ST. JOSEPH'S COLLEGE (AUTONOMOUS)

BENGALURU-27

Re-accredited with **'A++' GRADE with 3.79/4 CGPA** by NAAC
Recognized by UGC as College of Excellence

DEPARTMENT OF CHEMISTRY

SYLLABUS FOR UNDERGRADUATE PROGRAMME

For Batch 2021-2024

SUMMARY OF CREDITS IN CHEMISTRY

Semester 1	Code Number	Title	No. of Hours of Instructions	Number of Hours of teaching per week	Number of credits	Continuous Internal Assessment (CIA) Marks	End Semester Marks	Total marks
Theory	CH-121	CHEMISTRY-I	60	04	04	30	70	100
Practical	CH-1P1	PRACTICAL-I	33	03	01	15	35	50
Total Number of credits:			**05**					
Semester 2	**Code Number**	**Title**	**No. of Hours of Instructions**	**Number of teaching hrs /week**	**Number of credits**	**Continuous Internal Assessment (CIA) Marks**	**End Semester Marks**	**Total marks**
Theory	CH-221	CHEMISTRY-II	60	04	04	30	70	100
Practical	CH-2P1	PRACTICAL-II	33	03	01	15	35	50
Total Number of credits:			**05**					
Semester 3	**Code Number**	**Title**	**No. of Hours of Instructions**	**Number of teaching hrs /week**	**Number of credits**	**Continuous Internal Assessment (CIA) Marks**	**End Semester Marks**	**Total marks**
Theory	CH-321	CHEMISTRY-III	60	04	04	30	70	100
Practical	CH-3P1	PRACTICAL-III	33	03	01	15	35	50
Total Number of credits:			**05**					
Semester 4	**Code Number**	**Title**	**No. of Hours of Instructions**	**Number of teaching hrs /week**	**Number of credits**	**Continuous Internal Assessment (CIA) Marks**	**End Semester Marks**	**Total marks**
Theory	CH-421	CHEMISTRY-IV	30	02	02	15	35	50
Theory	CHOE-4121	Cosmetic Chemistry	30	02	02	15	35	50
Theory	CHOE-4221	Industrial and Materials Chemistry	30	02	02	15	35	50
Theory	CHOE-4321	Chemistry of food production, health and nutrition	30	02	02	15	35	50
Practical	CH-4P1	PRACTICAL-IV	33	03	01	15	35	50
Total Number of credits:			**09**					

Semester 5	Code Number	Title	No. of Hours of Instructions	Number of teaching hrs /week	Number of credits	Continuous Internal Assessment (CIA) Marks	End Semester Marks	Total marks
Theory	CH-5121	CHEMISTRY -V	45	03	03	30	70	100
Practical	CH-5P$_1$	PRACTICAL-V	33	03	01	15	35	50
Theory	CH-5221	CHEMISTRY- VI	45	03	03	30	70	100
Practical	CH-5P$_2$	PRACTICAL-VI	33	03	01	15	35	50
Total Number of credits:					**08**			
Semester 6	**Code Number**	**Title**	**No. of Hours of Instructions**	**Number of teaching hrs /week**	**Number of credits**	**Continuous Internal Assessment (CIA) Marks**	**End Semester Marks**	**Total marks**
Theory	CH-6121	CHEMISTRY-VII	45	03	03	30	70	100
Practical	CH-6P$_1$	PRACTICAL - VII	33	03	01	15	35	50
Theory	CH-6221	CHEMISTRY-VIII	45	03	03	30	70	100
Practical	CH-6P$_2$	PRACTICAL - VIII	33	03	01	15	35	50
Total Number of credits:					**08**			

CORE COURSES (CC)	
Course Title	Code Number
CHEMISTRY-I	CH-121
CHEMISTRY-II	CH-221

DISCIPLINE SPECIFIC ELECTIVE COURSES (DSE)	
Course Title	Code Number
CHEMISTRY-I	CH-121
CHEMISTRY-II	CH-221

