S.P. Mandali's
Ramnarain Ruia Autonomous College

Syllabus for S.Y.B.Sc
Programme – B.Sc.
Course: Chemistry (RUSCHE)

(Credit Based Semester and Grading System with effect from the academic year 2019–2020)

For the subject of chemistry there shall be three papers for 45 lectures each comprising of three units of 15 L each.

Semester-III

1. Paper-I: Unit-I Physical Chemistry

   Unit-II Physical Chemistry

   Unit-III Inorganic Chemistry.

2. Paper-II: Unit-I Organic Chemistry

   Unit-II Organic Chemistry

   Unit-III Inorganic Chemistry.

3. Paper III: Unit I and II- Analytical Chemistry

   Unit III- Environmental Chemistry

Semester-IV

1. Paper-I : Unit-I Physical Chemistry

   Unit-II Physical Chemistry

   Unit-III Inorganic Chemistry.

2. Paper-II: Unit-I Organic Chemistry

   Unit-II Organic Chemistry

   Unit-III Inorganic Chemistry.

3. Paper III: Unit I and II- Analytical Chemistry

   Unit III- Industrial Chemistry

Semester III

Course Code	Unit	Topics	Credits	L/Week
RUSCHE301	I	Chemical Thermodynamics-II	2	1
	II	Electrochemistry-I : Electrolytic Conductance And Transport Number		1
	III	Chemical Bonding		1
RUSCHE302	I	Reactivity and reactions of halogenated hydrocarbons, Organomagnesium and organolithium compounds, Alcohols, phenols and epoxides	2	1
	II	Carbonyl Compounds		1
	III	Chemistry of p-block elements: (Group 13 and 14)		1
RUSCHE303	I	Introduction to Analytical Chemistry	2	1
	II	Gravimetric Analysis Titrimetric Analysis		1
	III	Environmental Chemistry: Chemistry of water		1
RUSCHEP301		Chemistry Practicals I	1	3
		Chemistry Practicals II	1	3
		Chemistry practicals III	1	3

Semester IV

Course Code	Unit	Topics	Credits	L/Week
RUSCHE401	I	Electrochemistry-II: Electromotive Force of Galvanic Cells pH and Buffers	2	1
	II	Solutions of Liquid In Liquid Phase Equilibria		1
	III	Comparative Chemistry of the transition metals Coordination Chemistry Nature of the Metal-Ligand Bond		1
RUSCHE402	I	Carboxylic acids and their derivatives, Sulphonic acids	2	1
	II	Amines, Diazonium Salts, Heterocyclic Compounds		1
	III	Chemistry of Group 15 and 16 elements Organometallic Chemistry		1
RUSCHE403	I	Separation Techniques Solvent Extraction Chromatography	2	1
	II	UV- Visible Absorption spectroscopy Photometric titrations Conductometric titrations		1
	III	Industrial Chemistry		1
RUSCHEP401		Chemistry Practicals I	1	3
		Chemistry Practicals II	1	3
		Chemistry Practicals III	1	3

Detail Syllabus
Academic Year 2019-20

Semester III
Course Code: RUSCHE301
Paper: I (Physical and Inorganic Chemistry)
Credits: 2

Learning Objectives:

As the learner progresses from FYBSc to SYBSc, taking into the account the concepts he has grasped in the first year, the syllabus for the SYBSc class has been designed. The student is now expected to correlate Free Energy Changes with various parameters like Temperature and pressure. Also, the liquid state is studied in deeper details and the applications of Raoult's law are explored. After studying basics of Electrochemistry in the First year, the students are made to explore even more finer aspects of the subject. Valence Bond Theory, being the most basic theory put forth to explain chemical bonding, has its applications which are incorporated in the syllabus followed by which the limitations of VBT have also been studied and the student is finally introduced to Molecular Orbital Theory and its application to Homonuclear diatomic molecules.

Learning Outcome :
After studying the syllabus, the student will have thorough knowledge of the following aspects of Physical and Inorganic Chemistry

- Significance of Gibbs' and Helmholtz Free Energy and its applications.
- Applications of Clapeyron-Clausius Equation.
- Van't Hoff's Reaction Isochore and Isotherm.
- Raoult's Law and deviations from the same.
- Concept of Critical Temperature and applications.
- Concept of Transport Number and its determination.
- Applications and Limitations of Valence Bond Theory
- Concept of Hybridization and its applications.
- Basic Postulates of Molecular Orbital Theory and determination of Bond Order, bond energy and magnetic behavior of the compound.

Unit I	**Physical Chemistry** **Physical Chemistry** **1.0 Chemical Thermodynamics-II** 1.1 Recapitulation 1.2 Variation of Gibb's free energy with Pressure and Temperature, Gibbs-Helmholtz equation. 1.3 Thermodynamics of open systems: partial molal properties, chemical potential and its variation with pressure and temperature, Gibb's Duhem equation.	**15 L**

