook to Stereochemistry**, Prentice Hall Press.
6. Gupta, S.S. (2018), **Basic Stereochemistry of Organic Molecules,** 2nd Edition, Oxford University Press.

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UCSC-03: PHYSICAL CHEMISTRY-I
(Gaseous and Liquid state)

Course Outcomes:

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

- Derive mathematical expressions for different properties of gas and liquid and understand their physical significance.
- Apply the concepts of gas equations and liquids while studying other chemistry courses and every-day life.
- Handle stalagmometer and Ostwald viscometer properly.
- Determine the density of aqueous solutions.
- Dilute the given solutions as per required concentrations.
- Data reduction using numerical and graphical methods.

Unit 1: Gaseous state-I

Kinetic theory of gases- postulates and derivation of kinetic gas equation, Maxwell distribution of molecular velocities and its use in evaluating average, root mean square and most probable velocities and average kinetic energy. Definition, expression, applications and temperature and pressure dependence of each one of the following properties of ideal gases: Collision frequency, Collision diameter, Mean free path. Coefficient of viscosity, definition, units and origin of viscosity of gases, relation between mean free path and coefficient of viscosity, temperature and pressure dependence of viscosity of a gas, calculation of molecular diameter from viscosity

Barometric distribution law, its derivation and applications, alternative forms of barometric distribution law in terms of density and number of molecules per unit volume, effect of height, temperature and molecular mass of the gas on barometric distribution

Unit 2: Gaseous state-II

Behaviour of real gases- Compressibility factor, Z , Variation of compressibility factor with pressure at constant temperature *(plot of Z vs P)* for different gases (H_2, CO_2, CH_4 and NH_3), Cause of deviations from ideal gas behaviour and explanation of the observed behaviour of real gases in the light of molecular interactions

Van der Waals (vdw) equation of state, Limitations of ideal gas equation of state and its modifications in the form of derivation of van der Waal equation, Physical significance of van der Waals constants, application of van der Waal equation to explain the observed behaviour of real gases.

Isotherms of real gases- Critical state, relation between critical constants and van der Waals constants, correlation of critical temperature of gases with intermolecular forces of attraction, Continuity of states, Limitations of van der Waals equation, Reduced equation of state and law of corresponding states (statement only).

Virial equation of state-Physical significance of second and third virial coefficients, van

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der Waals equation expressed in virial form, Relations between virial coefficients and van der Waals constants

Unit 3: Liquid state-I

Nature of liquid state, qualitative treatment of the structure of the liquid state
Physical properties of liquids-vapour pressure, its origin and definition, Vapour pressure of liquids and intermolecular forces, and boiling point
Surface tension, its origin and definition, Capillary action in relation to cohesive and adhesive forces, determination of surface tension by (i) using stalagmometer (drop number and drop mass method both) and (ii) capillary rise method, Effects of addition of sodium chloride, ethanol and detergent on the surface tension of water and its interpretation in terms of molecular interactions, Role of surface tension in the cleansing action of detergents

Unit 4: Liquid state-II

Coefficient of viscosity and its origin in liquids, Interpretation of viscosity data of pure liquids (water, ethanol, ether and glycerol) in the light of molecular interactions, Effects of addition of sodium chloride, ethanol and polymer on the viscosity of water, relative viscosity, specific viscosity and reduced viscosity of a solution, comparison of the origin of viscosity of liquids and gases, effect of temperature on the viscosity of a liquid and its comparison with that of a gas.

References:

1. Atkins, P.W.; Paula, J.de. (2014), **Atkin's Physical Chemistry Ed.**, 10th Edition, Oxford University Press.
2. Ball, D. W. (2017), **Physical Chemistry**, 2nd Edition, Cengage Learning, India.
3. Castellan, G. W. (2004), **Physical Chemistry**, 4th Edition, Narosa.
4. Kapoor, K.L. (2015), **A Textbook of Physical Chemistry**, Vol 1, 6th Edition, McGraw Hill Education.
5.

Additional Resources:

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

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UCLAB-01L: CHEMISTRY LAB-I

Course Outcomes:

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

- Apply fundamental principles of titrimetry and redox chemistry to accurately prepare solutions and perform quantitative estimations of inorganic compounds.
- Demonstrate skills in purification, separation, and identification of organic compounds using classical techniques like recrystallization, chromatography, and melting/boiling point determination.
- Analyze physical properties of liquids such as surface tension and viscosity using experimental methods, and interpret data based on molecular interactions.
- Employ scientific methodology, calibration techniques, and analytical instruments to obtain reproducible results, and develop competence in error analysis and data interpretation.

Note: Any experiment can be introduced or deleted in the practical class on the basis of availability of instruments/chemicals.

List of Practical's

Inorganic Chemistry-I

1. Titrimetric Analysis:

(i) Calibration and use of apparatus

(ii) Preparation of solutions of different Molarity/Normality.

2. Acid-Base Titrations: Principles of acid-base titrations to be discussed.

(i) Estimation of oxalic acid using standardized NaOH solution

(ii) Estimation of sodium carbonate using standardized HCl.

(iii) Estimation of carbonate and hydroxide present together in a mixture.

(iv) Estimation of carbonate and bicarbonate present together in a mixture.

3. Redox Titration: Principles of oxidation-reduction titrations to be discussed.

(i) Estimation of oxalic acid using standardized $KMnO_4$ solution

(ii) Estimation of water of crystallization in Mohr's salt by titrating with $KMnO_4$.

(iii) Estimation of oxalic acid and sodium oxalate in a given mixture.

Organic Chemistry-I

1. Calibration of a thermometer and determination of the melting points of the organic compounds using any one of the following methods-Kjeldahl method, electrically heated melting point apparatus and BODMEL).
2. Concept of melting point and mixed melting point.
3. Concept of recrystallisation using alcohol/water/alcohol-water systems (Any two).

