Chowgule Education Society's

Parvatibai Chowgule College of Arts and Science Autonomous

Accredited by NAAC with Grade 'A+'

Best Affiliated College-Goa University Silver Jubilee Year Award

DEPARTMENT OF CHEMISTRY

Course Syllabus

SEMESTER V

SEMESTER VI

SEMESTER V

CORE COURSE

THEORY
Course Code: CHE-V. C-7
Course Title: Advanced Chemistry -I (Physical and Inorganic Chemistry)
Credits: 3
Duration: 45 Hours
Maximum Marks: 75

Course Objectives:

1. Will have a working knowledge of the main areas of Physical Chemistry, will develop critical thinking abilities and be able to work in chemical or related fields.
2. Will help to get better understanding about the basics of Physical and Inorganic Chemistry.
3. Will be able to carry out experiments with required skills.

Course Learning Outcomes:

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

CO1: Understand the interactions of electromagnetic radiation and matter in IR and Raman spectroscopy and their applications.
CO2: Express applications and harmful effects of nuclear radioisotopes.
CO3: Demonstrate a sound knowledge of the photochemistry principles and their application.
CO4: Employ the theories that govern metal ligand bonding.
CO5: Interpret the types of crystal field splitting and calculate the crystal field stabilization energy.
CO6: Discuss the types of d-d transitions and its theory.
CO7: Perform instrumental methods of analysis.
CO8: Synthesize and analyze complexes.

SECTION I (PHYSICAL CHEMISTRY)

UNIT I: Molecular Spectroscopy **07 hours**

Definition of spectrum. Electromagnetic radiation, quantization of different forms of energies in molecules: translational, rotational and electronic, Born Oppenheimer approximation, factors affecting line width and intensity.

Infrared spectroscopy - Hook's law, energy levels and transitions: Simple harmonic oscillator, anharmonic oscillator (derivations expected), Calculation of force constant, Stretching and bending vibrations, modes of vibration of diatomic, linear triatomic (CO_2) and non-linear triatomic (H_2O) molecules, applications of IR spectroscopy.

Raman spectroscopy - Rayleigh and Raman scattering, Stokes and Antistokes lines. Mutual exclusion principle. Differences between Raman and IR spectroscopy. Numerical problems expected.

UNITII: Photochemistry **04 hours**

Interaction of radiation with matter, difference between thermal and photochemical processes, Laws of photochemistry: Grothus–Drapper law, Stark–Einstein law, Jablonski diagram depicting various processes occurring in the excited state, qualitative description of fluorescence, phosphorescence, non-radiative processes (internal conversion, intersystem

crossing), quantum yield, photosensitized reactions. Numerical problems expected.

UNITIII: Electrochemistry **07 hours**

EMF of a cell and its measurements, concentration cells: electrode and electrolyte with and without transport, liquid junction potential and its measurement; applications of concentration cell: determination of ionic product of water, transport number of ions, solubility and solubility product. Numerical problems expected.

UNIT IV: Nuclear Chemistry **05 hours**

Natural Radioactivity: kinetics of radioactive decay, half-life and average life of radioelements (derivations expected), Measurement of radioactivity: GM counter, Scintillation counterArtificial radioactivity: Chain reaction and conditions for its control. Radioisotopes and their applications; radiolabelled reactions, radiocarbon dating, medicinal and agricultural field, hazards of radiation. Numerical problems expected.

SECTION II (INORGANIC CHEMISTRY)

UNIT V: Metal-Ligand Bonding in TransitionMetalComplexes **11 hours**

Principles and limitations of Valence bond theory, Crystal field theory (CFT) splitting of d-orbitals inoctahedral, tetrahedral and square planar complexes. Crystal Field Stabilization Energy (CFSE), Measurement of 10 Dq for $[Ti(H_2O)_6]^{3+}$ complex, Factors affecting 10 Dq, Spectrochemical series, Effect of crystal field splitting on properties of Octahedral complexes: Magnetic, Spectral.

UNIT VI: Electronic spectra of Transition Metal Complexes **11 hours**

Introduction, types of electronic transitions: The d-d transitions (d^1/d^9 and d^2/d^8), charge transfer transitions and ligand-ligand transitions, selection rules (Laporte orbital and spin), applications (ligand field strength, colour of complexes, *cis*-, *trans*- isomerism and geometry of complexes).

PRACTICALS
Course Code: CHE-V.C-7
Course Title: Advanced Chemistry I: Physical and Inorganic Chemistry
Credit: 1
Duration: 30 Hours
Maximum Marks: 25

LIST OF EXPERIMENTS:
PHYSICAL CHEMISTRY

1. To determine the percent composition of acid mixture (strong acid and weak acid) by titrating against strong base conductometrically.
2. To determine the strength of mixture containing weak acid (CH_3COOH) and salt of strong acid and weak base (NH_4Cl) by titrating against strong base conductometrically.
3. To determine the formal redox potential of Fe^{2+}/Fe^{3+} system using standard 0.1N $K_2Cr_2O_7$ solution potentiometrically.
4. To determine the percent composition and amount of halide ions from their mixture (any two halides) using standard 0.1 N $AgNO_3$ solution potentiometrically.
5. To determine the dissociation constant of weak monobasic acid (CH_3COOH) by titrating against standard 0.1 N NaOH solution using pH meter.

6. To study the acid hydrolysis of ethyl acetate at two different temperatures and calculate the energy of activation.
7. To determine solubility product of silver halide potentiometrically.
8. To investigate the reaction between H_2O_2 and HI

INORGANIC CHEMISTRY

Preparation of the complexes:

1. $[Ni(NH_3)_6]Cl_2$
2. $[Co(NH_3)_3(NO_2)_3Cl_3$
3. $K_3[Fe(C_2O_4)_3]. 3H_2O$
4. Estimation of Al from the $K_3[Al(C_2O_4)_3]. H_2O$ complex.
5. Preparation of zinc oxalate and estimation of zinc from the complex.
6. To estimate the amount of barium as $BaSO_4$ in a solution of Barium chloride containing ferric chloride and free HCl.
7. To estimate aluminium by back titration using zinc sulphate.

PHYSICAL CHEMISTRY TEXT BOOK:

Bahl B. S., et.al., Essentials *of Physical Chemistry*, S. Chand and Co., New Delhi.

ADDITIONAL READING:

1. Arnikar H. J., *Essentials of Nuclear Chemistry*, Wiley-Eastern Ltd., New Delhi.
2. Atkins P, et. al., *Physical Chemistry*, Oxford University Press, New Delhi.
3. Castellan G. W., *Physical Chemistry*, Narosa Publishing House, New Delhi.
4. Kundu K. et.al., *Physical Chemistry*, S. Chand and Co., Ltd., New Delhi.
5. Puri B.R., et.al, *Principles of Physical Chemistry*, Vishal Publishing Company, Jalandhar.
6. Raj G., *Advanced Physical Chemistry*, Goel Publishing House, Meerut.

WEB REFERENCES:

1. https://www2.chemistry.msu.edu/faculty/reusch/VirtTxtJml/photchem.htm
2. https://www.nde-ed.org/EducationResources/HighSchool/Radiography/detectionmeasurement.htm
3. https://ocw.mit.edu/courses/chemistry/5-35-introduction-to-experimental-chemistry-fall-2012/labs/MIT5_35F12_Mod1_Background.pdf

INORGANIC CHEMISTRY TEXT BOOK:

Atkins P, Overton T, Rourke J et.al, *Shriver and Atkins' Inorganic Chemistry*, 5th Edition, Oxford University Press.

ADDITIONAL READING:

1. Cotton F. A and Wilkinson G., *Basic Inorganic Chemistry*, Wiley Eastern Ltd.
2. Huheey J. E, Keiter E. A, Keiter R. L, Medhi O. K, *Inorganic Chemistry: Principles of Structure and Reactivity*, Pearson Edu.
3. Lee J. D, *Concise Inorganic Chemistry*, Wiley-India

WEB REFERENCES:

1. http://cdn.intechopen.com/pdfs/38537/InTech-Electronic_absorption_spectra_of_3d_transition_metal_complexes.pdf
2. https://employees.csbsju.edu/cschaller/Principles%20Chem/New_Folder/TMligands.htm3. https://link.springer.com/chapter/10.1007/978-3-662-25191-1_8

ELECTIVE COURSE

THEORY
Course Code: CHE-V. E-9
Course Title: Heterocyclic Chemistry
Credits: 3
Duration: 45 Hours
Maximum Marks: 75

Course Objectives:
1. Students will learn about important aspects with respect to heterocyclic chemistry.
2. Students will develop understanding with regards to reactivity of heterocyclic chemistry.
3. Students will learn efficient chemical synthesis involved in heterocyclic compounds.