	1.4 Clapeyron equation and its application to phases in equilibria. Clausius-Clapeyron equation and its application to Liquid-Vapour equilibrium. 1.5 Concept of fugacity and activity 1.6 van't Hoff reaction isotherm and van't Hoff reaction isochore. 1.7 Maxwell's relations. 1.8	
Unit II	**Physical Chemistry** **2.0 Electrochemistry-I : Electrolytic Conductance And Transport Number** 2.1 Electronic and electrolytic Conductors: Conductance, cell constant, specific conductance, equivalent conductance and molar conductance and their relationships. Variation of Molar conductance with concentration, for weak and strong electrolytes. Concept of limiting molar conductance. Numerical problems based on 2.1 2.2 Debye-Huckel theory for strong electrolytes: 1) Relaxation effect 2) Electrophoretic effect. 2.3 Kohlrausch's law of independent migration of ions. Limiting molar conductances for ions, determination of limiting molar conductance for weak electrolytes. 2.4 Measurement of conductance and determination of cell constant. 2.5 Applications of conductance measurements: 1) Determination of degree of dissociation and dissociation constant of weak electrolyte. 2) Determination of solubility and solubility product of sparingly soluble salts. 2.6 Transport number, relation between transport number and velocity of ions. Factors affecting transport number. 2.7 Hittorfs Rule and experimental determination of transport number using Hittorf's method 2.8 Experimental determination of transport number by moving boundary method. Numerical problems based on 2.8 **2.9** Absolute ionic mobility, relation between transport number, absolute ionic mobility and limiting molar conductance of ion.	**15L**
Unit III	**Inorganic Chemistry** **3.1 Chemical Bonding** 3.1.1 Valence bond theory: postulates of VBT, need for hybridisation, Orbitals involved in hybridisation (*sp, sp^2, sp^3, dsp, ^{2} sp^3d, and sp^3d^2*,sd), energetics of hybridisation, interaction between two hydrogen atoms and their Potential energy diagram, Bond energy of hydrogen molecule (experimental value), Theoretical improvements in bond energy of hydrogen molecule, 3.1.2 Concept of resonance and Formal Charge; rules for resonance or canonical structures with examples. 3.2 **Molecular Orbital Theory**	**(7L)**

	3.2.1. Concept of orbital overlaps, types of orbital overlaps (s-s,s-p,p-p) 3.2.2. Linear combination of atomic orbitals to form molecular orbitals (LCAO-MO approach). 3.2.3. Application of MOT to Homonuclear diatomic molecules from He_2 molecule and for all the elements of second period, heteronuclear diatomic molecules (HCl, NO) 3.2.4 Molecular orbital Theory and determination of Bond Order and magnetic behavior for $O_2, O_2^+ O_2^-, O_2^{2-}$ (Problems are expected wherever applicable)	**(8L)**

Semester III
Course Code: RUSCHE302
Paper: II (Organic and Inorganic Chemistry)
Credits: 2

Learning Objectives :

After introduction to the fundamentals of Organic Reaction Mechanism in the FYBSc Class, the student is expected to apply these concepts to various functional groups like the Halogen Derivatives, Arenes, Phenols, Ethers and Epoxides. So also, the student is now newly introduced to the Organometallic Compounds viz Organomagnesium and Organolithium compounds. Chemistry of p-block elements will facilitate students to understand the concept of electron-deficient compounds. Also the chemistry of Silicon and Germanium is very important as the compounds of these elements have immense commercial importance. Chemical reactivity of Nitrogen group, their hydrides and their oxides have major environmental impact.

Learning Outcome:

After studying this syllabus, the student will know

- Reactions and reactivity of halogenated hydrocarbons.
- Nomenclature, nature, type and reactivity of carbon-metal bond of Organomagnesium and organolithium compounds.
- Preparation and reactions of Organomagnesium and organolithium compounds.
- Nomenclature, Preparation and reactions of Alcohols, phenols and epoxides.
- Comparative acidic strengths of alcohols and phenols.
- Mechanisms of some condensation reactions.
- Active methylene compounds and their synthetic applications.
- Concept of electron deficient compounds and its correlation with Lewis acidity;
- Structure and bonding in diborane and tetraborane; formation of banana bond

- Synthesis of Borax-compound with commercial importance.
- The electronic configuration of group 14 elements
- Silicon compounds ; their occurrence; structure and inertness of SiO_2
- Synthesis of commercially important hydride of nitrogen i.e. Ammonia by Haber's process.
- Physicochemical principles involved in the synthesis.

Unit I	**Organic Chemistry** **1.1. Reactivity and reactions of halogenated hydrocarbons:** 1.1.1. **Alkyl halides:** Nucleophilic substitution reactions: S_N1, S_N2 and S_Ni mechanisms with stereochemical aspects, factors affecting nucleophilic substitution reactions: nature of substrate, solvent, nucleophile and leaving group. 1.1.2. **Aryl halides:** Reactivity of aryl halides towards nucleophilic substitution reactions. Nucleophilic aromatic substitution (S_NAr), addition-elimination and benzyne mechanism. **1.2 Organomagnesium and organolithium compounds:** Type, Nomenclature. Nature, and reactivity of carbon-metal bond. Method of preparation using alkyl / aryl halide. Structure, stability and reactions of these compounds with compounds containing, acidic hydrogen, carbonyl, cyanides group, epoxides and CO_2. **1.3 Alcohols, phenols and epoxides:** 1.3.1.**Alcohols:** Nomenclature, Methods of Preparation: 1. Hydration of alkenes 2.Hydrolysis of alkyl halides 3. Reduction of aldehydes and ketones 4. Using Grignard reagent. Properties: Hydrogen bonding, effect of hydrogen bonding on properties. Acidity of alcohols, Reactions of alcohols 1.3.2. **Phenols:** methods of preparation, physical properties and acidic character, comparative acidic strengths of alcohols and phenols, resonance stabilization of phenoxide ion, reactions of phenols. 1.3.3.**Epoxides:** Nomenclature, methods of preparation and reactivity of epoxides, reactions of epoxides, ring opening reactions by nucleophiles , acid hydrolysis, reaction with halogen halide, alcohol, hydrogen cyanide. Reactions with ammonia, amines, Grignard reagents, alkoxides.	**(4L)** **(3L)** **(8L)**
Unit II	**Organic Chemistry** **2.1 Carbonyl Compounds:**	**(15L)**