GENERIC ELECTIVE COURSES (GSE)/ Can include open electives offered	
Course Title	Code Number
Cosmetic Chemistry	CHOE-4121
Industrial and Materials Chemistry	CHOE-4221
Chemistry of food production, health and nutrition	CHOE-4321

SKILL ENHANCEMENT COURSE (SEC) – Any practical oriented and software based courses offered by departments to be listed below	
Course Title	Code Number
PRACTICAL-I	CH-1P1
PRACTICAL-II	CH-2P1

VALUE ADDED COURSES (VAC) Certificate courses that add value to the core papers can be listed	
Course Title	Code Number
Post Graduate Diploma in Chemistry for Industry	

Online courses offered or recommended by the department to be listed	
Course Title	Code Number
Bioinorganic Chemistry	https://nptel.ac.in/courses/104104109/
Laws of Thermodynamics from Swayam	https://www.classcentral.com/course/swayam-laws-of-thermodynamics-17672
Solid and hazardous Waste Management from Swayam	https://www.classcentral.com/course/swayam-solid-and-hazardous-waste-management-14299

Course Content and Course Outcomes

Semester	**I**
Paper Code	**CH-121**
Paper Title	**CHEMISTRY– I**
Number of teaching hours per week	04
Total number of teaching hours per semester	60
Number of credits	04

NOTE: 1. Text underlined and in italics correspond to self-study.
2. Text within parenthesis and italics correspond to recall/review.

1. ATOMIC STRUCTURE AND INTRODUCTION TO QUANTUM CHEMISTRY 11+2 hours

(*Historical development of atomic structure, failure of classical mechanics in the study of sub atomic particles: Black body radiation, Photoelectric effect*). de Broglie relation and Heisenberg's uncertainty principle, problems based on these equations. Thought experiment to understand uncertainty principle.

Introduction to the principles of quantum (wave) mechanics: Operators - definition, quantum mechanical operators for position, momentum and energy; eigen functions and eigen values. Schrodinger equation; Born interpretation of wave function (significance of ψ^2); postulates of quantum mechanics. Quantum mechanical treatment of particle in one-dimensional box: Derivation of expressions for energy and normalized wave functions of a particle in 1D box; energy level diagram; problems pertaining to particle in 1D box. Energy expression for a particle in 3D box (no derivation); degeneracy in a cubic box.

Schrodinger equation for H-atom in cartesian coordinates and spherical polar coordinates. Qualitative explanation of the emergence of quantum numbers; radial and angular components of the wave functions; radial distribution functions of s and p orbitals.

Shapes of s, p and d orbitals. Polyelectron atoms: electron spin and spin quantum number, (n+ℓ) rule, Pauli's exclusion principle, Aufbau principle, Hund's rule, electronic configuration of atoms.

Exchange energy, pairing energy, promotional energy; symmetric distribution of electrons in atomic orbitals; prediction of the stable electronic configuration in p and d orbitals (Cu and Cr as examples).

2. PERIODIC TABLE — 6 hours

General electronic configurations of s, p, d and f block elements and position of elements in the long form of periodic table. Atomic radius: covalent, metallic and van der Waal's radii; ionic radii. Effective nuclear charge (qualitative treatment); periodic trends in atomic radii; comparison of ionic radii of isoelectronic ions. Ionization energy and electron affinity – periodic trends. Electronegativity- Pauling scale, calculation of electronegativity, periodic trends.

3. CHEMICAL BONDING — 19+2 hours

Ionic bonding: lattice energy, Born-Lande equation, Born-Haber cycle. Problems based on Born-Lande equation and Born-Haber cycle. Relation between lattice energy and melting point of an ionic solid.

Covalent bonding: octet rule and its limitations, Lewis structures of molecules and ions (when provided with sequence of atoms). Formal charge calculation for different atoms in molecules/ions. *Partial covalent character of ionic bonds: Fajan's rules. Partial ionic character of covalent bonds, calculation of % ionic character*.