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4. Determination of boiling point of liquid compounds (boiling point lower than and more than 100 °C by distillation, capillary method and BODMEL method)
5. Separation of a mixture of two amino acids/sugars by radial/ascending paper chromatography.
6. Separation of a mixture of *o*-and *p*-nitrophenol or *o*-and *p*-aminophenol by thin layer chromatography (TLC).
7. Detection of extra elements

Physical Chemistry-I

Gases

1. To verify the Charles law using Charles law apparatus
2. To determine the value of universal gas constant R using the reaction $Mg(s) + 2HCl\ (aq) \longrightarrow MgCl_2\ (aq) + H_2\ (g)$

Surface tension measurements using stalagmometer

1. Determine the surface tension of a liquid by drop number method.
2. Determine the surface tension of a liquid by drop weight method.
3. Study the variation of surface tension with different concentration of detergent solutions. Determine CMC.
4. Study the effect of the addition of solutes on the surface tension of water at room temperature and explain the observations in terms of molecular interactions:
   a. sugar
   b. ethanol
   c. sodium chloride
5. Study the variation of surface tension with different concentration of sodium chloride solutions.

Viscosity measurement using Ostwald's viscometer

1. Determination of co-efficient of viscosity of two unknown aqueous solution.
2. Study the variation of viscosity with different concentration of sugar solutions.
3. Study the effect of the addition of solutes such as (i) polymer (ii) ethanol (iii) sodium chloride on the viscosity of water at room temperature and explain the observations in terms of molecular interactions
4. Study the variation of viscosity of water with the amounts of a solute and calculate the intrinsic viscosity at room temperature.
5. Determine the viscosity average molecular mass of the polymer (PVA) using viscosity measurements.

References:

1. Jeffery, G.H.; Bassett, J.; Mendham, J.; Denney, R.C. (1989), Vogel's Textbook of
2. Quantitative Chemical Analysis, John Wiley and Sons.
3. Harris, D. C.; Lucy,C. A.(2016), Quantitative Chemical Analysis, 9th Edition, Freeman and Company
4. Mann, F.G., Saunders, B.C. (2009), **Practical Organic Chemistry**, 4th Edition, Pearson Education.

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5. Ahluwalia, V.K., Dhingra, S. (2004), **Comprehensive Practical Organic Chemistry: Qualitative Analysis**, University Press.
6. Furniss, B.S., Hannaford, A.J., Smith, P.W.G.; Tatchell, A.R (2004), **Vogel's Textbook of Practical Organic Chemistry**, Pearson.
7. Leonard, J., Lygo, B., Procter, G. (2013) **Advanced Practical Organic Chemistry**, 3rd Edition, CRC Press.
8. Pasricha, S., Chaudhary, A. (2021), **Practical Organic Chemistry: Volume–I**, I K International Publishing house Pvt. Ltd, New Delhi.
9. Khosla, B.D.; Garg, V.C.; Gulati, A. (2015), Senior Practical Physical Chemistry, R. Chand & Co, New Delhi.
10. Kapoor, K.L. (2019), A Textbook of Physical Chemistry, Vol.7, 1st Edition, McGraw Hill Education.
11. Garland, C. W.; Nibler, J. W.; Shoemaker, D. P. (2003), Experiments in Physical Chemistry, 8th Edition, McGraw-Hill, New York.

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UCGE-01: CONDUCTANCE AND ELECTROCHEMISTRY

Course Outcomes:

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

- Understand factors influencing conductance and ionic mobility.
- Apply conductance measurements to determine physical and chemical properties.
- Explain electrochemical cells, electrode potentials, and EMF.
- Use EMF and potentiometric methods for titrations and pH determination.

Unit I: Fundamentals of Conductance

Quantitative aspects of Faraday's laws of electrolysis. Arrhenius theory of electrolytic dissociation. Conductivity: equivalent and molar conductivity and their variation with dilution for weak and strong electrolytes, Kohlrausch Law of independent migration of ions. Wein Effect and Debye–Falkanhegan Effect.

Unit II: Applications of Conductance

Transference number and its experimental determination using Hittorf and moving boundary methods, Ionic mobility, applications of conductance measurements: determination of degree of ionization of weak electrolytes, solubility and solubility products of sparingly soluble salts, ionic product of water, hydrolysis constant of a salt. Conductometric titrations (only acid base).

Unit III: Basics of Electrochemistry

Reversible and irreversible cells with Examples, concept of EMF of a cell, measurement of EMF of a cell, Nernst equation and its importance, types of electrodes, standard electrode potential (reduction Potential) and its application to Gas–ion half-cell. Electrochemical series.

Unit IV: Applications of Electrochemistry

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 with transference and without transference, liquid junction potential; determination of activity coefficients and salt bridge, pH determination using hydrogen electrode. Potentiometric titrations qualitative treatment (acid-base and oxidation-reduction only).

References/Books:

1. Castellan, G.W. (2004), Physical Chemistry, Narosa.

2. Kapoor, K.L. (2015), A Textbook of Physical Chemistry,Vol 1, 6th Edition, McGraw Hill Education.

3. Kapoor, K.L. (2013), A Textbook of Physical Chemistry,Vol 3, 3rd Edition, McGraw Hill Education.

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UCGE-01L: CONDUCTANCE AND ELECTROCHEMISTRY LAB

Course Outcomes:

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

- Perform volumetric and redox titrations for quantitative analysis of inorganic compounds.
- Apply techniques for purification, separation, and identification of organic compounds.
- Analyze physical properties of liquids and gases to understand molecular interactions.
- Conduct electroanalytical experiments using conductometric and potentiometric methods.

Note: Any experiment can be introduced or deleted in the practical class on the basis of availability of instruments/chemicals.

List of Practical's

Conductance

1. Determination of cell constant.

2. Determination of equivalent conductance, degree of dissociation and dissociation constant of a weak acid.

3. Perform the following conductometric titrations:

a) Strong acid vs strong base

b) Weak acid vs strong base.

Potentiometry

Perform the potentiometric titrations of (i) Strong acid vs strong base, (ii) Weak acid vs strong base and (iii) Mohr's salt vs $KMnO_4$.

Reference:

1. Khosla, B.D.; Garg, V.C.;Gulati, A.(2015), **Senior Practical Physical Chemistry**, R. Chand & Co

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UCGE-02: STATISTICAL METHODS AND DATA ANALYSIS-I

Course Outcomes:

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

- Familiar with interpretation and use of analytical data collected by different techniques.
- Significance of different analytical techniques and their applications.
- Reliability and presentation of data for reporting to different forum.

Unit I: Basics of Chemical Analysis

Analytical Chemistry, Qualitative and quantitative analysis, Analytical methodology. Calibration of glass wares, recording laboratory data.