Course Learning Outcomes:
On successful completion of the course, the student will be able to:
CO1: Identify, name and classify the various heterocyclic compounds.
CO2: Describe the structure, different reactions and preparations of selected nitrogen and oxygen containing aliphatic heterocycles such as oxiranes, aziridines, tetrahydrofuran and pyrrolidine.
CO3: Describe the structure, diverse reactions and syntheses of pyrrole, furan, thiophene and pyridine heterocycles.
CO4: Describe the structure, diverse reactions and synthetic routes with mechanisms of numerous condensed heterocycles such as benzofuran, indole, benzothiophene, quinoline and isoquinoline.
CO5: Predict the reactivity of complex heterocyclic compounds containing the structural motif of these simple heterocycles.
CO6: Apply the synthetic methodologies for the synthesis of complex heterocycles.
CO7: Apply practical knowledge for the synthesis of other heterocycles.

UNIT I: Introduction to heterocyclic compounds and Aliphatic heterocycles 15 hours
Classification and Nomenclature of aliphatic and aromatic heterocycles. Structure and reactivity of nitrogen and oxygen containing aliphatic heterocycles. Any two methods of preparation and reactions of oxiranes, aziridines, tetrahydrofuran, pyrrolidine.

UNIT II: Five and six membered aromatic heterocycles 15 hours
Structure and reactivity of five and six membered heterocycles: furan, pyrrole, thiophene and pyridine; comparison of basicity of pyrrole, pyridine and piperidine. Electrophilic substitution reactions of five and six membered heterocycles: General mechanism, mechanism of halogenation, nitration and reaction using acids (HCl, H_2SO_4 and HNO_3). Any two methods of preparation of furan, pyrrole, thiophene and pyridine. Nucleophilic substitution reactions of aromatic heterocycles.

UNIT III: Condensed heterocycles 15 hours
Structure and reactivity of condensed heterocycles like benzofuran, indole, benzothiophene, quinoline and isoquinoline. Electrohilic and nucleophilic substitution reactions of condensed heterocycles: General mechanism and with examples. Oxidation and reduction of condensed heterocycles. Any two methods of preparation of benzofuran, Indole, benzothiophene,

quinoline and isoquinoline.

PRACTICALS
Course Code: CHE-V. E-9
Course Title: Heterocyclic Chemistry
Credits: 1
Duration: 30 Hours
Maximum Marks: 25

LIST OF EXPERIMENTS:

1. Epoxidation of chalcones (2 steps).
2. Synthesis of the Coumarins via Pechmann condensation.
3. Synthesisof 3,4- dihydropyrimidin-2(1H)-ones by a one-pot three component cyclo condensation reaction of 1,3 dicarbonyl compound, aldehyde, and urea via Biginelli reaction.
4. Synthesis of 1,3,5-tri substituted pyrazoles (2 steps).
5. Synthesis of benzimidazole from o-phenylenediammine and formic acid.
6. Synthesis of 2-substituted benzoxazoles from 2-amino phenol and aromatic aldehydes.
7. Synthesis of quinoxaline derivatives.
8. Synthesis of flavones via Baker-Venkataraman rearrangement (3 steps).
9. Preparation of 2-phenyl indole via Fischer indole synthesis.
10. Synthesis of Quinoline.
11. Synthesis of Isoquinoline.
12. One pot synthesis of flavones.
13. Synthesis of flavanone.
14. Synthesis of bisindolylmethane.
15. Synthesis of 3,4-dihydrocoumarin.

TEXT BOOK:

Joule, J. A. and Mills, K., *Heterocyclic Chemistry*, Wiley publications.

ADDITIONAL READING:

1. Carey, F. C. and Giuliano, R. M., *Organic Chemistry*, Tata McGraw-Hill India.
2. Gilchrist, T., Heterocyclic *Chemistry*, Pearson Education India.
3. Smith, M. B. and March, J.**,** *March's Advanced Organic Chemistry*, Wiley publications.

WEB REFERENCES:

1. https://www.britannica.com/science/heterocyclic-compound
2. https://www2.chemistry.msu.edu/faculty/reusch/VirtTxtJml/heterocy.htm
3. http://www.3rd1000.com/chem301/chem302a.htm
4. http://www.chem.gla.ac.uk/staff/stephenc/teaching/HeterocycleLectures2011_2C12.pdf
5. .http://www.chtf.stuba.sk/~szolcsanyi/education/files/Chemia%20heterocyklickych%20zlucenin/Hetero cyclic%20Reviews%20and%20Summaries/Short%20Course%20on%20Heterocyclic%20Chemistry_Katritzky.pdf
6. http://www.chem.gla.ac.uk/staff/stephenc/teaching/HeterocycleLectures2011_2C12.pdf
7. https://www.studocu.com/en/document/glasgow-caledonian-university/organic-chemistry-2/lecture-notes/heterocyclic-compounds-lecture-notes/2771041/view

ELECTIVE COURSE

THEORY
Course Code: CHE-V. E-10
Course Title: Nanomaterials and Solid State Chemistry
Credits: 3
Duration: 45 Hours
Maximum Marks: 75

Course Objectives:
1. Will be able to have a basic and concise knowledge of nanomaterials.
2. Will develop skills in nanomaterial synthesis.
3. Will be able to understand characterization techniques in solid state chemistry.

Course Learning Outcomes:
On successful completion of the course, the student will be able to:
CO1: Recall the history, occurrence and technological development of nanomaterials and classify them.
CO2: Compare different synthesis techniques of nanoparticles like biological, chemical and physical and design various nanomaterials.
CO3: Evaluate XRD data, and calculate its parameters; carry out analysis of TG-DTA thermogram; assess morphology and particle size from SEM/TEM images.
CO4: Express the physical and chemical properties of solids like magnetic, electrical and dielectric which can interpret the applications of materials in various field like catalysis, ferrofluids, etc.
CO5: Synthesize and characterize the nanomaterials.

UNIT I: Introduction, synthesis, properties, characterization of nanomaterials 15 hours
Fundamentals: terminology and history, classification of nanomaterials, properties of nanomaterials- mechanical, optical, magnetic, electronic, catalytic and surface area; synthetic approach with at least one example of each- Chemical methods (sol-gel, hydrothermal, sonochemical, microwave, precursor); Top down and bottom up; physical methods (mechanical methods, methods based on evaporation, sputter deposition, chemical vapour deposition); biological methods (using microorganism and plant extract); Characterization techniques- diffraction techniques, electron microscopic techniques (SEM/TEM), magnetic measurement, UV-Visible spectroscopic, BET surface area.

UNIT II: Applications of nanomaterials and Solid State Reactions 15 hours
Energy, automobiles, sports, textile, cosmetics, medicinal, space, defense, engineering and catalytic applications; toxicity of nanomaterials; reactions of solids- tarnish reactions, decomposition reaction, solid-solid reactions, addition reactions, double decomposition reaction, electron transfer reaction, solid- gas reactions; sintering; phase transformations in solids- structural change in phase transformation, Martensite transformation, temperature and pressure induced transformations, order-disorder transitions.

UNIT III: Electrical and magnetic properties of solids 15 hours
Electrical conductivity, insulators, semiconductor and conductors; Band theory of semiconductors, photo conductivity and ionic conductivity; Piezoelectric, ferroelectric

materials and applications; Introduction to magnetism, behavior of substance in a magnetic field, magnetic moments, diamagnetism, paramagnetism, ferromagnetism, antiferromagnetism, ferrimagnetism, magnetizations of a ferromagnetic substance; experimental determinations of susceptibility; Superconductors: Theory of Superconductivity, discovery, critical temperature, Meissner effect, types of superconductors.