VSEPR concept: Application to AB_n and AB_nL_m type molecules/ions (A= s or p block element; $n \leq 7$).

Valence bond treatment of hydrogen molecule: Qualitative discussion of wave functions, concept of resonance. Molecular structure: Bond length, bond angle, dihedral angle and molecular geometry. Overlapping of atomic orbitals, sigma and pi bonds.

Hybridisation: sp, sp^2, sp^3, sp^3d, sp^3d^2 with examples (inorganic molecules AB_n and AB_nL_m type with and without π-bonds).

Molecular orbital (MO) treatment of hydrogen molecule: Linear combination of atomic orbitals, bonding and antibonding orbitals, energy level diagram. MO energy level diagram of homonuclear diatomic molecules/ions ($Z \leq 9$): Bond order and magnetic behaviour of these molecules and ions, correlation of bond order with bond length and bond strength. MO energy level diagram of heteronuclear diatomic molecules – HF and CO.

Metallic bonding: Band theory (qualitative), classification of solids into conductors, insulators and semiconductors based on band theory, electrical conductance of Li and Be.

4. STOICHIOMETRY — 6+2 hours

Classification of chemical reactions, balancing chemical equations (including redox reactions). Atomic mass, gram atomic mass, molar mass, formula mass: problems based on these concepts Avogadro number, mole, problems based on chemical equations, concept of limiting reagent.

Supplementary assignments.

5. NUCLEAR CHEMISTRY — 3 hours

Radioactive equilibrium. Radioactive series – first and last nuclide in all four series to be mentioned (No calculation). Nuclear reactions: Nuclear reactions induced by alpha particles, protons, neutrons deuterons and gamma radiation (one example each). Induced radioactivity. Nuclear fission and fusion (one example each). Applications of radioactivity.

6. FIRST LAW OF THERMODYNAMICS 9 hours

Introduction to terminology in thermodynamics: phase, system and surroundings. Types of systems - open, closed and isolated; homogeneous and heterogeneous systems. Macroscopic properties: Extensive and intensive properties. State of a system; thermodynamic equilibrium. Zeroth law of thermodynamics and absolute temperature scale. Thermodynamic processes - isothermal, adiabatic, isochoric, isobaric, cyclic, reversible, irreversible and spontaneous processes. Heat and work - sign convention; internal energy; state functions and path functions, exact and inexact differentials. Statement and mathematical form of first law of thermodynamics, enthalpy of a system, heat capacity, relation between Cp and Cv. Expressions for I law of thermodynamics for isothermal, adiabatic, isobaric, isochoric and cyclic processes. Work done in i) irreversible isothermal expansion and compression of an ideal gas, ii) reversible isothermal expansion and compression of an ideal gas. Kirchoff's law - derivation.

REFERENCES:

1. Principles of Inorganic Chemistry, B R Puri; L R Sharma and K.C. Kalia; Milestone Publishers (2011).
2. Physical Chemistry, P.W. Atkins, 6th Edition, Oxford University Press (1998).
3. Chemistry; R. Chang; 9th & 13th Edition, McGraw-Hill Higher Education (2006 & 2019).
4. Principles of Physical Chemistry; B. R. Puri, L. R. Sharma, M.S. Pathania; 47th edition, Vishal Publishing Co., (2017).
5. Concise Inorganic Chemistry, 5th edition, J. D. Lee, Blackwell Science, Oxford University press, New Delhi (1996).

Course Outcomes: At the end of the course, the student should be able to

CO1	Knowledge	Recall the basic concepts of atomic structure, periodic table of elements, chemical bonding in molecules, concepts of stoichiometry and thermodynamics.
CO2	Understand	Explain concepts, relationships, laws, concerning atoms, molecules, atomic structure, chemical bonding, periodic table, stoichiometry, nuclear chemistry, and first law of thermodynamics.
CO3	Apply	Apply the bonding theories in predicting structure, bonding and magnetic properties of molecules, laws and relationships to real chemical systems and compute properties.
CO4	Analyze	Compare and contrast theories and generalisations in atomic/molecular structures, bonding, and periodic properties.