Unit II: Different Methods of Chemical Analysis

Titrimetric method: volumetric titremetry, standard solution, titrimetric curve, calculation;

Gravimetric method: precipitation gravimetry, calculation and applications of gravimetry; and

Spectrometric methods: introduction, principle and instrument, working quantitative aspects

absorbance, applications in chemical analysis

Unit III: Accuracy and Precision

Comparison of precision, Errors, Distribution of random errors, propagation of errors, measurement of errors, significant figure, inter laboratory error.

Unit IV: Statistical Method of Chemical Analysis

Methods of least square analysis of variance, Q test, Z test, T test, statistical treatment of finite sample, recommendations for treating outliers. Minimising errors in analytical procedure.

References/Books:

1. Dey, R. A. and Underwood, A. L., Quantitative Analysis, 6th Edition, Pearson.

2. Skoog, D. A., West, D. M., Holler, F. J., Crouch, S. R., Fundamental analytical chemistry, Thomson Asia Ltd.

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UCGE-02L: STATISTICAL METHODS AND DATA ANALYSIS-I LAB

Course Outcomes:

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

- Demonstrate the ability to calibrate laboratory glassware and apply calibration constants to ensure accuracy in quantitative analysis.
- Apply Good Laboratory Practices (GLP) to maintain accuracy, safety, and consistency during experimental procedures.
- Perform quantitative analysis of heavy metals and other elements using volumetric, gravimetric, and complexometric methods.
- Analyze experimental data to evaluate errors, calculate standard deviation, and assess the precision and reliability of analytical results.

Note: Any experiment can be introduced or deleted in the practical class on the basis of availability of instruments/chemicals.

List of Practical's

1. Calibrate the volume of laboratory glass wares i.e. volumetric flask, beaker, burette and calibration constant.
2. Demonstrate the good laboratory practices like effect of dilution, temperature, taking observation, personal and apparatus safety.
3. Determine the quantitative presence of heavy metals like copper, chromium and iron in natural and laboratory samples using volumetric and gravimetric titration.
4. Determine the presence of magnesium ion in heavy water by EDTA method and prepare calibration curve.
5. Evaluate the absolute and method errors in a set of data collected during determination of nitrogen in an organic compound.
6. Calculate the standard deviation and predict precision of analytical results.

References:

1. Dey, R. A. and Underwood, A. L., **Quantitative Analysis**, 6th Edition, Pearson.
2. Skoog, D. A., West, D. M., Holler, F. J., Crouch, S. R., **Fundamental analytical chemistry**, Thomson Asia Ltd.
3. Encyclopaedia of analytical chemistry: Applications, Theory, and Instrumentation, R A Meyor (Eds) Wiley and Sons (2000).

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UAEC-01: ENVIRONMENTAL SCIENCE AND SUSTAINABLE DEVELOPMENT-I

Course Outcomes:

After completing this course, students will be able to:

- Gain in-depth knowledge on natural processes and resources that sustain life and govern economy.
- Understand the consequences of human actions on the web of life, global economy, and quality of human life.
- Develop critical thinking for shaping strategies (scientific, social, economic, administrative, and legal) for environmental protection, conservation of biodiversity, environmental equity, and sustainable development.
- Acquire values and attitudes towards understanding complex environmental- economic-social challenges, and active participation in solving current environmental problems and preventing the future ones.

Unit I

Introduction to Environmental Studies: Multidisciplinary nature of environmental studies; components of environment: atmosphere, hydrosphere, lithosphere, and biosphere; Scope and importance; Concept of sustainability and sustainable development; Brief history of environmentalism.

Unit II

Ecosystems: Definition and concept, Structure of ecosystem (biotic and abiotic components); Functions of Ecosystem: Physical (energy flow), Biological (food chains, food web, ecological succession), and Biogeochemical (nutrient cycling) processes. Concepts of productivity, ecological pyramids and homeostasis, Types of Ecosystems: Tundra, Forest, Grassland, Desert, Aquatic (ponds, streams, lakes, rivers, oceans, estuaries); importance and threats with relevant examples from India, Ecosystem services (Provisioning, Regulating, Cultural, and Supporting); Ecosystem preservation and conservation strategies; Basics of Ecosystem restoration

Unit III

Natural Resources: Land resources- Minerals, soil, agricultural crops, natural forest products, medicinal plants, and forest-based industries and livelihoods; Land cover, land use change, land degradation, soil erosion , and desertification; Causes of deforestation; Impacts of mining and dam building on environment, forests, biodiversity, and tribal communities; Water resources-Natural and man-made sources; Uses of water; Over exploitation of surface and ground water resources; Floods, droughts, and international &interstate conflicts over water; Energy resources-Renewable and non-renewable energy sources; Use of alternate energy sources; Growing energy needs; Energy contents of coal, petroleum, natural gas and bio gas; Agro-residues as a biomass energy source.

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Unit IV

Case studies: Contemporary Indian issues related to mining, dams, forests, energy, etc (e.g ., National Solar Mission, Cauvery river water conflict, Sardar Sarovar dam, Chipko movement, Appiko movement, Tarun Bharat Sangh, etc)

References/ Books:

1. Raven, P.H, Hassenzahl, D.M., Hager, M.C, Gift, N.Y., and Berg , L.R. (2015). Environment, 9th Edition. Wiley Publishing, USA.

2. Singh, J.S., Singh, S.P., and Gupta, S.R. (2017). Ecology, Environmental Science and Conservation. S. Chand Publishing, New Delhi.

3. Odum, E.P., Odum, H.T., and Andrews, J. (1971). Fundamentals of Ecology. Saunders, Philadelphia, USA.

4. Brusseau, M.L., Pepper, I.L. and Gerba, C.P. (2019). Environmental and Pollution Science, 3rd Edition. Academic Press, USA.

5. Carson, R. (2002). Silent Spring. Houghton Mifflin Harcourt, USA. Pp. 1-264.

6. Gadgil, M. and Guha, R. (1993). This Fissured Land: An Ecological History of India. University of California Press, Berkeley, USA.

7. McCully, P. (1996). Rivers no more: the environmental effects of dams, In: Silenced Rivers: The Ecology and Politics of Large Dams, Zed Books, New York, USA.