PRACTICALS
Course Code: CHE-V. E-10
Course Title: Nanomaterials and Solid State Chemistry
Credits: 1
Duration: 30 Hours
Maximum Marks: 25

LIST OF EXPERIMENTS:

1. Synthesis of Silver nanoparticles by chemical method.
2. Synthesis of ZnO nanoparticles by chemical method.
3. Synthesis of CdS nanoparticles by chemical method.
4. Synthesis of Nickel oxide nanoparticles by sol-gel method.
5. Synthesis of Silver nanoparticles using plant extract
6. Synthesis of Copper/Gold nanoparticles by chemical method.
7. To determine the particle size of metal oxides using SEM/TEM data.
8. To study the X-ray diffraction pattern of given sample (Phase and particle size).
9. Preparation of zinc oxalate dihydrate and analysis of its TG/DTA pattern.
10. To prepare mixed metal oxide of Zn and Fe using co-precipitation technique.
11. To prepare mixed metal oxide of Zn and Fe using precursor technique.
12. Measurements of electrical and magnetic properties of pure and mixed metal oxides.
13. To determine the crystallinity of any three metal oxides using their X-ray diffraction data.
14. To calculate the lattice parameter of any three-metal oxide/ mixed metal oxides using their X-ray diffraction data.
15. To study the EDS pattern of Metal Oxide/ Mixed Matal Oxide.

TEXTBOOK:

Atkins P. W., Overton T. L., Rourke J. P., Weller M. T. and Armstrong F. A., Shriver and Atkins Inorganic Chemistry, Oxford University Press.

ADDITONAL READING:

1. Keer H. V., Principles of Solid State Chemistry, New Age International Publishers.
2. Kulkarni S. K., Nanochemistry, Principles and Practices, Capitalpublishers.
3. Poole C. P. and Owens F. J., Introduction to Nanotechnology, John-Wiley and Sons.
4. Rao M. B. and Reddy K. K., Introduction to Nanotechnology, Campus books International.
5. West A. R., Solid State Chemistry and its Applications, John-Wiley and Sons.

WEB REFERENCES:

1. https://www.toppr.com/guides/physics/electric-charges-and-fields/conductors-and-insulators/
2. https://www.livescience.com/38059-magnetism.html
3. https://www.understandingnano.com/nanomaterials.html
4. https://www.sciencedirect.com/topics/chemistry/solid-state chemistry
5. https://link.springer.com/article/10.1007/s11837-013-0826-6
6. https://www.slideshare.net/Krishanyadav28/synthesis-of-nanomaterials

ELECTIVE COURSE
THEORY
Course Code: CHE-V.E-11
Course Title: Organometallic Chemistry
Credits: 03
Duration: 45 Hours
Maximum Marks: 75

Course Objectives:

1. Understand the basic principles of chemistry and molecular orbital theory with respect to chemical bonding.
2. To predict the structure and stability of organometallic cluster compounds based on the electron count and explain the chemical behavior and reactivity of organometallic compounds.
3. Describe and explain catalytic processes using an organometallic compound as a catalyst and explain how organometallic compounds are used as catalysts in organic synthesis.
4. Develop practical skills in the preparation of organometallic compounds and their precursors.

Course Learning Outcomes:

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

CO1: Illustrate metal-ligand interaction in formation of different metal carbonyls based on valence bond theory.

CO2: Explain and rationalize the synthesis, structure, bonding, properties of organometallic compounds of main group elements.

CO3: Apply the EAN concept and Wade's rules to any organometallic system and predict its stability, structure and bonding.

CO4: Understand the chemical behavior and predict the reaction mechanism of organometallic compounds.

CO5: Illustrate the catalytic cycles using an organometallic compound as a catalyst for industrial synthesis of some organic compounds.

CO6: Carry out synthesis of organometallic compounds and Interpret IR spectra of metal carbonyls and predict their structure.

UNIT I: Introduction to organometallic chemistry and metal carbonyls 15 hours

Definition, classification of organometallic compounds, Nomenclature, ligands, concept of hapticity of organic ligands, 18 electron rule, EAN concept, electron counting and oxidation states incomplexes.

Classification of metal carbonyls; Mononuclear metal carbonyls: Preparation, properties, structure and bonding of $Ni(CO)_4$, $Fe(CO)_5$, $Cr(CO)_6$ using VBT; Polynuclear metal carbonyls: Preparation, properties, structure and bonding of $Co_2(CO)_8$, $Mn_2(CO)_{10}$, $Fe_2(CO)_9$ and $Fe_3(CO)_{12}$. -acceptor behaviour of CO (MO diagram of CO), synergic effect and use of IR data to explain structure and bonding in metal carbonyls.

UNIT II: Metallocenes and Reactivity oforganometallic compounds 15 hours

Sandwich compounds, Ferrocene: Preparation and reactions (acetylation, alkylation, metallation, Mannich Condensation etc.). Structure and aromaticity, comparison of aromaticity and reactivity with benzene. Synthesis and reactivity of cyclopentadienyl compounds, bonding

in bis(cyclopentadienyl) complexes, Fluxional behaviour of metallocenes. Metal-metal bonding and metal clusters: structure of clusters, electron counting in clusters, synthesis ofclusters.

Reactions of organometallic compounds: Ligand substitution, Oxidative addition and reductive elimination, σ- bond metathesis, 1,1-migratory insertion reactions, 1,2-insertions and β-hydride elimination. Catalysis by organometallic compounds: Alkene hydrogenation with Wilkinson's catalyst.

UNIT III: Organometallic compounds of Main group elements 15 hours

Preparation, properties, reactions, uses and structure of alkyls and aryls of Group 1 elements (Li, Na); Group 2 elements (Be, Mg); Group 13 elements (B, Al) Group 14 (Sn, Pb). Alkyl and aryl compounds of Ti, Zn and Hg.

PRACTICALS

Course Code: CHE-V. E-11

Course Title: Organometallic Chemistry

Credit: 1

Duration: 30 Hours

Maximum Marks: 25

LIST OF EXPERIMENTS:

1. Synthesis of chloro cobaloximes [Co $(Dmg)_2LCl$] {L*= quinoline, indole, benzimidazole, NH_3, aquo}
2. Synthesis of $[Co(dmg)_2(qui)Cl]$
3. Synthesis of $[Co(dmg)_2(Im)Cl]$
4. Synthesis of (phenyl)(pyridine) cobaloxime
5. Preparation of alkyl(aquo) cobaloxime
6. Preparation of aquo bromobis(dimethylglyoximato) cobalt (III)
7. Preparation of chlorobis(dimethylglyoximato) triethanolaminecobalt (III)
8. Preparation of chlorobis(dimethylglyoximato)(1,10 phenanthroline) cobalt (III)
9. Structure analysis of metal-carbonyls based on IR data
10. Synthesis of Co $(PPh_3)_2Cl_2.2H_2O$
11. Synthesis of Ni $(PPh_3)_2Cl_2.2H_2O$
12. Synthesis of Ni $(NCS)_2(PPh_3)_2$

* NOTE: Four synthesis to be carred out using different ligands as per the list given in brace bracket.

TEXT BOOK:

Atkins P, Overton T, Rourke J et.al, *Shriver and Atkins' Inorganic Chemistry*, 5th Edition, Oxford University Press.

ADDITIONAL READING:

1. Cotton F. A. and Wilkinson G., *Basic Inorganic Chemistry*, Wiley Eastern Ltd.
2. Huheey J. E, Keiter E.A, Keiter R.L, Medhi O. K, *Inorganic Chemistry: Principles of Structureand Reactivity*, PearsonEdu.
3. Lee J. D., *Concise Inorganic Chemistry*, Wiley-India

WEB REFERENCES:

1. https://www.nature.com/subjects/organometallic-chemistry
2. https://nptel.ac.in/content/storage2/courses/104108062/module2.pdf
3. https://chem.libretexts.org/Bookshelves/Inorganic_Chemistry/Book%3A_Introduction_to_Organometallic_Chemistry_(Ghosh_and_Balakrishna)/8%3A_Carbonyls_and_Phosphine_Complexes/8.1%3A_Metal_Carbonyls
4. https://www.intechopen.com/books/recent-progress-in-organometallic-chemistry/radical-mechanisms-in-the-metallocenes
5. https://www.uni-due.de/ak_schulz/roocind.php

ELECTIVE COURSE

THEORY
Course Code: CHE-VI.E-12
Course Title: Selected Topics in Physical Chemistry
Credits: 3
Duration: 45 Hours
Maximum Marks: 75

Course Objectives:

1. To understand quantum mechanics.
2. To understand fundamentals and applications of Electrochemistry.
3. To understand types of electrodes and electrode processes.