CO5	Evaluate	Assess the applicability of theories of structure and bonding for a given system.
CO6	Create	Place hitherto unknown element in the periodic table and predict its physical and chemical properties.

BLUE PRINT

Code number: **CH-121**

Title of the paper: **CHEMISTRY-I.**

Chapter	**Number of Hours**	**Total marks for which the questions are to be asked (including bonus questions)**
1	13	20
2	6	9
3	21	31
4	8	12
5	3	5
6	9	14
TOTAL	**60**	**91**
Maximum marks for the paper (Including bonus question)= 91		

Practical I

CH $1P_1$– Practical I

(11 sessions 3hr/week)

1. Inorganic semi-micro qualitative analysis: salt mixture containing two acid and two basic radicals.

Course Outcomes: At the end of the course, the student should be able to

CO1	Knowledge	Explain and identify the acids and basic radicals in a given salt and salt mixtures.
CO2	Understand	Explain ionic product, solubility product and related these to the separation of cations in a given mixture and develop laboratory skill to classify the ions into the respective groups
CO3	Apply	Identify the acid and basic radicals present in the given salt mixture.
CO4	Analyze	Analyze and distinguish the ions in a given mixture qualitatively.

Semester	**II**
Paper Code	**CH-221**
Paper Title	**CHEMISTRY– II**
Number of teaching hours per week	04
Total number of teaching hours per semester	60
Number of credits	04

NOTE: 1. Text underlined and in italics correspond to self-study.
2. Text within parenthesis and italics correspond to recall/review.

1. SECOND AND THIRD LAW OF THERMODYNAMICS 15 hours

Limitations of I law, scope of II law, Spontaneous and non-spontaneous processes, spontaneity and equilibrium, Driving forces for spontaneous processes. various statements of II law of thermodynamics. Concept of entropy and its significance. Entropy and thermodynamic probability (microstates configurations: tossing of a coin as an example); Entropy as a criterion for spontaneity. concept of heat engine; Carnot's engine – working of Carnot's engine. Derivation of efficiency based on entropy concept. Second Law's statement based on Carnot's study. Entropy of an ideal gas as a function of P, V and T. Entropy change for isothermal, adiabatic isochoric and isobaric processes in reversible expansion of an ideal gas. Entropy of phase transitions. Entropy changes in the system and surroundings for reversible and irreversible processes.

Free energy – Helmholtz free energy and Gibbs free energy, relation between work done and ΔA; work done and ΔG. Standard free energy change of a reaction. Free energy and criterion of spontaneity, variation of Gibbs free energy with T and P for an ideal gas; derivation of Gibbs - Helmholtz equation – derivation of van't Hoff reaction isotherm (relation between free energy and equilibrium constant of a reaction). Derivation of Clausius–Clapeyron equation –application to liquid-vapour and solid-liquid equilibria.

Third law of thermodynamics -statement, calculation of statistical entropies (residual entropy).

2. SPECTROSCOPY- THEORETICAL CONCEPTS 13+2 hours

Electromagnetic radiation (EMR)- Characteristics – Frequency, wavelength and wave number and mathematical expressions connecting them. Types of Spectra: (Atomic and molecular). <u>*Different types of spectra*</u>. Absorption and emission spectra: continuous, band and line. Regions of electromagnetic spectrum. Processes and spectral techniques associated with different regions. Different types of Molecular spectra i) Rotational (ii) vibrational and vibrational - rotational iii) Electronic. Born Oppenheimer approximation. Rotational Spectra of diatomic molecules: Rigid rotor model. Final expression for moment of inertia $I = \mu r^2$ and its significance.