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UCSEC-01: LAB TESTING AND QUALITY ASSURANCE

Course Outcomes:
By the end of the course, the students will be able to:
- Describe role of quality control chemist
- Discuss and demonstrate analytical and separation techniques
- Carry out sample preparation
- Illustrate fundamentals of quality check
- Describe and use safety procedures

UNIT-1 Introduction

Industry and sub-sectors, standards for manufacturing in life-sciences, drug regulatory agencies, role of quality control chemist, quality management systems

UNIT-2 Modern Analytical methods and separation techniques

Gravimetric methods, volumetric methods, electroanalytical methods, spectroscopic methods, chromatographic techniques

UNIT-3 Sample preparation

Basics of sample preparation, preservation and storage, standards and guidelines for sample handling, good storage practices

UNIT-4 Quality check

Overview, productivity concept, statistical analysis of laboratory data, measurements, calibrations, validation, reference standards and materials, requirements of a calibration lab, fundamentals of advanced QC approaches, Trouble shooting in QC, documentation, audit/ process related query, Quality certifications, Government regulations in industries like pharmaceuticals, food supplements, cosmetics.

Hands-on-Training
1. Calibration of glassware
2. Weighing of samples, accuracy of measurements
3. Preparation of TLC plates and separation of amino acids
4. Working protocols of various laboratory instruments-oven, pH-meter, conductivity meter, water baths, muffle furnace, spectrophotometer.
5. Calibration of instruments like colourimeter, pH-meter, conductivity meter, spectrophotometer using reference standards or reference materials.

Suggested exercise: Visit some industries to study the validation of simple procedures.

References:

- Skoog D.A., West D.M., Holler, F.J., Crouch S.R., **Fundamentals of Analytical Chemistry**, 9th Edition, Cengage learning.
- **Quality control chemist participant manual** prepared by LSSSDC in collaboration with NSDC India.

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UVAC-01: SCIENCE AND SOCIETY

Course Outcomes:

After successful completion of the course, a student will be able to:

- Understand and apply the principles of scientific thinking and the scientific method to differentiate facts from myths.
- Analyse contributions of ancient science and technology in water management, sustainable construction, and agriculture.
- Evaluate the role of modern science in addressing public health challenges and ensuring food security in society.
- Examine the impact of modern technologies, including IT, renewable energy, and space exploration, on environmental sustainability and governance.

Unit I

Philosophy of science, the scientific method, importance of observation, questions and experimental design, rational thinking, myths vs. Facts.

Unit II

Ancient Science and Technology in Society: Water harvesting structures and Practices; Construction, architecture and design - use of natural environment-friendly designs and materials; Agriculture including domestication of plants and animals.

Unit III

Modern Science in Society: Public Health: Nutrition, Hygiene, Physical and Mental Health, Vaccines and Antibiotics, Anti-microbial resistance; Food Security: Green Revolution, White Revolution.

Unit IV

Modern Technology in Society: IT Revolution, E-Governance; Clean Energy, Renewable Energy; Space Science and Exploration; Evolution, Ecology and Environment.

References/Books:

1. Basu and Khan (2001). Marching Ahead with Science. National Book Trust
2. Gopalakrishnan (2006). Inventors who Revolutionised our Lives. National Book Trust
3. Yash Pal and Rahul Pal (2013) Random Curiosity. National Book Trust
4. Hakob Barseghyan, Nicholas Overgaard, and Gregory Rupik. Introduction to History and Philosophy of Science
5. John Avery {2005). Science and Society, 2nd Edition, H.C. Ørsted Institute, Copenhagen.
6. Dharampal (2000). Indian Science and Technology in the Eighteenth Century, OIP.

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UCSC-04: INORGANIC CHEMISTRY –II
(Chemistry of s- and p-Block Elements)

Course Outcomes

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

- Explain the fundamental principles of metallurgy and emphasize the importance of recovering by-products during extraction.
- Apply thermodynamic concepts, such as Gibbs energy and entropy, to metal extraction principles.
- Describe the characteristics of s- and p-block elements and apply this knowledge to chemical synthesis.
- Utilize the concept of internal and external redox indicators in analytical procedures. Explain and apply the theory and practice of iodometric and iodimetric titrimetric analysis.

Unit – 1: General Principles of Metallurgy

Chief modes of occurrence of metals based on standard electrode potentials. Ellingham diagrams for reduction of metal oxides using carbon and carbon monoxide as reducing agent. Electrolytic Reduction, Hydrometallurgy with reference to cyanide process for silver and gold. Methods of purification of metals: Electrolytic process, Van Arkel-De Boer process, Zone refining. Brief discussion of metals and alloys used in ancient and medieval India.

Unit – 2: Chemistry of s- Block Elements

General characteristics: melting point, flame colouration, reducing nature, diagonal relationships and anomalous behavior of first member of each group. Reactions of alkali and alkaline earth metals with oxygen, hydrogen, nitrogen and water. Common features such as ease of formation, thermal stability, energetics of dissolution, and solubility of the following alkali and alkaline earth metal compounds: hydrides, oxides, peroxides, superoxides, carbonates, nitrates, sulphates. Complex formation tendency of s-block elements; structure of the following complexes: crown ethers and cryptates of Group I; basic beryllium acetate, beryllium nitrate, EDTA complexes of calcium and magnesium.

Solutions of alkali metals in liquid ammonia and their properties

Unit – 3: Chemistry of *p*-Block Elements

Electronic configuration, atomic and ionic size, metallic/non-metallic character, melting point, ionization enthalpy, electron gain enthalpy, electronegativity, Catenation, Allotropy of C, P, S; inert pair effect, diagonal relationship between B and Si and anomalous behaviour of first member of each group.

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Unit – 4: Compounds of *p*-Block Elements

Acidic/basic nature, stability, ionic/covalent nature, oxidation/reduction, hydrolysis, action of heat on the following:

- Hydrides of Group 13 (only diborane), Group 14, Group 15 (EH_3 where E = N, P, As, Sb, Bi), Group 16 and Group 17.
- Oxoacids of phosphorus, sulphur and chlorine
- Interhalogen and pseudohalogen compound
- Clathrate compounds of noble gases, xenon fluorides (MO treatment of XeF_2).