Course Learning outcome:

CO1: Will be able to understand Schrödinger wave equation and its importance.
CO2: Will be able to understand electrochemical cells and their applications.
CO3: Will be able to set up electrochemical cells and use them for applications.

UNIT I: Quantum Mechanics **15 hours**

Black body radiation, Plank's radiation law, photoelectric effect, Bohr's model of hydrogen atom (no derivation) and its defects, Compton Effect, de Broglie hypothesis, Heisenberg's uncertainty principle, sinusoidal wave equation, Hamiltonian operator, Schrödinger wave equation and its importance, physical interpretation of the wave function, postulates of quantum mechanics, particle in one dimensional box; Schrödinger wave equation for H-atom, separation into three equations (without derivation), quantum numbers, hydrogen like wave function, radial wave functions, angular wave functions.

UNIT II: Quantum Chemistry and Electrochemistry **15 hours**

Molecular orbital theory, Formation of M.O from A.O, construction of M.O's by LCAO-H^{2+} ion, calculation of energy levels from wave functions, physical picture of bonding and antibonding wave functions, concept of σ, σ^*, π, π^* orbitals and their characteristics, Hybrid orbitals sp, sp^2, sp^3; Calculation of coefficients of A. O's used in the hybrid orbitals sp, sp^2, sp^3; introduction to valence bond model of H_2; comparison of M. O. and V. B. models.

Electrolytic and galvanic cells, reversible and irreversible cells, conventional representation of electrochemical cells, types of reversible electrodes, gas-metal ion, metal-metal ion, metal-insoluble salt-anion, redox electrodes; electrode reaction, Nernst equation, derivation of cell E. M. F. and single electrode potential, reference electrodes, standard hydrogen electrode, calomel

electrodes, standard electrodes potential, sign convention, electrochemical series, and its applications.

UNIT III: Electrochemistry **15 hours**

EMF of a cell and its measurements, computation of cell EMF, calculations of thermodynamic quantities of cell reactions (ΔG, ΔH and K); Polarization, elimination of polarization, decomposition potential, measurement of decomposition potential, factor affecting decomposition potential; over voltage, types of over voltage, measurement of over voltage, factor affecting overvoltage; Corrosion: types, theories, and methods; Energy sources- acid and alkaline battery; Ni-Cd cell, fuel cells, solar cells; Secondary batteries; Definition of pH, pOH, pK_a and pK_b; buffer solution, types, buffer action, buffer capacity, mechanics of buffer action, Henderson- Hazelbulch equation; Hydrolysis of salts (Numerical).

PRACTICALS
Course Code: CHE-V. E-12
Course Title: Selected Topics in Physical Chemistry
Credit: 1
Duration: 30 Hours
Maximum Marks: 25

LIST OF EXPERIMENTS:

1. To determine the standard oxidation potential of Zn/Zn^{2+} at three different concentrations.
2. To determine the standard oxidation potential of Cu/Cu^{2+} at three different concentrations.
3. To determine the dissociation constant of weak dibasic acid ($H_2C_2O_4$) by potentiometric titration.
4. To determine the dissociation constant of tribasic acid (H_3PO_4) by potentiometric titration.
5. To determine the activity coefficient of silver ion using concentration cell.
6. To determine the equilibrium constant for the reaction: $[Ag(NH_3)_2]^+ = Ag^+ + 2\ NH_3$.
7. To determine solubility of silver bromide by potentiometric method.
8. To determine the mean ionic activity coefficients of HCl solutions at different concentrations.
9. To determine the amount of strong acid (HCl) and weak acid (CH_3COOH) present in the mixture by potentiometric method.
10. To determine the amount of ferrous ion, present in the given solution using $KMnO_4$ by potentiometric method.
11. To study the effect of ionic strength on the mean ionic activity coefficient of silver ions in $AgNO_3$ solution.
12. To prepare different buffer solutions using Henderson- Hazelbulch equation and confirm the pH of prepared solutions using pH meter.
13. To study the effect of concentration on the cell EMF: $Cu_{(s)}|Cu^{2+}_{(aq)}||Ag^{1+}_{(aq)}|Ag_{(s)}$ at room temperature.
14. To determine the pH values of various mixture of sodium acetate and acetic acid in aqueous solution and hence determine the dissociation constant of the acid.
15. To construct standard Daniell cell and determine the EMF of a cell at three different temperature.

REFERENCE BOOKS

1. Gurdeep Raj, Advanced Physical Chemistry, Goel Publishing House, Meerut.
2. Puri, Sharma, Pathania, Principles of Physical Chemistry by Vishal Publishing Company, Oxford University Press.
3. Donald A. McQuarrie and John D. Simon, Physical Chemistry: A Molecular Approach, Viva Books Private Limited.
4. Donald A. McQuarrie, Quantum Chemistry, Viva Books Private Limited.

SEMESTER VI

CORE COURSE

THEORY
Course Code: CHE-VI. C-8
Course Title: Advanced Chemistry - II (Organic and Analytical Chemistry)
Credits: 3
Theory: 45 Hours
Maximum Marks: 75

Course Objectives:

1. Will learn to write mechanisms with stereochemistry.
2. Will learn principles of separation and its applications.
3. Will have practical knowledge of chromatographic techniques.
4. Will be able to carry out experiments with required skills.

Course Learning Outcomes:

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

CO1: Assess conditions for obtaining maximum efficiency of extraction.

CO2: Classify chromatographic methods.

CO3: Apply chromatographic method for separation, qualitative and quantitative estimation.

CO4: Predict the stereochemistry of products for various reactions using the mechanisms involved in the course.

CO5: Explain the reactivity of organic compounds containing nitro, amino and cyano functional groups.

CO6: Name, classify the carbohydrates and analyze their chemical reactivity.

CO7: Name, classify organo sulphur and organo phosphorous compounds and analyze their chemical reactivity.

CO8: Perform qualitative and quantitative analysis based on theory.

SECTION I (ORGANIC CHEMISTRY)

UNIT I: Mechanism and stereochemistry of addition, substitution and elimination reactions **07 hours**

Mechanism and stereochemistry of i) Addition of halogens acids (HX) and halogen (X_2) to open chain alkenes. Markownikoff's and anti-Markownikoff's addition. ii) S_N1, S_N2, S_Ni, substitutions and iii) E1, E2 and E1 cb eliminationreactions.

UNIT II: Organic Compounds containing Nitrogen **06 hours**

Preparation of nitroalkanes and nitroarenes. Chemical reactions of nitroalkanes. Mechanisms of nucleophilic substitution in nitroarenes and their reductions in acidic, neutral and alkaline media. Picric acid: preparation and properties. Structure and nomenclature of amines, physical properties. Structural features affecting basicity of amines. Preparation of alkyl and aryl amines by reduction of nitro compounds and nitriles, reductive amination of carbonyl compounds, Gabriel phthalimide reaction and Hofmann rearrangement.

UNIT III: Carbohydrates **06 hours**

Classification and nomenclature. Monosaccharides: General reactions. Configuration of

monosaccharides with reference to glucose. d(+)/ l(-) and D/L systems of nomenclature. Interconversion of glucose to fructose and glucose to mannose. Cyclic structure of D (+) glucose. Mechanism of mutarotation. Formation of glycosides, ethers and esters. Structure of sucrose and inversion of cane sugar.

UNIT IV: Chemistry of Organosulphur and Organophosphorus compounds 04 hours

Nomenclature and classification of Organosulphur compounds. Methods of preparation and chemical reactions of thiols, disulphides and sulphonic acids. Nomenclature and classification of organophosphorus compounds. Preparation of phosphines. Phosphorous ylides and their general methods of preparation. Wittig reaction and its synthetic applications.

SECTION II (ANALYTICAL CHEMISTRY)

UNIT V: Solvent Extraction 07 hours

Principle, efficiency of extraction, percentage extraction, complexing agents in solvent extraction, separation factor, types of extraction, applications of solvent extraction (Numerical expected).

UNIT VI: Chromatographic techniques 15 hours

Principle, classification of chromatographic techniques; Theory of chromatographic separation thin layer chromatography: Principle, technique and applications; Paper chromatography: Principle, technique and applications; Column Chromatography: Principle, technique and applications; Ion exchange chromatography: Principle, classification of ion exchangers, factors affecting the distribution of ions between the resin and the solution, ion exchange capacity, applications of ion exchange chromatography; Gas chromatography: Principle, instrumentation and applications; Comparison of GSC and GLC; HPLC: Principle, instrumentation and applications; Hyphenated techniques: GC-MS and LC-MS (Numerical expected).