Calculation of reduced mass. Expression for rotational energy in terms of joule and cm-1. Expression for rotational constant; selection rule (gross and quantum selection rules) $\Delta J = \pm 1$. Energy level diagram for a rigid rotor and rotational spectrum. Vibrational Spectra of diatomic molecule. Hooke's Law. Oscillator frequency of Simple Harmonic Oscillator. Mathematical equation for fundamental vibrational frequency and fundamental wave number in terms of force constant, significance of force constant, effect of reduced mass on vibrational frequency. Equation relating wave number and force constant. Potential energy curve for a diatomic molecule of a harmonic oscillator. Selection rule. $\Delta v = \pm 1$. Energy level diagram. Expression for vibrational energy and zero-point energy. Fundamental vibrations, total degrees of freedom (translational, rotational and vibrational) for linear and non-linear molecules. Calculation of number of fundamental vibrations for linear and non-linear molecules. Schematic representation of fundamental vibrations for H_2O, CO_2 and their IR activity. Raman spectra – elastic and inelastic scattering, Rayleigh and Raman scattering. Raman shift, Stokes and anti-Stokes lines, intensity of Stokes and anti-Stokes lines, mutual exclusion rule. *Difference between IR and Raman spectroscopy*.

3. GASEOUS STATE 3 hours

Review of kinetic theory of gases (ideal gases) and van der Waals equation; Andrews experiments on liquefaction of CO_2, critical constants. Relationship between critical constants and van der Waals constants (no derivation). Joule – Thomson effect for liquefaction of gases. Joule – Thomson coefficient of gases and inversion temperature.

4. CHEMICAL KINETICS 8 hours

Review of chemical kinetics (*definitions of rate of a reaction, order, molecularity, rate constant, rate equations for reactions of different orders, half-life*).

Derivation of rate expression for a 2^{nd} order reaction when $a = b$ and $a \neq b$. Methods of determination of order of a reaction – i) integral and graphical methods, ii) half-life period method; derivation of $t_{1/2}$ for n^{th} order reaction. Effect of temperature on reaction rates - temperature coefficient, Arrhenius theory, concept of energy barrier. Bimolecular collision theory - [final equation given, no derivation]. Limitations of bimolecular collision theory. Transition state theory – qualitative approach based on thermodynamics. Steady state approximation, Lindemann theory - kinetics of unimolecular reactions.

5. ACIDS, BASES AND SOLVENTS 7+1 hours

Theories of acids and bases: Lowry- Bronsted concept, conjugate acid –base pairs, amphiprotic substances, relative strengths of acid-base pairs, solvent system concept of acids and bases and examples. Lewis concept- types of molecules or species that can act as Lewis acids and Lewis bases, Pearson's Hard and Soft Acid- Base concept. Characteristics of hard and soft acids and bases, HSAB principle. Applications of HSAB principle- stability of complexes, prediction of coordination in complexes of ambidentate ligands, predicting feasibility of a reaction, prediction of hardness and softness. Solvent properties- liquid range, dielectric constant, solvent polarity, classification of solvents. Protic solvents – autoionisation of protic solvents (H_2O, liq. NH_3). Aprotic solvents –classification with examples. Molten salts - Classification with examples for each, and uses. Levelling effect of solvents- explanation, levelling solvents and differentiating solvents. Liquid NH_3- autoionisation, acid-base reactions, solvation, solvolysis (comparison with H_2O in each case). Solutions of alkali metals in liquid ammonia. Advantages and disadvantages of liq. NH_3 solvent. *Liquid SO_2 as solvent- autoionisation and acid base reactions. Anhydrous HF-autoionisation, acid-base reactions*. Superacids and superbases- Hammett acidity function (equation is not required). Examples of superacids and superbases. Applications of superacids and superbases.