References

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. 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.
4. Miessler, G. L.; Fischer P. J.; Tarr, D. A. (2014), **Inorganic Chemistry**, 5th Edition, Pearson.
5. Housecraft, C. E.; Sharpe, A. G., (2018), **Inorganic Chemistry**, 5thEdition, Pearson.
6. Canham, G. R., Overton, T. (2014), **Descriptive Inorganic Chemistry,** 6th Edition, Freeman and Company.
7. Greenwood, N. N.; Earnsaw, A., (1997), **Chemistry of Elements**, 2nd Edition, Elsevier.

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UCSC-05: ORGANIC CHEMISTRY –II

(Haloalkanes, Arenes, Haloarenes, Alcohols, Phenols, Ethers and Epoxides)

Course Outcomes:

On completion of the course, the student will be able to:

- Explain and use reactions of arenes, haloarenes and some oxygen containing functional groups for practical applications.
- Apply the concept of protection and deprotection in organic synthesis.
- Use the synthetic chemistry learnt in this course to do functional group transformations.
- Propose plausible mechanisms for the reactions under study.

Unit - 1: Haloalkanes

Alkyl halides: Methods of preparation and properties, nucleophilic substitution reactions – SN^1, SN^2, and SN^i mechanisms with stereochemical aspects and effect of solvent; Nucleophilic substitution v/s elimination.

Organometallic compounds of Mg (Grignard reagent) – Use in synthesis of organic compounds.

Unit - 2: Aromatic Hydrocarbons and

Concept of Aromaticity and anti-aromaticity; Electrophilic aromatic substitution: halogenation, nitration, sulphonation, Friedel Crafts alkylation/acylation with their mechanism. Directing effects of groups in electrophilic substitution.

Unit - 3: Aryl Halides

Preparation (including preparation from diazonium salts) and properties, nucleophilic aromatic substitution; S_NAr, Benzyne mechanism. Relative reactivity of alkyl, allyl, benzyl, vinyl, and aryl halides towards nucleophilic substitution reactions.

Unit - 4: Alcohols, Phenols, Ethers & Epoxides

Alcohols: Relative reactivity of 1°, 2°, 3° alcohols, reactions of alcohols with sodium, HX (Lucas test), esterification, oxidation (with PCC, alkaline $KMnO_4$, acidic dichromate, conc. HNO_3). Oppenauer oxidation; Diols: oxidation of diols by periodic acid and lead tetraacetate, Pinacol-Pinacolone rearrangement.

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Phenols: Preparation using Cumene hydroperoxide, acidity and factors affecting it, Kolbe's–Schmidt reactions, Riemer-Tiemann reaction, Houben–Hoesch condensation, Schotten–Baumann reaction, Fries and Claisen rearrangements and their mechanism.

Ethers and Epoxides: Acid and base-catalyzed cleavage reactions.

References:

1. Morrison, R. N., Boyd, R. N., Bhattacharjee, S.K. (2010), **Organic Chemistry**, 7th Edition, Dorling Kindersley (India) Pvt. Ltd., Pearson Education.
2. Finar, I.L. (2002), **Organic Chemistry**, Volume 1, 6th Edition, Dorling Kindersley (India) Pvt. Ltd., Pearson Education.
3. Ahluwalia, V.K.; Bhagat, P.; Aggarwal, R.; Chandra, R. (2005), **Intermediate for Organic Synthesis,** I.K. International.
4. Solomons, T.W.G., Fryhle, C.B., Snyder, S.A. (2017), **Organic Chemistry**, 12th Edition, Wiley.

Suggestive readings:

1. Carey, F.A., Sundberg, R. J. (2008), **Advanced Organic Chemistry: Part B: Reaction and Synthesis**, Springer.
2. Bruice, P.Y. (2020), **Organic Chemistry**, 3rd Edition, Pearson.
3. Patrick, G. (2012), **BIOS Instant Notes in Organic Chemistry**, Viva Books.
4. Parashar, R.K., Ahluwalia, V.K. (2018), **Organic Reaction Mechanism,** 4th Edition, Narosa Publishing House.

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UCSC-06: PHYSICAL CHEMISTRY –II
(Chemical Thermodynamics and its Applications)

Course outcomes

On completion of the course, the student will be able to:

- Explain and apply the three laws of thermodynamics, concept of State and Path functions, extensive and intensive properties to solve critical problems.
- Derive the expressions of ΔU, ΔH, ΔS, ΔG, ΔA for an ideal gas under different conditions and use them for solving real world problems.
- Explain the concept of partial molar properties.

UNIT – 1: Basic Concepts of Chemical Thermodynamics and First Law

Intensive and extensive variables; state and path functions; isolated, closed and open systems. Mathematical treatment - Exact and inexact differential, Partial derivatives, Euler's reciprocity rule, cyclic rule.

Concept of heat, Q, work, W, internal energy, U, and statement of first law; enthalpy, H, relation between heat capacities, Joule Thompson Porous Plug experiment, Nature of Joule Thompson coefficient, calculations of Q, W, ΔU and ΔH for reversible, irreversible and free expansion of gases (ideal and van der Waals) under isothermal and adiabatic conditions.

UNIT – 2: Thermochemistry

Enthalpy of reactions: standard states; enthalpy of neutralization, enthalpy of hydration, enthalpy of formation and enthalpy of combustion and its applications, bond dissociation energy and bond enthalpy; effect of temperature (Kirchhoff's equations) on enthalpy of reactions.

UNIT – 3: Second Law

Concept of entropy; statement of the second law of thermodynamics, Carnot cycle. Calculation of entropy change for reversible and irreversible processes (for ideal gases). Free Energy Functions: Gibbs and Helmholtz energy; variation of S, G, Awith T, V, P; Free energy change and spontaneity (for ideal gases). Relation between Joule-Thomson coefficient and other thermodynamic parameters; inversion temperature; Gibbs-Helmholtz equation; Maxwell relations; thermodynamic equation of state.

UNIT – 4: Third Law and Systems of Variable Composition

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Statement of third law, unattainability of absolute zero, calculation of absolute entropy of molecules, concept of residual entropy, calculation of absolute entropy of solid, liquid and gases.

Partial molar quantities, dependence of thermodynamic parameters on composition; Gibbs Duhem equation, chemical potential of ideal mixtures, Change in thermodynamic functions on mixing of ideal gases.