	2.1.1 Nomenclature of aliphatic, alicyclic and aromatic carbonyl compounds, structure, reactivity of aldehydes and ketones . methods of preparation: oxidation of primary and secondary alcohols using PCC, hydration of alkynes, action of Grignard reagent on esters, Rosenmund reduction, Gattermann – Koch formylation and Friedel Craft acylation of arenes. 2.1.2 Mechanism of nucleophilic addition, and acid catalyzed nucleophilic addition reactions. 2.1.3 Reactions of aldehydes and ketones with $NaHSO_3$, HCN, RMgX, alcohol, amine, phenyl hydrazine, 2,4-Dinitrophenyl hydrazine, $LiAlH_4$ and $NaBH_4$. 2.1.4 Mechanism of the following reactions: Benzoin condensation, Knoevenagel condensation, Claisen-Schmidt and Cannizzaro reaction. 2.1.5 Keto-enol tautomerism: mechanism of acid and base catalysed enolization 2.1.6 Compounds with active methylene: Acetylacetone, ethyl acetoacetate diethyl malonate, stabilised enols. Reactions of Acetylacetone and ethyl acetoacetate: alkylation, conversion to ketone, mono- and dicarboxylic acid.	
Unit III	**3.0 Chemistry of p block elements (Group 13 & 14)** **3.1 Chemistry of Group 13 elements** 3.1.1 Electronic configuration, Trends in metallic characters: Oxidation states and Inert pair effect. 3.1.2 Electron deficient compounds – BH_3, BF_3, BCl_3 with respect to Lewis acidity and applications. 3.1.3 Preparation of simple boranes like diborane and tetraborane. 3.1.4 Structure and bonding in diborane and tetraborane (2e-3c bonds) 3.1.5 Borazine – Preparation, properties, Structure and bonding. **3.2 Chemistry of Group 14 elements** 3.2.1 Electronic configuration, Trends in metallic characters: Oxidation states and Inert pair effect. 3.2.1 Silica: Occurrence, Structure and inertness. 3.2.2 Methods of preparation of $SiCl_4$ and its structure. 3.2.3 Preparation of extra pure Silicon – Zone refining and Single Crystal method 3.2.4 Silicones – Preparation, classification, properties and uses.	**(15L)**

Semester III
Paper: III (Analytical Chemistry)
Course Code: RUSCHE303
Credits: 2

Learning Objectives:

Analytical Chemistry is of utmost importance since it requires thorough knowledge of all other branches of chemistry. The current syllabus introduces the learner to the basic concepts of Analytical chemistry and various methods of analysis which have major industrial and academic relevance.

Learning Outcome:

After studying the syllabus, the student will be able to understand the following nuances of analytical chemistry:

- Scopes and Importance of Analytical Chemistry
- Concept of Accuracy and Precision
- Classical Methods of Analysis
- Chemistry of Water and various aspects of assessment of quality of water.

Unit I	**1.1 Introduction to analytical chemistry** **1.1.1** - Scope and importance of analytical chemistry, difference between analytical chemistry and chemical analysis, qualitative and quantitative analysis, steps involved in analytical chemistry, types of analysis on the basis of sample size and the components estimated. Factors for choosing a method. **1.1.2** Classification of analytical methods, classical and instrumental, subdivision of classical and instrumental methods with the emphasis on the property measured, devices used and the nature of analysis . **1.1.3** Steps involved in chemical analysis from sampling to presentation of results and the conclusions. **1.1.4** Performance characteristics of an analytical method- qualitative and quantitative: LOD. LOQ. dynamic range, working range, sensitivity, selectivity. **1.1.5** Quantitative analysis using calibration curve method, standard addition method and internal standard method **1.1.6** LR and AR grade chemicals, MSDS of chemicals, glassware and its categories, calibration of volumetric glassware, burettes, pipettes and volumetric flasks. **1.1.7** Measurement, errors involved in the measurement, propagation of errors, random, gross and determinate errors, classification of determinate errors ,instrumental, methodic, operational personal errors, minimization of errors. **1.1.8 A**ccuracy and precision, measures of accuracy: absolute error and relative error, constant error and proportionate error, measures of central tendency and dispersion: mean, mode, median, deviation, absolute, relative, average, standard deviation, range, review of data with respect to accuracy and precision.	**(15L)**