PRACTICALS
Course Code: CHE-VI. C-8
Course Title: Advanced Chemistry II: Organic and Analytical Chemistry
Credit: 1
Duration: 30 Hours
Maximu, Marks: 25

LIST OF EXPERIMENTS:
ORGANIC CHEMISTRY

1. Organic mixture separation, purification of individual compounds and qualitative analysis of separated compound.
   Solid-solid, Solid-liquid, Liquid-liquid
   Note: 0.5 g solid-solid mixture to be analyzed on small scale. 3-4 mL liquid to be added in mixture.
2. Preparation of 2-bromo styrene.
3. Reduction of nitrobenzene to aniline.
4. Estimation of Glucose.
5. Acetyl derivative of Salicylic acid.
   Note: Any four to be performed.

ANALYTICAL CHEMISTRY

1. To separate metal ions by paper chromatography and determine the retardation factor
2. To study separation of organic compounds by TLC
3. To estimate nickel from Zn^{2+}/Ni^{2+} mixture by ion exchange chromatography
4. To estimate zinc from Zn^{2+}/Ni^{2+} mixture by ion exchange chromatography
5. To determine the equilibrium constant for the reaction $KI + I_2 = KI_3$
6. To separate a mixture of carboxylic acid and neutral compound by using solvent extraction technique
7. To estimate amount of potassium ions in the given solution by cation ion exchange chromatography.
8. To separate the mixture of o-and p-nitroanilines column chromatography.

ORGANIC CHEMISTRY TEXT BOOK:

Morrison R. T., et. al., *Organic Chemistry*, Pearson Publications, Noida- India.

ADDITIONAL READING:

1. Bruice P. Y., *Organic Chemistry*, Pearson Publications, Noida- India.
2. Carey F. C., et. al., *Organic Chemistry*, Tata McGraw-Hill India.
3. Finar I. L., *Organic Chemistry*, Volume 1. Pearson Publications, Noida- India.

WEB REFERENCES:

1. https://www.khanacademy.org/science/organic-chemistry/stereochemistry-topic
2. https://www.khanacademy.org/science/organic-chemistry/substitution-elimination-reactions
3. https://www.khanacademy.org/science/organic-chemistry/amines-topic
4. https://www.saddleback.edu/faculty/jzoval/mypptlectures/ch12_carbohydrates/lecture_notes_ch12_carbohydrates_current.pdf

ANALYTICAL CHEMISTRY TEXT BOOK:

1. Christian, G. D., *Analytical Chemistry*, 5th Edition, John Wileypublications
2. Skoog D.A., West D. M., Holler F. J., *Fundamentals of Analytical Chemistry*, 2nd edition, Saunders College Publishing

PRACTICAL BOOK:

Khosla B. D., Garg V. C., Gulati A., *Senior Practical Physical Chemistry*, S. Chand and Co., New Delhi

WEB REFERENCES:

1. http://www.ccamp.res.in/sites/default/files/Basics%20of%20Chromatography_KR_C-CAMP.pdf
2. https://www.biochemden.com/ion-exchange-chromatography/
3. http://gonuke.org/wp-content/acad/Solventextraction.pdf

ELECTIVE COURSE

THEORY
Course Code: CHE VI. E-13
Course Title: Spectroscopic Methods in Organic Chemistry
Credits: 3
Duration: 45 Hours

Maximum Marks: 75

Course Objectives:

1. Will be able to do spectral analysis of organic compounds.
2. Will learn theory of important spectroscopic techniques.
3. Will be able to elucidate structures of organic compounds based on spectral data.
4. Will be able to operate an UV-visible spectrometer.

Course Learning Outcomes:

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

CO1: Describe the principles of IR, UV and Mass spectrometry.

CO2: Calculate UV maxima of any given organic compound using Woodward-Fieser rules.

CO3: Predict the presence of various functional groups in a given organic compound using IR spectroscopy.

CO4: Interpret the mass spectra of various organic compounds.

CO5: Predict the structures of organic compounds based on the given ^{1}H NMR and ^{13}CMR data.

CO6: Interpret the ^{1}H NMR and ^{13}CMR spectra of organic compounds.

UNIT I: UV-Visible Spectroscopy and IR-Spectroscopy 15 hours

UV Spectroscopy: Ultraviolet (UV) absorption spectroscopy: Absorption laws (Beer-Lambert law), molar absorptivity, presentation and analysis of UV spectra, types of electronic transitions, effect of conjugation. Concept of chromophores and auxochromes, bathochromic, hypsochromic, hyperchromic and hypochromic shifts. UV spectra of conjugated dienes and enones, Woodward-Fieser rules for calculation of UV maxima of the above two systems. Numerical expected.

IR Spectroscopy: Molecular vibrations, Hooke's law, selection rules, intensity and position of IR bands, measurement of IR spectrum, functional group region, finger print region and its use to establish identity, applications to determine purity, to study progress of chemical reactions and hydrogen bonding, characteristic absorption bands of various functional groups and interpretation of IR spectra of organic compounds.

UNIT II: Proton Magnetic Resonance (^{1}H NMR) and ^{13}C Nuclear Magnetic Resonance Spectroscopy 15 hours

^{1}H NMR: Introduction to NMR Spectroscopy, types of protons: equivalent, non-equivalent, homotopic, enantiotopic and diastereotopic protons, NMR Spectrometer (block diagram), nuclear shielding and deshielding, chemical shift and molecular structure, spin-spin splitting and coupling constants, intensity of peaks, interpretation of ^{1}H NMR spectra of simple organic molecules. Structure elucidation of organic compounds using ^{1}H NMR spectral data is expected.

^{13}C NMR Spectroscopy: Number of signals, splitting of signals, proton coupled and decoupled spectra, off resonance decoupled spectra. ^{13}C NMR chemical shifts, identification of hybridization of carbons and nature of functionalization. Structure elucidation of organic compounds using ^{13}C NMR spectral data is expected.

UNIT III: Mass Spectrometry and spectral problems 15 hours

Mass Spectrometry: Instrumentation, definitions of parent or molecular ion peak and base peak. Isotope effect with respect to alkyl halides. Fragmentation of alkanes, alkenes, aromatic

hydrocarbons, alkyl halides, alcohols, aldehydes, ketones: α -cleavage and Mc-Laffertyrearrangement.
Structure elucidation of organic compounds using Mass, UV, IR, ^{1}H NMR and ^{13}C NMR spectral data is expected.

PRACTICALS
Course Code: CHE-VI. E-13
Course Title: Spectroscopic Methods in Organic Chemistry
Credit: 1
Duration: 30 Hours
Maximum Marks: 25

LIST OF EXPERIMENTS:
1. Calculate UV maxima for given organic structure and match it with the given spectra of organic compounds.
2. Match the given set of organic compounds with the given set of spectra. List: Alkane, alkene, alcohol, ether, amine, carboxylic acid, ester and amides.
3. Verify Bathochromic, hypsochromic, hyperchromic and hypochromic shifts in phenol and aniline using UV-Vis spectrometer.
4. Identification of organic compounds based on given IR spectra of organic compounds.
5. Distinguish between given set of organic compounds on basis of their IR spectra (3 sets of 2 compounds).
6. Identify the compounds based on given Mass Spectra. List: Alkane, alkene, alcohol, ether, amine, carboxylic acid, ester and amides.
7. Give the fragmentation patterns for the given mass spectra of organic compounds.
8. Compare relative abundance of isotopes of halogen containing compound.
9. Determination of organic compound using given set of ^{1}H NMR data.
10. Determination of organic compound using given ^{1}H NMR spectrum.
11. Assigning the chemical shift values to the peaks of given ^{1}H NMR spectrum of organic compounds.
12. Determination of organic compound using given set of ^{13}C NMR data.
13. Assigning the chemical shift values to the peaks of given ^{13}C NMR spectrum of organic compounds.
14. Assigning the chemical shift values to the peaks of given ^{1}H NMR spectrum of organic compounds.
15. Identification of organic compounds based on given spectroscopic information.