Essential/recommended readings

1. Peter, A.; Paula, J. de. **Physical Chemistry**, 9th Edition, Oxford University Press.
2. Castellan, G. W. **Physical Chemistry**, 4th Edition, Narosa.
3. Kapoor, K.L. (2015), **A Textbook of Physical Chemistry**, Vol 2, 6th Edition, McGraw Hill Education.
4. Kapoor, K.L., **A Textbook of Physical Chemistry**, Vol 3, 5th Edition, McGraw Hill Education.
5. McQuarrie, D. A.; Simon, J. D. (2004), **Molecular Thermodynamics**, Viva Books Pvt. Ltd.
1. Levine, I.N. (2010), **Physical Chemistry**, Tata Mc Graw Hill.
2. Assael, M. J.; Goodwin, A. R. H.; Stamatoudis, M.; Wakeham, W. A.; Will, S. (2011), **Commonly asked Questions in Thermodynamics**. CRC Press.

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UCLAB-02L: CHEMISTRY LAB-II

Course outcomes

On completion of the course, the student will be able to:

- Perform redox and iodometric titrations for quantitative analysis of metal ions and iodine content.
- Carry out key organic transformations using conventional and green methods, and identify functional groups through qualitative analysis.
- Estimate organic compounds through acetylation and bromination methods with a focus on yield and purity.
- Determine thermodynamic parameters such as enthalpy changes, heat capacity, and solubility to understand energy changes in physical processes.

Note: Any experiment can be introduced or deleted in the practical class on the basis of availability of instruments/chemicals.

List of Practical's: Inorganic Chemistry-II

1. Redox Titrations

(i) Estimation of Fe (II) with $K_2Cr_2O_7$ using diphenylamine as internal indicator

(ii) Estimation of Fe (II) with $K_2Cr_2O_7$ using N-phenyl anthranilic acid as internal indicator

(iii) Estimation of Fe (II) with $K_2Cr_2O_7$ using external indicator

2. Iodo/Iodimetric Titrations

(i) Estimation of Cu(II) using sodium thiosulphate solution (Iodometrically).
(ii) Estimation of $K_2Cr_2O_7$ using sodium thiosulphate solution (Iodometrically).
(iii) Estimation of antimony in tartaremetic iodimetrically.
(iv) Estimation of Iodine content in iodized salt.

List of Practical's: Organic Chemistry-II

1. Acetylation of any one of the following compounds: amines (aniline, *o*-, *m*-, *p*- toluidines and *o*-, *m*-, *p*-anisidine) and phenols (β-naphthol, salicylic acid) by any one method:
i. Using conventional method ii. Using green approach

2. Benzolyation of one of the following amines (aniline, *o*-, *m*-, *p*-toluidines and *o*, *m*-, *p*-anisidine) or one of the following phenols (β-naphthol, resorcinol, *p*-cresol) by Schotten-Baumann reaction.

3. Bromination of acetanilide/aniline/phenol by anyone of the following:

(a) Green method b) Conventional method

4. Nitration of nitrobenzene/chlorobenzene/phenols.

5. Haloform reaction of ethanol.

6. Oxidation of benzyl alcohol to benzoic acid

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7. Estimation of the given sample of phenol/amine by:

a) Acetylation b) Bromate-Bromide method

8. Functional group tests for alcohols, phenols, carboxylic acids, phenols, carbonyl compounds, esters.

List of Practical's: Physical Chemistry-II

1. Determination of heat capacity of a calorimeter for different volumes using change of enthalpy data of a known system (method of back calculation of heat capacity of calorimeter from known enthalpy of solution of sulphuric acid or enthalpy of neutralization).
2. Determination of heat capacity of a calorimeter for different volumes using heat gained equal to heat lost by cold water and hot water.
3. Determination of enthalpy of neutralization of hydrochloric acid with sodium hydroxide.
4. Determination of the enthalpy of ionization of ethanoic acid.
5. Determination of integral enthalpy solution of endothermic salts.
6. Determination of integral enthalpy solution of exothermic salts.
7. Determination of basicity of a diprotic acid by the thermochemical method in terms of the changes of temperatures observed in the graph of temperature versus time for different additions of a base. Also calculate the enthalpy of neutralization of the first step.
8. Determination of enthalpy of hydration of salt.
9. Study of the solubility of benzoic acid in water and determination of ΔH.

References:

1. Jeffery, G. H.; Bassett, J.; Mendham, J.; Denney, R. C. (1989), Vogel's Text book of **Quantitative Chemical Analysis**, John Wiley and Sons.
2. Harris, D. C.; Lucy, C. A. (2016), **Quantitative Chemical Analysis**, 9th Edition, Freeman and Company.
3. Day, R. A.; Underwood, A. L. (2012), **Quantitative Analysis**, 6th Edition, PHI Learning Private Limited.
4. Mann, F.G., Saunders, B.C. (2009), **Practical Organic Chemistry**, 4th Edition, Pearson Education.
5. Furniss, B.S., Hannaford, A.J., Smith, P.W.G., Tatchell, A.R. (2005), **Vogel's Textbook of Practical Organic Chemistry**, Pearson.
6. Ahluwalia, V.K., Aggarwal, R. (2004), **Comprehensive Practical Organic Chemistry: Preparation and Quantitative Analysis**, University Press.
7. Ahluwalia, V.K., Dhingra, S. (2004), **Comprehensive Practical Organic Chemistry: Qualitative Analysis**, University Press.
8. Pasricha, S., Chaudhary, A. (2021), **Practical Organic Chemistry: Volume–I**, I K International Publishing house Pvt. Ltd, New Delhi
9. Pasricha, S., Chaudhary, A. (2021), **Practical Organic Chemistry: Volume–II**, I K International Publishing house Pvt. Ltd, New Delhi.
10. Khosla, B.D.; Garg, V.C.; Gulati, A. (2015), **Senior Practical Physical Chemistry**, R. Chand & Co, New Delhi.
11. Kapoor, K.L. (2019), **A Textbook of Physical Chemistry**, Vol.7, 1st Edition, McGraw Hill Education.
12. Garland, C. W.; Nibler, J. W.; Shoemaker, D. P. (2003), **Experiments in Physical Chemistry**, 8th Edition, McGraw-Hill, New York.