Unit II	**Classical methods of analysis** **2.1 Gravimetric analysis:** **2.1.1** Introduction to gravimetric analysis, types of gravimetric analysis, conditions for a reaction to be used in gravimetric analysis, solubility and solubility product, factors affecting solubility: temperature, common and diverse ion effect, pH, nature of the solvent, complexation. **2.1.2** Unit operations in gravimetric analysis, precipitation, homogenous and heterogeneous precipitation, relative super saturation, nucleation and crystal growth, their effect on particle size, Ostwald's ripening, impurities associated with precipitate formation, filtration, washing of the precipitate, drying and incineration, use of thermal methods. **2.2 Titrimetric analysis** **2.2.1** Introduction to titrimetric analysis, conditions for a reaction to be used in titrimetric analysis, terms involved: titrant, titrand, indicator, equivalence point, endpoint, titration error, types of titrations. **2.2.2 Acid –base titrations** **2.2.2.1** Acid base indicators, theory of acid base indicators, conditions for choosing an indicator. **2.2.2.2** Types of acid base titrations, titration curves. **2.2.2.3** Construction of the titration curves and the choosing of the indicator for A) strong acid –strong base B) strong acid –weak base C) weak acid – strong base D) weak acid –weak base **2.2.4** Titration of dibasic acid with a strong base, condition for obtaining two separate equivalence points, qualitative description of the titration curve, determination of the dissociation constant **2.2.4** Titration of phosphoric acid with a strong base	**(07L)** **(08L)**
Unit III	**Environmental Chemistry** **3.1** Chemistry of water **3.1.1** Water as a natural resource : Physical and Chemical properties of water, significance of water as an universal solvent and its properties viz. pH , Dielectric constant ,boiling point. Anomalous behaviour of water. **3.1.2** Hydrological cycle. chemical composition of ground water. **3.1.3** Factors affecting solubility of gases in water . Solubility of CO_2 and O_2 in water **3.1.4** Water quality : Parameters for determining water quality i) Physical parameters: - pH, pE, conductivity, TS , TSS, TDS ii) Chemical Parameters- acidity, alkalinity, hardness, salinity , chlorine demand , DO, COD, iii) Biological parameter – BOD, MPN **3.1.5** Standards for Potable and industrial water.	**(15L)**

Semester- III
Chemistry Practicals I, II and III
Credits: 3

Course Code	Experiments
RUSCHEP301	**Paper I Physical Chemistry** 1. To study the kinetics of the reaction between $K_2S_2O_8$ and KI for equal concentration. 2. To determine conductance, specific conductance and molar conductance for given electrolyte solution. 3. To determine degree of dissociation and dissociation constant of weak electrolyte and hence to verity Ostwald's dilution law. 4. To determine solubility of a sparingly soluble salt conductometrically. 5. To determine the amount of strong acid in the given solution by conductometric titration. 6. To determine the amount of strong acid in the given solution by pH-metric titration. **Paper II Inorganic and Organic Chemistry** Quantitative determination of salts such as copper sulphate pentahydrate, nickel chloride hexahydrate, anhydrous cupric chloride using standard volumetric methods.
	Organic preparation and their purification: Use 0.5-1.0g of the organic compound. Purify the product by recrystallization. Report theoretical yield, percentage yield and melting point of the purified product. **Preparation of:** 1. Cyclohexanone oxime from cyclohexanone. 2. Tribromoaniline from aniline. 3. m-Dinitrobenzene from nitrobenzene 4. Phthalic anhydride from phthalic acid by sublimation 5. Preparation of 5-nitrosalicylic acid from salicylic acid. 6. Benzoic acid from benzamide. 7. Magneson – II from p-nitroaniline
	Chemistry practicals III 1. Gravimetric estimation of Nickel (II) as Ni-DMG. 2. Gravimetric estimation of barium ions as $BaSO_4$. 3. To carry out the calibration of pipette, burette and 100.0cm^3 standard volumetric flask 4. To determine hardness of given water sample. 5. To determine Dissolved Oxygen of the given water sample. 6. To determine the COD of water sample.

Semester IV
Paper: I (Physical and Inorganic Chemistry)
Course Code: RUSCHE401
Credits: 2

Learning Objectives:

The current syllabus aims at correlating the concepts that the learner has understood in the previous semester. The first unit correlates the thermodynamic parameters with EMF measurements. Also, the classification of galvanic cells and their applications are studied. The concept of pH and Buffer action is of immense importance since it has major biological implications. Keeping in mind the syllabi of TYBSc, the learner is introduced to the basic concepts of the Solid State chemistry, Phase Rule and its applications and Co-Ordination chemistry.

Learning Outcome :

After studying the syllabus, the student will be able to have thorough knowledge of the following aspects of Physical and Inorganic Chemistry

- Significance of Gibbs' and Helmholtz Free Energy and its applications to EMF measurements.
- Types of Electrodes and Electrochemical Cells
- Nernst Equation and its importance.
- Calculation of pH for strong and weak electrolytes.
- Buffer Action
- Laws of Crystallography
- Bragg's Equation and its applications.
- Phase Rule and its applications to One-Component and Two-Component systems.
- Various Properties of Transition Metals
- Basic Terms involved in Co-ordination chemistry, Werner's Theory
- Applications of Co-Ordination Compounds
- Nature of the Metal-Ligand Bond