TEXT BOOK:
Silverstein, R. M., et. al., *Identification of Organic Compounds*, Wiley Publications

REFERENCE BOOKS:
1. Kalsi, P. S., *Spectroscopy of Organic compounds*, New Age International (P) Ltd. New Delhi.
2. Morrison, R. T., et. al., *Organic Chemistry* Pearson Publications, Noida India.
3. Pavia, D. L., et. al., *Introduction to Spectroscopy,* Cengage Learning.

WEB REFERENCES:
1. https://www.khanacademy.org/science/organic-chemistry/spectroscopy-jay

2. http://web.mit.edu/5.33/www/lec/spec1.pdf
3. http://www.uni-salzburg.at/fileadmin/oracle_file_imports/359201.PDF
4. https://nptel.ac.in/content/storage2/courses/104106075/Week6/MODULE%2025.pdf
5. https://nptel.ac.in/content/storage2/courses/104106075/Week4/MODULE%2017.pdf
6. https://www.brown.edu/academics/chemistry/sites/academics-chemistry/files/NMR_Introductory_Lecture.pdf

ELECTIVE COURSE

THEORY
Course Code: CHE-VI. E-14
Course Title: Environmental Chemistry
Credits: 3
Duration: 45 Hours
Maximum Marks: 75

Course Objectives:
The course provides understanding how:
1. Pollution affects our environment
2. Knowledge of chemistry can be used to solve problems.
3. Instrumental techniques can be used for chemical analysis of pollutants.

Course Learning Outcomes:
On successful completion of the course, the student will be able to:
CO1: Delineate how pollutants are transported and accumulated in the environment.
CO2: Recognize different types of toxic substances and analyze toxicology.
CO3: Describe water purification and waste treatment processes.
CO4: Apply knowledge of chemical and biochemical principles of fundamental environmental processes in air, water, and soil.
CO5: Apply basic chemical concepts to analyze chemical processes involved in different environmental problems.
CO6: Develop skills in procedures and few instrumental methods applied in analysis of soil and water pollution.

UNIT I: Introduction **15 hours**

Atmosphere: Composition, Structure, properties vertical temperature behavior, lapse rate and temperature inversion. Air pollution: Introduction, classification of pollutants, sources, control, effect with respect to oxides ofNitrogen, Carbon and Sulphur, Photochemical smog, acid rain and Green House effect. Water pollution: Chemical, physical and biological characteristics of water pollution, specific and Nonspecific characterization of water. DO, BOD, COD and chlorine demand, typical water treatment and waste water treatment. Importance of buffer and buffer index in waste water treatment. Ozone Chemistry: Major atmospheric species involved in ozone formation and destruction, some major chemical reactions in the troposphere associated with ozone. Stratospheric ozone: pollutants, destroying stratospheric ozone layer. Species destroying ozone layer: i) catalytic NO, ii) photo dissociation, of CFCs, iii) catalytic role of chlorine, and iv) combined chain reaction. The ozone holes.

UNIT II: Chemistry of Atmosphere, Soil and Pollutants **15 hours**

Chemistry of Atmosphere and soil: Reactions in the atmosphere: i) formation in the atmosphere ii) reaction of hydroxyl radical with trace gases and as sources of hydroperoxy radical and hydrogen peroxide. The methane cycles. Macro- and micro-nutrients in soil (N, P, K), chemistry of minerals of soil forming rocks. Sampling of Pollutants: Sampling of air pollutants: Absorption in liquids, Adsorption on solids- cold trapping adsorption and collection of particulates. Sampling of water pollutants: sampling and sample preservation. Sampling of solids: sample size, equipment and methods of sampling, Auger sampler, tube sampler. Adverse effects of specific pollutants: Effects of Hg, Pb and nitrites on humans and other living organisms, Oil Spill: Biological and physical effects, Acid, mine and drainage: Reactions of FeS_2 (pyrites), Cr, As and F. Toxic elements in soil including those are in trace quantities.

UNIT III: Application of instrumental techniques in environmental analysis and Solid waste management 15 hours

Air analysis: a) SO_2, b) H_2S, c) CO d) CO_2 and e) NOx. Water analysis: a) determination of organic loadings b) determination of toxic metal ions c) C.O.D d) B.O.D and e) D.O. Soil/Sediment analysis: a) Bulk density, b) Specific gravity, c) Moisture content d) Water holding capacity e) Conductivity f) Alkalinity, and g) detection of sulphate, calcium and iron. Optical and radiochemical techniques: Introduction, basic principle and applications of Turbidimetry, Nephelolmetry, Isotope dilution analysis and Neutron activation analysis. Techniques of water treatment: a) Treatment of water for municipal purpose: Important processes involved in purification of water. b) Treatment of water for Industries: Removal of hardness of water by Clark's method and use of ion exchange resins. Solid waste origin and management: a) Origin and Classification of solid waste types b) Solid waste management method: i) Utilisation, ii) Recovery, iii) Reuse iv) Recycling of wastes residues, v) Recycling avoidance of solid waste, Use of Remote Sensing in Environmental Management

PRACTICALS
Course Code: CHE-VI. E-14
Course Title: Environmental Chemistry
Credit: 1
Duration: 30 Hours
Maximum Marks: 25

LIST OF EXPERIMENTS:

1. Determination of sodium in water: ion exchange method.
2. Determination of Total solids, Total dissolved solids and total suspended solids and its significance.
3. Determination of chloride content in tap water samples: Mohr'smethod.
4. Determination of acidity and alkalinity in water samples.
5. Determination of total, permanent and temporary hardness of water sample.
6. Determination of DO of water sample.
7. Determination of polluting elements such as Pb, Hg and As in water.
8. Analysis of Mn in a water sample by spectrophotometry.
9. Analysis of different types of soil- pH, conductivity, alkalinity.
10. Determination of nitrite in water by colorimetric method.
11. Determination of COD of water samples.
12. Determination of BOD of water samples.

13. Determination of phosphate: Colorimetric method.
14. Determination of free acidity in ammonium sulphate fertilizer.
15. Determination of alkalinity of a given mixture of OH^- and $CO3^{2-}$ using phenolphthalein and methyl orange indicator.

REFERENCE BOOKS:

1. Christan G. D., 5th Edition, Analytical Chemistry, Wiley publication.
2. De, A. K., Environmental Chemistry, Wiley Eastern Ltd. House, New Delhi.
3. Katyal Jimmy et.al., Environmental Pollution", Anmol Publications, New Delhi.
4. Manahan, S.E., Environmental Chemistry, Lewis Publishers.
5. Neil, P. O., Environmental Chemistry, Blackie Academic and Professional.
6. Raghuraman, K.et al, 4th Edition, Basic Principles of Analytical Chemistry, Sheth Publishers.
7. Schroede, E. D., Water and waste water treatment, McGraw Hill.Skoog et.al, Principles of
8. Analytical Chemistry, 4th Edition, Saunders college Publishers Trivedi P. R. et.al, Environmental Water and Soil Analysis, 1st Edition, Akashdeep Publishing house, New Delhi
9. Tyagi, O. D. et.al, A Text Book of Environmental Chemistry, Anmol Publications, New Delhi
10. Vanloon G. W. et.al, Environmental Chemistry, Oxford University Press

WEB REFERENCES:

1. https://www.clearias.com/composition-structure-earth-atmosphere/
2. https://www.nrdc.org/stories/air-pollution-everything-you-need-know
3. https://www.nrdc.org/stories/water-pollution-everything-you-need-know
4. https://biologyreader.com/ozone-depletion.html
5. https://www.conserve-energy-future.com/sources-effects-methods-of-solid-waste-management.php

ELECTIVE COURSE

THEORY
Course Code: CHE- VI. E-15
Course Title: Selected Topics in Inorganic Chemistry
Credits: 3
Duration: 45 Hours
Maximum Marks: 75

Course Objectives:

1. Understand and integrate concepts relevant to graduate level Inorganic Chemistry.
2. Acquire knowledge about the bond formation of compounds with special reference to MOT and CFT.
3. Determine the stability and instability of complexes using spectrophotometry.
4. Develop practical skills to carry out separation of metal ions by ion exchange method and analyze them using titrimetry or gravimetry.

Course Learning Outcomes:

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

CO1: Differentiate between thermodynamic stability and kinetic stability and apply it to transition metal complexes.