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UCGE-03: COORDINATION AND ORGANOMETALLIC COMPOUNDS

Course Outcomes

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

- Familiarize with different types of organometallic compounds, their structures and bonding involved.
- Apply 18-electron rule to rationalize the stability of metal carbonyls and related species
- Apply standard rules to name 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 Δ_o, Δ_t, pairing energy, CFSE, high spin and low spin. Explain how CFSE affects thermodynamic properties like lattice enthalpy and hydration enthalpy and use it to explain behaviour of organometallics

Unit 1: Coordination Chemistry

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.

Unit-2 Bonding in coordination compounds

Valence Bond Theory (VBT): Salient features of theory, concept of inner and outer orbital complexes of Cr, Fe, Co and Ni. 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 Δo. 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, square planar coordination.

Unit 3: Organometallic Compounds

Definition and classification with appropriate examples based on nature of metal-carbon bond (ionic, s, p and multicentre bonds). Structure and bonding of methyl lithium and Zeise's salt. Structure and physical properties of ferrocene.

Unit 4: Metal Carbonyls

18-electron rule as applied to carbonyls. Preparation, structure, bonding and properties of mononuclear and polynuclear carbonyls of 3d metals. 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.

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References:

1. Atkins, P.W.; Overton, T.L.; Rourke, J.P.; Weller, M.T.; Armstrong, F.A. (2010), **Shriver and Atkins Inorganic Chemistry**, W. H. Freeman and Company.
2. Miessler, G. L.; Fischer P.J.; Tarr, D.A. (2014), **Inorganic Chemistry**, Pearson.
3. Huheey, J.E.; Keiter, E.A., Keiter; R.L., Medhi, O.K. (2009), **Inorganic Chemistry-Principles of Structure and Reactivity**, Pearson Education.
4. Pfennig, B. W. (2015), **Principles of Inorganic Chemistry.** John Wiley & Sons.
5. Cotton, F.A.; Wilkinson, G. (1999), **Advanced Inorganic Chemistry** Wiley-VCH.

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UCGE-03L: COORDINATION AND ORGANOMETALLIC COMPOUNDS LAB

Course Outcomes

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

- Understand and apply the principles of gravimetric analysis for accurate estimation of metal ions.
- Synthesize coordination and organometallic compounds using classical and modern techniques.
- Characterize inorganic complexes using TLC, UV-Vis, and IR spectroscopy.
- Demonstrate proper laboratory practices in purification, precipitation, and complexation processes.

Note: Any experiment can be introduced or deleted in the practical class on the basis of availability of instruments/chemicals.

List of Practical's

1. Gravimetry

Discuss basic principles of gravimetry (precipitation, co- precipitation and post precipitation, digestion, washing etc)

(i) Estimation of Ni(II) using dimethylglyoxime (DMG).

(ii) Estimation of copper as CuSCN.

(iii) Estimation of Al (III) by precipitating with oxine and weighing as $Al(oxime)_3$ (aluminium oxinate).

2. Inorganic Preparations

(i) Schiff's base involving ethylenediamine and salicylaldehyde (or any other amine and aldehyde/ketone) and to check its purity using TLC.

(ii) Nickel/ Copper complex of the above prepared Schiff's base and its characterisation using UV/Vis spectrophotometer. The IR spectra also to be interpreted

(iii) tetraamminecopper (II) sulphate

(iv) potassium trioxalatoferrate (III) trihydrate.

(v) tetraamminecarbonatocobalt(III) nitrate

References:

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

2. Schiff Base Complex of Cu (II) with Antibacterial and Electrochemical Study, Arjun C. Bhowmick, Majharul I. Moim, Miththira Balasingam , **American Journal of Chemistry** 2020, 10(2): 33-37, DOI: 10.5923/j.chemistry.20201002.03

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UCGE-04: STATISTICAL METHODS AND DATA ANALYSIS-II

Course Outcomes:

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

• Understand key statistical tools such as confidence intervals and hypothesis testing for analytical data interpretation.

• Apply least square methods and evaluate figures of merit for data calibration and performance evaluation.

• Demonstrate proficiency in sampling techniques, sample handling, and laboratory data management.

• Analyse the role of standards, calibrations, and multivariate techniques in modern analytical methodologies.

Unit I: Statistical Foundations in Analytical Chemistry

Confidence interval, Testing of hypothesis, plotting of data, least square method.

Unit II: Analytical Performance Evaluation and Quality Control

Figures of merit: sensitivity, detection limit, linear dynamic range, control test, upper control limit and lower control limit, Validation, reporting analytical results and significant figures.

Unit III: Sampling Techniques and Sample Handling

Analytical samples, sample size, constituent sample, real samples, sample, sample handling, preparing laboratory samples, automated sample handling, lab on chip.

Unit IV: Laboratory Standards and Calibration Methods

General laboratory principles, recording laboratory data, standards, comparison of standards, internal standard, external standards calibration, least square method, and multivariant calibration.

References/Books:

1. Encyclopaedia of analytical chemistry: Applications, Theory, and Instrumentation, R A Meyor (Eds) Wiley and Sons (2000).

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UCGE-04L: STATISTICAL METHODS AND DATA ANALYSIS-II LAB

Course Outcomes:

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

- Evaluate detection limits and control interferences in colorimetric and complexometric analyses.
- Apply statistical tools to report analytical data with precision and confidence intervals.
- Use internal standard calibration methods for accurate metal estimation.
- Analyze and present data effectively using various types of graphical representations.

Note: Any experiment can be introduced or deleted in the practical class on the basis of availability of instruments/chemicals.

List of Practical's

1. Evaluate the limit of detection for colorimetric analysis of dyes and coloured metals in wastes water samples.
2. Demonstrate the control of interference by masking by complexation.
3. Report the ten analytic results in significant numbers along with standard deviation.
4. Determine the confidence limit and interval for a laboratory instrument like breath alcohol Analyser
5. Demonstrate the internal standard method for calibration of metal estimation.
6. Estimate the comparative effectiveness of different types of graphs like line, pi chart and bar graph.

References:

1. Dey, R. A. and Underwood, A. L., **Quantitative Analysis**, 6th Edition, Pearson.
2. Skoog, D. A., West, D. M., Holler, F. J., Crouch, S. R., **Fundamental analytical chemistry**, Thomson Asia Ltd.
3. Encyclopaedia of analytical chemistry: Applications, Theory, and Instrumentation, R A Meyor (Eds) Wiley and Sons (2000).