Unit I	**Physical Chemistry** **1.1 Electrochemistry-II: Electromotive Force of Galvanic Cells** 1.1.1 Electrochemical cells, galvanic cells, reversible cells and reversible electrodes, conventions to represent Galvanic cells. 1.1.2 Types of electrodes, standard electrode potential, Electrochemical series. 1.1.3 Cell potential and standard cell potential. 1.1.4 Nernst equation and its importance. 1.1.5 Calculation of thermodynamic parameters: ΔG, ΔH, ΔS and equilibrium	**(10L)**

	constant from EMF data. 1.1.6 Classification of galvanic cells: chemical cells and concentration cells 1.1.7 Determination of pH using glass electrode and quinhydrone electrode. **1.2 pH and Buffers** 1.2.1 pH concept, calculation of pH for strong and weak electrolytes 1.2.2 Buffer, Henderson's equation for acidic and basic buffer 1.2.3 Buffer Capacity. Numerical Problems based on 1.2	**(5 L)**
Unit II	**Physical Chemistry** **2.1 Solutions of Liquid In Liquid** **2.1.1** Thermodynamics of ideal solutions: ideal solutions and Raoult's law, deviations from Raoult's law. **2.1.2** Vapour pressure-composition and temperature –composition curves of ideal and non-ideal solutions. Distillation of liquids forming ideal and non-ideal solution, Azeotropes, steam distillation. **2.1.3** Partially miscible liquids: critical solution temperature; systems with upper critical solution temperature, lower critical solution temperature and having both. **2.1.4** Nernst distribution law and its applications to solvent extraction. **2.2 Phase Equilibria** **2.2.1** Terms involved: Phases, components and degrees of freedom. Gibbs Phase Rule. **2.2.2** Phase diagrams of one-component systems (water, CO_2 and sulphur). **2.2.3** Two component systems involving eutectic (lead-silver system)	**(8 L)** **(7L)**
Unit III	**Unit-III** **3.1 Comparative Chemistry of the transition metals** **3.1.1** Position in the periodic table, electronic configuration. **3.1.2** Significance of special stability of d^0, d^5 and d^{10} configurations, Variable oxidation states and their stabilities in aqueous solutions; ability to form complexes, colour, magnetic property, catalytic property, **3.2 Coordination Chemistry:** **3.2.1** Historical perspectives; **3.2.2**Molecular compounds – Double salts and Complex salts **3.2.4** Werner's theory **3.2.5**Basic terms viz complex ion, charge on the complex, ligands, coordination	**(6 L)** **(5 L)**

	number, oxidation state, & Nomenclature **3.2.6** Sidgwick – Powel Theory of coordination compounds; Effective atomic number rule. **3.2.7** Stereoisomerism and optical isomerism of coordination compounds (C.N= 4 and 6) **3.2.8** Evidence for the formation of coordination compounds. **3.2.9**. Application of coordination compounds. **3.3. Nature of the Metal-Ligand Bond:** **3.3.1** Application of VBT to complexes with coordination number 4, 5 & 6, Inner and outer orbital complexes.	**(4L)**

Semester IV
Paper: II (Organic and Inorganic Chemistry)
Course Code: RUSCHE402
Credits: 2

Learning Objectives :

This syllabus stresses on the applications of fundamentals of Organic Reaction Mechanism to various functional groups like carboxylic and sulphonic acids and their derivatives. It also introduces the learner to Nitrogen containing compounds and heterocycles which play a major role in synthesis of biologically active compounds. The nature of the metal-ligand bond is further explored and the applications of metal carbonyls are introduced to the learner. Along with this, the learner also is introduced to the importance of certain essential elements to the living system.

Learning Outcome:

After studying this syllabus, the student will have knowledge of

- Reactions and reactivity of Carboxylic and sulphonic Acids and their derivatives
- Nomenclature, nature, type and reactivity of Amines and Diazonium Compounds
- Preparation and reactions of Heterocyclic Compounds- Furan, Pyrrole and Thiophene
- Fundamentals of Organometallic Chemistry
- Role of essential metal ions in Biological systems
- Chemistry of Inorganic Polymers such as Silicones and their various applications.

Unit I	**Organic Chemistry** **1.1 Carboxylic acids and their derivatives:** 1.1.1. Nomenclature, structure and physical properties, acidity of carboxylic acids, effects of substituents on acid strength of aliphatic and aromatic carboxylic acids. 1.1.2. Preparation of carboxylic acids: oxidation of alcohols and alkyl benzene, carbonation of Grignard reagent and hydrolysis of nitriles. 1.1.3. Reactions: Acidity, salt formation, decarboxylation, reduction of carboxylic acids with $LiAlH_4$, diborane, Hell-Volhard-Zelinsky reaction, conversion to acid chlorides, esters, amides and acid anhydrides and their relative reactivity. 1.1.4. Mechanism of nucleophilic acyl and acid-catalysed nucleophilic acyl substitution. Interconversion of acid derivatives by nucleophilic acyl substitution. 1.1.5. Mechanism of Claisen condensation and Dieckmann condensation. **1.2 Sulphonic acids:** 1.2.1 Nomenclature, preparation of aromatic sulphonic acids by sulphonation of benzene (with mechanism), toluene and naphthalene. 1.2.2 Reactions: Acidity of arene sulfonic acid, comparative acidity of carboxylic acid and sulfonic acids, salt formation, desulphonation reaction with alcohol, phosphorous pentachloride, IPSO substitution.	**(11L)** **(4L)**
Unit II	**Organic Chemistry** **2.1 Amines:** 2.1.1 Nomenclature, effect of substituent on basicity of aliphatic and aromatic amines. 2.1.2. Preparation: Reduction of aromatic nitro compounds using catalytic hydrogenation, chemical reduction using Fe-HCI, Sn-HCl, Zn-acetic acid. Reduction of nitriles, ammonolysis of halides, reductive amination, Hofmann bromamide reaction. 2.1.3 Reactions: salt Formation, N-acylation, N-alkylation, Hofmann's exhaustive methylation (HEM), Hofmann-elimination, carbylamine reaction, reaction with nitrous acid, Electrophilic substitution in aromatic amines: bromination, nitration and sulphonation. **2.2 Diazonium Salts**: 2.2.1 Preparation: - Sandmeyer reaction, Gattermann reaction, Gomberg reaction Reactions: Replacement of diazo group by -H,-OH. Azo coupling with phenols, naphthols and aromatic amines, reduction of diazonium salt to aryl hydrazine and hydroazobenzene. Synthetic application. **2.3 Heterocyclic Compounds:** 2.3.1. Classification, nomenclature, electronic structure, aromaticity in 5-numbered and 6-membered rings containing one heteroatom. 2.3.2. Synthesis of Furan, Pyrrole (Paal-Knorr synthesis, Knorr pyrrole synthesis,	**(4L)** **(3L)**