CO2: Apply the concepts to determine the reaction mechanism of transition metal complexes.
CO3: Determine the factors that govern the stability and lability of transition metal complexes.
CO4: Understand the chemistry and function of some of the technologically useful materials like liquid crystals, superconductors and fullerides.
CO5: Discuss what are polymers and their properties, to classify the polymers (based on coordination, addition and condensation reaction).
CO6: Illustrate the preparation, structure and bonding and applications of polymers comprising of B, P, Si and S.
CO7: Analyze the magnetic properties of the transition metal complexes as well as interpret the effect of temperature on magnetic properties.
CO8: Explain Guoy's balance for determining the magnetic susceptibility.
CO9: Identify and apply the symmetry elements in molecules and to evaluate the Point groups and symmetry elements in molecules with appropriate examples.
CO10: Carry out separation and estimation of ions from compounds.

UNIT I: Magnetic Properties of Metal Complexes and Molecular Symmetry 15 hours

Types of magnetic behaviour, magnetic susceptibility, effect of temperature on magnetic properties, Curie temperature, Neel temperature, Curie-Weiss law, methods of determining magnetic susceptibility, Guoy's balance, spin only formula, calculation of magnetic moment of transition metal ions, application of magnetic moment data for 3d-metal complexes.
Symmetry elements and operations: Centre of symmetry, Rotation axis, Mirror plane, rotation-reflection axis, Identity element, point groups, identifying symmetry elements and point group in molecules. (Examples to be solved).

UNIT II: Thermodynamic and Kinetic Aspects of Metal Complexes 15 hours

Thermodynamic and kinetic stability of metal complexes, equilibrium constants, formation constants, labile and inert complexes, factors affecting the stability, substitution reactions in tetrahedral and octahedral complexes, Factors affecting the rate of substitution reactions. Electron transfer reactions- inner sphere mechanism and outer sphere mechanism. Trans effect with respect to square planar complexes.

UNIT III: Inorganic Materials Chemistry 15 hours

Definition, properties, classification (condensation, addition and coordination), preparation, structure and bonding and applications of polymers containing Boron (borazine), phosphorous (phosphazenes), silicon (silicones), sulfur (S_4N_4, thiazylhalides).
Zeolites: Types, structure and applications.
Composite materials: Metal-organic frameworks (MOF's); structure, ligands, applications.
Molecular materials: Fullerides, liquid crystals, molecular magnets.
Corrosion: Response of material to chemical environments, galvanic corrosion and other forms of corrosion, Prevention methods.

PRACTICALS
Course Code: CHE- VI. E-15
Course Title: Selected Topics in Inorganic Chemistry
Credit: 1
Duration: 30 Hours
Maximum Marks: 25

LIST OF EXPERIMENTS:

1. Separation and determination of transition metal ions: Separation of Mg^{2+} and Zn^{2+} by ion exchange and its estimation.
2. Separation and determination of transition metal ions: Separation of Cd^{2+} and Zn^{2+} by ion exchange and its estimation.
3. Determination of stability constant of complex ions in solution, Fe(III)- salicylic acid complex (Job's Method).
4. Determination of stability constant of complex ions in solution, Fe(II)-1,10-phenanthroline.
5. Determination of instability constant for the reaction between Cu^{2+} and NH_3.
6. Determination of instability constant for the reaction between Cu^{2+} and en.
7. Estimation of Ni from Nickel Chloride volumetrically.
8. Estimation of Cu from Copper Chloride volumetrically.
9. Estimation of metal ions in mixed metal compound by titrimetric method.
10. Preparation of Malachite.
11. Preparation of Chrome Yellow.
12. Preparation of Prussian blue.
13. To estimate amount of ferrous (Fe^{2+}) and ferric (Fe^{3+}) ions in the given solution containing ferric chloride and ferrous sulphate by using potassium dichromate solution.
14. Estimation of Co from Cobalt Chloride volumetrically.

TEXT BOOKS:

Atkins P., et.al., *Shriver and Atkins Inorganic Chemistry*, Oxford University Press.

ADDITIONAL READING:

1. Lee J. D., *Concise Inorganic Chemistry*, Wiley-India.
2. Huheey J. E., Keiter E. A., Keiter R. L., Medhi O. K., *Inorganic Chemistry: Principles of structure and reactivity*, Pearson Edu.
3. Cotton F. A. and Wilkinson G., *Basic Inorganic Chemistry*, Wiley Eastern Ltd.
4. Puri B. R., Sharma L.R., Kalia K. C., *Principles of Inorganic Chemistry*, Vishal Publishing Co.

WEB REFERENCES:

1. http://asdn.net/asdn/chemistry/zeolites.php
2. https://www.nanowerk.com/mof-metal-organic-framework.php
3. https://www.materialstoday.com/carbon/news/alkali-fullerides-reveal-more-superconductivity-se/
4. https://galvanizeit.org/corrosion/corrosion-process/types-of-corrosion
5. https://saylordotorg.github.io/text_general-chemistry-principles-patterns-and-applications-v1.0/s15-08-liquid-crystals.html
6. http://mathworld.wolfram.com/SymmetryOperation.html

ELECTIVE COURSE

Course Code: CHE-VI.E-16
Course Title: Electroanalytical Chemistry
Credits: 3
Maximum Marks: 75
Duration: 45 Hours

Course Objectives:

1. To provide students the basic understanding about the principles of electro analytical chemistry
2. To incorporate the electrochemical measurements and understanding the cell construction

Course Learning Outcomes:

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

CO1: Understand the basic concepts of potentiometry and different electrodes

CO2: Understand physical and chemical properties of a material which can be studied by commonly used electroanalytical techniques

CO3: Differentiate and compare different voltamograms

CO4: Apply theoretical concepts to analyse various compounds quantitatively

UNIT I: Potentiometry and Ion-selective potentiometry 15 Hours

Electrochemical cell; reversible and irreversible cells; EMF series; standard electrode potential; Nernst equation; calculation of cell potential; introduction to potentiometer; types of electrodes: metallic electrodes- electrodes of first and second kind; reference electrodes- hydrogen gas electrode, calomel electrode and silver/silver chloride; different types of potentiometric titrations: acid-base titration, precipitation titration, redox titration; different method for determination of equivalent point; applications of potentiometric titrations; Membrane electrodes- classifications and properties; principle, design; theory of ion selective electrodes; membrane potential; selectivity; crystalline liquid membrane and enzyme electrodes; crystalline liquid membrane, enzyme membrane and glass membrane electrodes; solid-state sensors; membrane gas-sensor.

UNIT II: Polarography and Amperometry 15 Hours

Introduction; basic principle; deposition potential; dissolution potential, polarization of electrode; polarography instrumentation, electrodes in polarography; advantages and limitations of dropping mercury electrode; polarographic wave, half wave equation with derivation; Ilkovic equation; supporting electrolytes; interference of oxygen; half wave maxima; applications of polarography- organic and inorganic; numerical; amperometry- introduction to amperometric titrations, instrumentation; titration procedure; indicator electrodes, reference electrodes; advantages and disadvantages of amperometric titrations; applications.

UNIT III: Coulometry, Voltammetry and Conductometric Titrations 15 Hours

Coulometry- introduction, theory, current measuring devices- hydrogen-oxygen coulometer, silver coulometer, iodine coulometer; coulometry at controlled potential; coulometry at constant current; variation in coulometric techniques; coulometric applications; Voltammetry- introduction, fundamental, excitation signals, instrumentation of voltammetry; working electrodes and modified electrodes; voltammagram; hydrodynamic voltammetry, applications- oxygen sensor and enzyme-based sensor; cyclic voltammetry, pulse voltammetry; differential pulse voltammetry and square wave voltammetry, applications of voltammetry; Conductometric Titrations- types of conductometric titrations, applications.