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UCSEC-02/UPGE-03: ENGINEERING MATERIALS

Course Outcomes:

After successful completion of the course on Engineering Materials, a student will be able to:

- Identify and classify key engineering materials including metals, ceramics, polymers, composites, and carbon-based nanomaterials.
- Explain the principles and techniques of top-down and bottom-up nanomaterial synthesis methods.
- Demonstrate an understanding of thermal and chemical processing techniques such as annealing, sintering, and green synthesis.
- Illustrate the applications and processes involved in thin-film fabrication techniques including PVD, CVD, and photolithography.

Unit I:

Engineering Materials: Introduction to engineering materials, Properties and applications of Metals and Alloys, Ceramics: types, properties, and uses, Polymers and Composites, Carbon-based nanomaterials (graphene, CNTs, fullerenes).

Unit II:

Nanomaterials Synthesis Techniques: Top-down vs. Bottom-up approaches, Mechanical milling: Ball milling, Wet chemical methods: Co-precipitation, Sol-gel synthesis, Green synthesis of nanomaterials.

Unit III:

Advanced Synthesis and Processing Techniques, Hydrothermal and Solvothermal synthesis, Thermal treatments: Annealing and sintering, Process parameters and their impact on material properties.

Unit IV:

Thin Film Deposition and Fabrication: Vacuum deposition and Thermal evaporation, Physical Vapor Deposition (PVD) and Chemical Vapor Deposition (CVD), Photolithography: Principles and applications in micro/nanofabrication.

References/Books:

1. "Materials Science and Engineering: An Introduction" by William D. Callister Jr. and David G. Rethwisch
2. "Nanostructures and Nanomaterials: Synthesis, Properties and Applications" by Guozhong Cao and Ying Wang
3. "Introduction to Nanoscience and Nanotechnology" by Gabor L. Hornyak et al.
4. "Thin Film Technology Handbook" by Aicha Elshabini and Fred D. Barlow III

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UAEC-02: ENVIRONMENTAL SCIENCE AND SUSTAINABLE DEVELOPMENT-II

Course Outcomes:

After completing this course, students will be able to:

- Understand the causes and impacts of climate change on human health, biodiversity, and global economy.
- Analyse international environmental agreements and their relevance in addressing climate-related challenges.
- Assess the role of renewable energy sources in promoting sustainable development and environmental conservation.
- Evaluate the importance of environmental justice and movements in shaping national and global policies.

Unit I

Causes of Climate change, Global warming, Ozone layer depletion, and Acid rain; Impacts on human communities, biodiversity, global economy, and agriculture.

International agreements and programmes: Earth Summit, UNFCCC, Montreal and Kyoto protocols, Convention on Biological Diversity (CBD), Ramsar convention, The Chemical Weapons Convention (CWC), UNEP, CITES, etc.

Unit II

Sustainable Development Goals: India's National Action Plan on Climate Change and its major missions.

Human population growth: Impacts on environment, human health, and welfare; Carbon foot-print.

Unit III

Resettlement and rehabilitation of developmental project affected persons and communities; relevant case studies.

Environmental movements: Chipko movement, Appiko movement, Silent valley movement, Bishnois of Rajasthan, Narmada Bachao Andolan, etc.

Unit IV

Environmental justice: National Green Tribunal and its importance.

Renewable Energy Sources: Solar Energy, Wind Energy, Hydropower, Biomass and Bioenergy, Tidal and Wave Energy, Hydrogen and Fuel Cells, Geothermal Energy.

References/ Books:

1. Divan, S. and Rosencranz, A. Environmental Law and Policy in India: Cases, Material & Statutes.

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(Dr. Neha Chauhan) (Dr. Rakhee Choudhary) (Dr. Anshu Dandia)

2. Raven, P.H, Hassenzahl, D.M., Hager, M.C, Gift, N.Y. and Berg, L.R. Environment.
3. Singh, J.S., Singh, S.P. and Gupta, S.R. Ecology, Environmental Science and Conservation.

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UVAC-02: INDIAN KNOWLEDGE SYSTEM

Course Outcomes:

After successful completion of the course, a student will be able to:

- Understand the foundational concepts and scope of Indian Knowledge Systems (IKS).
- Examine the historical and cultural evolution of IKS from ancient to modern India.
- Explore the technological and scientific advancements of ancient India in fields such as aeronautics, metallurgy, and astronomy.
- Analyse archaeological and literary evidence supporting India's contributions to early science and engineering.

Unit I

Introduction to Indian Knowledge Systems (IKS): Definition, Concept and Scope of IKS, IKS-based approaches on Knowledge Paradigms, IKS in Ancient and Modern India, Genesis of the Land and Antiquity of Civilization, Traditional Knowledge System: Concept of Matter, Life and Universe.

Unit II

Scientific Thought and Technology in Ancient India: Sage Agastya's Model of Battery, Concept of Gravity and Velocity of Light, Vimāna: Aeronautics in Ancient Texts, Vedic Cosmology and Modern Concepts, Bhāratīya Kāla-gaṇanā (Indian Time Calculation).

Unit III

Astronomy and Cosmological Understanding: History and Culture of Astronomy, Sun, Earth, Moon, and Eclipses, Earth's Sphericity and Rotation, Archeoastronomy in Ancient India.

Unit IV

Material Sciences and Archaeological Insights: Laboratory Tools and Apparatus in Ancient India, Traditional Juices, Dyes, Paints, and Cements, Glass and Pottery Production, Metallurgy and Engineering in the Vedic & Post-Vedic Age Iron Pillar of Delhi, Rakhigarhi, Mehrgarh, Bet–Dwārkā Marine Technology and the Sindhu Valley Civilization.

References/Books:

1. The Knowledge System of Bhārata by Bhag Chand Chauhan.
2. Pride of India: A Glimpse of India's Scientific Heritage, edited by Pradeep Kohle
3. History of Science in India, Volume I and Volume VIII, edited by Sibaji Raha
4. India's Glorious Scientific Tradition by Suresh Soni.
5. Science and Technology in Ancient India by Debiprasad Chattopadhyaya.

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