	and Hantzsch synthesis), Thiophene, Pyridine (Hantzsch synthesis). 2.3.3. Reactivity of furan, pyrrole and thiophene towards electrophilic substitution reactions on the basis of stability of intermediate and of pyridine on the basis of electron distribution. Reactivity of pyridine towards nucleophilic substitution on the basis of electron distribution. 2.3.4. Reactions of furan, pyrrole and thiophene: halogenation, nitration, sulphonation, Vilsmeier-Haack reaction, Friedel-Crafts reaction. Furan: Diels-Alder reaction, ring opening. Pyrrole: Acidity and basicity of pyrrole. Comparison of basicity of pyrrole and pyrrolidine. 2.3.5. Pyridine: Basicity. comparison of basicity of pyridine, pyrrole and piperidine. Reaction: sulphonation (with and without catalyst), Chichibabin reaction.	**(8L)**
Unit III	**Unit III: Inorganic Chemistry** **3.1 Chemistry of Group 15 and 16 Elements** 3.1.1 Trends in physical and chemical properties of Group – 15 and Group – 16 Elements 3.1.2 Study of Compounds such as oxyacids of N and S with respect to preparation, properties and structure. 3.1.3 Physical properties of Hydrides of Group 15 and 16 Elements with respect to H- bonding. **3.2 Organometallic Chemistry** 3.1.1 Introduction, definition, classification based on hapticity and nature of metal-carbon bond. Eighteen electron rule and its applications, exceptions 3.1.2 Importance and few applications of organometallic compounds as catalysts (e.g. Ziegler-Natta catalyst, Wilkinson), reagents in organic synthesis etc. 3.1.3 Metal carbonyls: Bonding, general method of preparation and properties of $Ni(CO)_4$, $Fe(CO)_5$.	**(8L)** **(7L)**

Semester IV
Paper: III (Analytical Chemistry)
Course Code: RUSCHE403
Credits: 2

Learning Objectives:
Analytical Chemistry is of utmost importance since it requires thorough knowledge of all other branches of chemistry. The current syllabus introduces the learner to the basic concepts of Analytical Chemistry and makes the student familiar with various chromatographic techniques and separation methods along with methods of Instrumental Analysis. It also introduces the learner to various industrially important Unit Operations.

Learning Outcome:
After studying the syllabus, the student will be able to understand the following nuances of analytical chemistry:

- Separation and Purification Methods
- Methods of Instrumental Analysis
- Solvent Extraction
- Unit Operations

Unit I	**Analytical Chemistry:** **1.1 Separation Techniques in analytical Chemistry** **1.1.1 Introduction to separation Techniques** **1.1.2** Separation and its importance in analytical chemistry, estimation without separation. **1.1.3** Classification of separation methods physical and chemical **1.1.4** Chemical methods, precipitation, complex formation. **1.1.5** Physical methods of separation, precipitation, fractional precipitation, volatilization, distillation, fractional distillation, vacuum distillation. **1.2 Solvent extraction** **1.2.1** Nernst's distribution law, partition coefficient, distribution ratio, **1.2.2** Percentage extraction, extraction efficiency, percentage extraction for single step and multistep process with the same total volume of the extracting solvent **1.2.3**. Modes of extraction: Chelation, ion-pair formation and solvation. **1.2.4** Batch and continuous extraction, Counter current extraction **1.3 Chromatography** **1.3.1** Introduction, Stationary and mobile phase, common features of all chromatographic techniques, classification of chromatographic methods on the basis of physical state of the two phases. **1.3.2Paper chromatography** **1.3.2.1** Introduction and basic principles. **1.3.2.2** Stationary phase, transfer of the sample, mobile phase. **1.3.2.3** Methods of developing the chromatogram, methods of detection, physical, chemical and enzymatic.	**(8L)** **(07L)**