TEXTBOOK:

1. Fundamentals of Analytical Chemistry, D. A. Skoog, D. M. West, F. J. Holler; 7th Edition,

Sounders College Publishing

REFERENCES BOOKS:

1. Principles of Instrumental Analysis, F. J. Holler, D. A. Skoog, S. R. Crouch; 6th Edition, Thomson Books
2. Analytical Chemistry: Principles, J. H. Kennedy; 2nd Edition, Saunders College Publishing
3. Instrumental Methods of Analysis, H. H. Willard, L. L. Merritt, J. A. Dean, F. A. Settle; 7th Edition, CBS Publishing, New Delhi
4. Instrumental Methods of Chemical Analysis, G. W. Ewing; 5th Edition, McGraw-Hill
5. Instrumental Methods of Chemical Analysis, B. K. Sharma; Goel Publishing House

WEB REFERENCES:

1. https://derangedphysiology.com/main/core-topics-intensive-care/arterial-blood-gas-interpretation/Chapter%205.0.2/ion-selective-electrode-membranes
2. http://www.federica.unina.it/agraria/analytical-chemistry/potentiometry/
3. https://chem.libretexts.org/Bookshelves/Analytical_Chemistry/Supplemental_Modules_(Analytical_Chemistry)/Analytical_Sciences_Digital_Library/JASDL/Courseware/Analytical_Electrochemistry%3A_Potentiometry
4. https://nvlpubs.nist.gov/nistpubs/jres/34/jresv34n2p97_A1b.pdf
5. https://chem.libretexts.org/Bookshelves/Analytical_Chemistry/Supplemental_Modules_(Analytical_Chemistry)/Analytical_Sciences_Digital_Library/Active_Learning/In_Class_Activities/Electrochemical_Methods_of_Analysis/02_Text/7%3A_Electrochemical_Analytical_Me
6. http://rxpharmaworld.blogspot.com/2016/12/coulometry.html

PRACTICALS

Course Code: CHE-VI. E-16

Course Title: Electroanalytical Chemistry

Credit: 1

Duration: 30 Hours

Maximum Marks: 25

LIST OF EXPERIMENTS:

1. To determine the amount of HCl in the given solution using quinhydrone electrode by potentiometric method.
2. To determine the dissociation constant of Cu-ammonia complex by potentiometric method.
3. To determine the hydrolysis constant of sodium acetate by pH-metric method.
4. To determine the dissociation constant of dibasic acid by pH-metric method.
5. To determine potentiometrically, the standard free energy change and equilibrium constant for the reaction: $Cu_{(s)} + 2\ Ag^{1+}_{(aq)} \leftrightharpoons Cu^{2+}_{(aq)} + 2\ Ag_{(s)}$
6. To determine the hydrolysis constant of aniline hydrochloride by pH metric method.
7. To determine the acid- base dissociation constant and isoelectric point of amino acid by potentiometric method.
8. To determine the dissociation constant of weak organic acid by potentiometric method.
9. To determine the electrode potential of calomel electrode by potentiometric method.
10. To determine the electrode potential of Silver-Silver chloride electrode by potentiometric method.
11. To study the effect of temperature on EMF of a cell, $Pb_{(s)}|Pb^{2+}_{(aq)}||Cu^{2+}_{(aq)}|Cu_{(s)}$, at room temperature, below room temperature and higher temperature.

12. To construct the calibration curve for the quinhydrode electrode and hence determine the standard oxidation potential of quinhydrode electrode.
13. To estimate the amount of dibasic acid present in given solution against standard NaOH solution by conductometric method.
14. To estimate the amount of monobasic (HCl) and dibasic acid (Oxalic acid) present in the mixture solution against NaOH by conductometric method.
15. To estimate the amount of H_2SO_4, CH_3COOH and $CuSO_4$ present in the mixture against NaOH by conductometric method.

PRACTICAL TEXT BOOK:

1. Rajboj S. W.; Chondekar T. K.; Systematic Experimental Physical Chemistry, Anjali Publication
2. Khosla, B. D.; Garg, V. C. and Gulati, A.; Senior Practical Physical Chemistry, R. Chand and Co., New Delhi.
3. Garland, C. W., Nibler, J. W. and Shoemaker, D. P.; Experiments in Physical Chemistry, 8th Edition; McGraw-Hill, New York.
4. Halpern, A. M. and McBane, G. C., Experimental Physical Chemistry; 3rd Edition; W. H. Freeman and Co., New York.

GENERIC ELECTIVE COURSE (GEC)

Course Code: CHE-GEC-1
Course Title: Basics in Chemistry
Credits: 3
Duration: 45 Hours
Maximum Marks: 75

UNIT I: Introduction to Chemistry **15 Hours**

Introduction, Classification: Organic, Inorganic, Physical and Analytical, Reactants, products, catalysts (with two examples)

Physical: States of matter: solids, liquids, and gases

Organic: Nomenclature and classification of some basic organic compounds (Hydrocarbons: Alkanes, alkenes and alkynes, alcohols, amines, and carboxylic acids with examples), and selected applications. Purification techniques of solids (recrystallization, sublimation) and liquids (distillation)

Inorganic: Atomic structure and type of bonds: ionic, covalent, metallic, acids and bases, metals, non-metals, noble gases.

Analytical: Knowledge of basic chemistry instruments, preparation of solutions, standardization, normality, molarity, and molality

UNIT II: Laboratory Apparatus, Equipments and Safety **15 Hours**

Common apparatus: test tubes, evaporating dish, condenser, round bottom flaks, crucible, watch glass, glass rod, filtration flask, Buchner funnel

Measuring devices: Measuring cylinders, beakers, conical flasks, burette, pipette, standard volumetric flasks, Transfer devices: Dropper, glass funnel, tongs, forceps

Support devices: Piestem triangle, tripod stand, wire gauze, universal clamp, asbestos pad, rubber bulb Heating devices: Bunsen burner, water bath, sand bath Equipments: Analytical balance, oven, fuming chamber; Importance, safety rules, personal protective equipments (PPE): Lab coat, goggle, mask, gloves and shoes; Safety in handling chemicals and safe behaviour; Safety equipment's: Eye wash fountain, safety shower, fire extinguisher, emergency exits; Hazardous chemicals and its symbols: Corrosive, flammable, toxic and carcinogenic; Chemical waste disposal: Aqueous (toxic and non-toxic), organic, glass wastes First aid measures: Eyes, skin, inhalation and ingestion.

UNIT III: Pollution and Green Chemistry **15 Hours**

Types of pollution: Air, Water, Noise: Sources, harmful effects, hazards associated with flora and fauna, measures to control, upcoming methods for air/water pollution treatment Acid rain: causes and harmful effect with an example of effect on Taj mahal, Corrosion Rusting of iron, its causes and prevention, Impact of Toxic chemicals in environment, Pollutants and their statutory limits; 12 principles of green chemistry with one example, Global warming, Greenhouse gases, Greenhouse effect, Hydrochemistry: Reaction of water with atmospheric gases, Renewable and non-renewable sources of energy (examples) and its conservation.

PRACTICALS
Course Code: CHE-GEC-1
Course Title: Basics in Chemistry
Credits 1
Duration: 30 Hours
Maximum Marks: 25

LIST OF EXPERIMENTS:

1. Purification techniques of solid: Recrystallization, Sublimation
2. Purification techniques of liquids: Distillation
3. Stoichiometric calculation for preparation of solutions
4. Preparations of solution in terms of normality, molarity, ppm, percent
5. Standardisation of solution: Acid and base
6. Total hardness of water
7. Determination of alkanity of water
8. Determination of acidity of water
9. Demonstration experiments on conductometer and pH meter
10. Identification of Chemical type of organic compounds

TEXT BOOKS:

1. Gurdeep, R. *Advanced Physical Chemistry*, 27th Edition; Goel Publishing House, Meerut
2. Morrison, R. T. et. al. *Organic Chemistry* Pearsons publications, Noida India.
3. Shriver, D. F. et. al. *Inorganic Chemistry*, 5th Edition, Oxford University Press
4. Skoog, D. A., et. al. *Fundamentals of Analytical Chemistry*, 8th Edition

REFERENCE BOOKS:

1. Ahluwalia, V. K.; Green *Chemistry: Environmentally Benign Reactions*, Ane Books India, New Delhi.
2. Cooper, M. M.; *Cooperative chemistry laboratory manual*, International Editions McGraw-Hill Companies
3. Furniss, B. et. al. *Vogel's Textbook of Practical Organic Chemistry*, Pearson education
5. Iqbal, S. A. et. al. *Chemistry of Air and Air Pollution* Discovery Publishing House, New Delhi
6. Matlack, A. S. et. al.; *Introduction to Green Chemistry*, CRC Press, New York
7. Puri, B. R. et. al. *Principles of Physical Chemistry*
8. Tyagi, O. D. et. al. *A Text Book of Environmental Chemistry* Anmol Publications, New Delhi

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