	1.3.2.4 Applications. **1.3.2.5** Comparison of the paper and thin layer techniques. **1.3.3 Thin layer chromatography** **1.3.3.1** Introduction, mechanism of separation, retardation factor, basic principles. **1.3.3.2** Stationary phase, preparation and transfer of the sample, mobile phases and their nature. **1.3.3.3 Methods** of development of the chromatogram, detection methods, physical and chemical. **1.3.3.4** Applications, for determination of purity, following the course of a chemical reaction.	
Unit II	**2.1 UV- Visible Absorption spectroscopy:** **2.1.1** Recapitulation of basic concept of spectroscopy **2.1.2** Terms involved in absorption spectroscopy, monochromatic and polychromatic radiation, radiant power, absorbance, transmittance, absorptivity, molar extinction coefficient, wavelength of maximum absorption, **2.1.3** Statement of Beer's law & Lamberts' law, combined mathematical expression for Beer- Lambert's Law, deviations from Beer-Lambert's law, types of deviations . **2.1.4** Components of an optical instrument and their functions, photometers and spectrophotometers. 2**.1.5** Photometers: Sources, monochromators, sample containers and detectors, block diagram for a single and double beam photometer, (Numerical problems expected.) **2.2 Photometric titrations** **2.2.1** Basic principles, experimental set up and operational procedures, **2.2.2** Requirements for a photometric titration, types of photometric titration curves, and determination of equivalence point. **2.2.3** Advantages and limitations **2.3 Conductometric titrations** **2.3.1** Conductometry and conductometric titrations, basic principles, operational procedure,determination of the equivalence point., **2.3.2** Conductometric titration curves for the titration of 1] Acid –base titrations of all types 2] Mixture of a weak acid and a strong acid vs strong base and vice versa. 3] Mixture of acid ans salt ag. base 4] Precipitation titrations 5] Complexometric titrations **2.3.3** Advantages and limitations.	**(8L)** **(4L)** **(3L)**

Unit III	**Industrial Chemistry** 3.1 Concept of quality, Quality assurance, Product Development (Formulation), Stability Study, Quality control, Validation System, Audits. 3.2 International Standards and their significance 3.3 Unit Operations- Filtration, Distillation, Fractional distillation, Crystallisation	**(06L)** **(03L)** **(06L)**

Semester IV
Chemistry Practicals I, II and III
Credits: 3

Course Code	Experiments
RUSCHEP401	**Chemistry Practicals I** **(Paper-I): Physical Chemistry** 1. To determine order of the reaction between $K_2S_2O_8$ and KI. 2. To determine dissociation constant of weak acid by incomplete titration method using pH meter. 3. To determine dissociation constant of weak acid by pH metric titration. 4. To determine the amount of strong acid in the given solution by potentiometric titration 5. To determine standard cell potential (E^{o}_{cell}), standard free energy change (ΔG^{o}) and equilibrium constant (K) for a given galvanic cell. 6. To determine the amount of weak acid in the given solution by conductometric titration. **(Paper-II): Organic Chemistry:** Qualitative Analysis of bi-functional organic compounds (minimum six) on the basis of 1. Preliminary examination 2. Solubility profile 3. Detection of elements C, H, (O), N, S and X. 4. Detection of functional groups 5. Determination of physical constants (M.P/B.P) Solid or liquid Compounds containing not more than two functional groups from among the following classes may be given for analysisto be given: Carboxylic acids, phenol, carbohydrates, aldehydes, ketones, ester, amides, nitro, anilides, amines, alkyl and aryl halides.

	Chemistry Practicals II **Inorganic Chemistry** **Inorganic preparation –** 1. Nickel dimethyl glyoxime using microscale method. 2. *Tris* (ethylene diamine) nickel (II) thiosulphate. 3. Sodium Hexanitrocobaltate (III) 4. Preparation of magnesium oxalate using PFHS technique.
	Chemistry Practicals III **Analytical Chemistry** 1. Chromatography: a) Separation of cations Fe(III), Ni(II) and Cu(II) in a sample by paper chromatography b) Separation of a mixture of o-and p-nitrophenols by thin layer chromatography (TLC) 2. To determine partition coefficient of iodine between water and CCl_4 3. Estimation of Fe(II) in the given solution by titrating against $K_2Cr_2O_7$ potentiometrically. 4. Determination of amount of Fe (III) in the given solution by photometric titration using salicylic acid . 5. To verify Beer Lamberts law. 6. Determination of Calcium and Magnesium in the given sample of Dolomite ore. 7. To determine the purity of the given commercial sample of aspirin using phenol red indicator.

Reference Books for Physical Chemistry:

1) The Elements of Physical Chemistry, P.W. Atkins, Oxford University Press, Oxford.
2) University General Chemistry. By C.N. R. Rao Mc. Millan Publication.
3) Principles of Physical Chemistry. By Maron and Pruton 4th Ed. Oxford and IBH publication.
4) Physical Chemistry, G.M. Barrow, Tata McGraw Hill Publishing Co.Ltd. New Delhi.
5) Physical Chemistry, G.Castellan, Narosa Publishing House.
6) Modern Electrochemistry, J.O'M. Bockris & A.K.N. Reddy, Maria. Gamboa – Aldeco. Springer.
7) Chemical Kinetics. By Keith J. Laidler, G. K. Rollefson, Publisher, Pearson Education
8) Fundamentals of Molecular Spectroscopy by Colin N. Banwell, Elaine M. McCash, McGraw-Hill publishers.
9) Khosla B.D., Garg V.C. and Gulati A., Senior Practical Physical Chemistry, R. Chand and Co., New Delhi (2011).
10) Garland C. W., Nibler J.W. and Shoemaker D.P., Experiments in Physical Chemistry, 8th Ed., McGraw-Hill, New York (2003).

11) Halpern A.M. and McBane G.C., Experimental Physical Chemistry, 3rd Ed., W.H. Freeman and Co., New York (2003).
12) Athawale V.D. and Mathur P., Experimental Physical Chemistry, New Age International, New Delhi (2001)

References for Organic Chemistry:

1. Organic Chemistry, F. A. Carey, Tata McGraw-Hill Publishing company Ltd.
2. Paula Y. Bruice, Organic Chemistry, Pearson Education.
3. Organic Chemistry, Finar, I. L. (Volume 1), Dorling Kindersley (India) Pvt. Ltd.
4. Heterocyclic Chemistry, Synthesis reactions and Mechanisms, R.K Bansal, Wiley Eastern Ltd.
5. Mann, F.G. & Saunders, B.C. Practical Organic Chemistry, Pearson Education (2009)
6. Ahluwalia, V.K. & Aggarwal, R. Comprehensive Practical Organic Chemistry: Preparation and Quantitative Analysis, University Press (2000). Mann, F.G. & Saunders, B.C. Practical Organic Chemistry, Pearson Education (2009)
7. Furniss, B.S.; Hannaford, A.J.; Smith, P.W.G.; Tatchell, A.R. Practical Organic Chemistry, 5th Ed., Pearson (2012)
8. Vogel, A.I., Tatchell, A.R., Furnis, B.S., Hannaford, A.J. & Smith, P.W.G., Textbook of Practical Organic Chemistry, Prentice-Hall, 5th edition, 1996

Reference Books for Inorganic Chemistry

1. *Practical Inorganic Chemistry* by G. Marr and B. W. Rockett van Nostrand Reinhold Company (1972)
2. Inorganic Chemistry – Gary Wulfsberg, Viva Book, First Indian Edition 2002
3. Quantitative Analysis – R.A.Day, A.L. Underwood, sixth edition
4. Vogel's Textbook of quantitative chemical analysis – J Mendham, R C Denny, J D Barnes, M Thomas, B Sivasankar
5. J. D. Lee, 4th Edn., Concise Inorganic Chemistry, ELBS, The group III elements Pg. 359-648.
6. D. F. Shriver and P. W. Atkins, Inorganic chemistry, 3rd edition, Oxford University Press (1999) page 325-446.
7. CNR Rao edited, University General Chemistry, 513-578.
8. Gary Wulfsberg, Inorganic chemistry, Viva Books Pvt,. Ltd. (2002).
9. Puri, Sharma and Kalia, Milestone publishers, Principles of Inorganic Chemistry, page 416-628.
10. Bruce H. Mahan, University Chemistry, Narosa publishing house.
11. *Practical Inorganic Chemistry* by G. Marr and B. W. Rockett van Nostrand Reinhold Company (1972)

References for Paper III:

1. D. A. Skoog, D. M. West, F. J. Holler, and S. R. Crouch, Analytical Chemistry: An Introduction, 7th ed., Chapter 15, pp. 345-381.
2. A.I. Vogel. "Textbook of Quantitative Inorganic Analysis," Longman, London (1961).
3. R.V. Dilts. "Analytical Chemistry. Methods of Separation," van Nostrand, N.Y. (1974).
4. Some Experiments for B. Tech in Chemistry & Chemical Technology compiled by Prof. J.B.BARUAH, Mrs. Abhilasha Mohan Baruah and Mr. Parikshit Gogoi
5. Asim K. Das, 'Environmental Chemistry with Green Chemistry' Books & Allied (P) Ltd.
6. K.A. Gavhane, 'Unit operations-I and II'

Modality of Assessment:

Theory Examination Pattern:

05 Internal Assessment – 40% 40 marks.

Theory **40 marks**

Sr.No	Evaluation type	Marks
1	One Assignment	15
2	One class Test (multiple choice questions / objective/ numerical)	20
3	Active participation in routine class instructional deliveries(case studies/ seminars//presentation)	05

B) External examination – 60 %

Semester End Theory Assessment - 60% **60 marks**

These examinations shall be of **two hours** duration.

There shall be **three** questions each of **20** marks. On each unit there will be one question.

All questions shall be compulsory with internal choice within the questions.

Theory question paper pattern is as follows :-

Questions	Options	Marks	Questions on
Q.1)A)	Any 4 out of 6	16	Unit I
Q.1)B)	Any 4 out of 6	04	
Q.2)A)	Any 4 out of 6	16	Unit II
Q.2)B)	Any 4 out of 6	04	
Q.3)A)	Any 4 out of 6	16	Unit III
Q.3)B)	Any 4 out of 6	04	

Practical Examination Pattern:

(A)Internal Examination:-

	Paper I	Paper II	Paper III
Journal	05	05	05
Test	10	10	10
Participation	05	05	05
Total	20	20	20

(B) External (Semester end practical examination) :- 30 Marks Per Section

Sr.No.	Particulars	Marks Total
1.	Laboratory work	25 + 25+ 25 = 75
2.	Viva	05 + 05 +05 = 15

PRACTICAL BOOK/JOURNAL

Semester III and IV:

The students are required to present a duly certified journal for appearing at the practical examination, failing which they will not be allowed to appear for the examination.

In case of loss of Journal and/ or Report, a Lost Certificate should be obtained from Head/ Co-ordinator / Incharge of the department ; failing which the student will not be allowed to appear for the practical examination.

Overall Examination and Marks Distribution Pattern

Semester III

Course	301			302			303			Grand Total
	Internal	External	Total	Internal	External	Total	Internal	External	Total	
Theory	40	60	100	40	60	100	40	60	100	300
Practicals	20	30	50	20	30	50	20	30	50	150

Semester IV

Course	401			402			403			Grand Total
	Internal	External	Total	Internal	External	Total	Internal	External	Total	
Theory	40	60	100	40	60	100	40	60	100	300
Practicals	20	30	50	20	30	50	20	30	50	150

(Total: 900 marks)