6. LIQUID MIXTURES 5 hours

Completely miscible liquids Raoults' law, mathematical formulation, vapour pressure - composition curves of ideal (Type I, II and III) and non-ideal (Slight deviation from Raoults' law-Type I, positive deviation from Raoults' law-Type-II and negative deviation from Raoults' law Type III) solutions. Boiling point - composition curves of ideal and non-ideal (Type-I, II and III) solutions. Fractional distillation of binary liquid mixtures. Explanation for separation of components: ideal, non-ideal Type-I, II and III (azeotrope formation residue with minimum boiling and maximum boiling point).

Partially miscible liquid pairs: graphical representation, definition of critical solution temperature (CST): phenol-H_2O system, triethylamine-H_2O system: nicotine-H_2O system. Effect of impurity on CST.

Immiscible liquid pairs: Nernst distribution law, effect of association and dissociation of solute on distribution coefficient.

7. POLYMER CHEMISTRY 2+1 hours

Introduction to polymers; *Types of polymers,* number average and weight average molecular mass of polymers. Determination of molecular mass of polymers by viscosity and light scattering methods.

8. PROPERTIES OF COLLOIDS 2+1 hours

Introduction to colloids; dimensions of colloidal particles, dispersed phase and dispersion medium. Types of colloidal dispersions with examples.

Properties of colloids-optical properties, kinetic properties and electrical properties. Application of colloids in industries.

REFERENCES:

1. Principles of inorganic chemistry, B.R. Puri, L. R. Sharma, K. C. Kalia. 33rd ed, Vishal publishing Company (2016).
2. Physical Chemistry for Chemical and Biological Sciences: Raymond Chang; First Indian Edition-2015, Viva Book Pvt. Ltd.
3. Fundamentals of Molecular Spectroscopy by Colin N Banwel and Leaine Mccash, Fifth Edition-2013, McGraw Hill Education Pvt. Ltd.
4. Basic inorganic chemistry, F. A. Cotton, G. Wilkinson, Paul L. Gaus. 3rd ed., John Wiley and sons Cannada Pub (1995).
5. Inorganic chemistry, James H. Huheey, Ellen A. Keiter, Richard L. Keiter, 4th ed. Pearson education (2005).
6. Inorganic Chemistry, 4th Edition, D.F. Shriver and P.W. Atkins, ELBS Oxford Univ. Press. (2006).
7. Principles of Physical Chemistry; B. R. Puri, L. R. Sharma, M.S. Pathania; 47th edition, Vishal Publishing Co., (2017).

Course Outcomes: At the end of the course, the student should be able to

CO1	Remember	Recall definitions, laws, relationships in second and third law of thermodynamics, spectroscopy, gaseous state, acids, bases and solvents, liquid mixtures, polymer chemistry and properties of colloids.
CO2	Understanding	Explain concepts, relationships, theories, and models in second and third law of thermodynamics, spectroscopy, gaseous state, acids, bases and solvents, liquid mixtures, polymer chemistry and properties of colloids; classify liquid mixtures, colloids, polymers, solvents, acids, bases and solvent.
CO3	Apply	Calculate efficiency of heat engines, molecular properties from spectral data, rates of a chemical reaction and explore the properties of colloids and polymers useful for chemical investigations.
CO4	Analyze	Compare and contrast theories and generalisations of second and third law of thermodynamics, spectroscopy, gaseous state, acids, bases and solvents, liquid mixtures, polymer chemistry and properties of colloids.
CO5	Evaluate	Assess the applicability of theories of thermodynamics, kinetics, solvents, acids and bases for a given system.
CO6	Create	Design suitable separation method for liquids/solids in admixture.

BLUEPRINT

Code number: **CH-221**

Title of the paper: **CHEMISTRY– II.**

Chapter	Number of Hours	Total marks for which the questions are to be asked (including bonus questions)
1	15	22
2	15	23
3	3	5
4	8	12
5	8	12
6	5	7
7	3	5
8	3	5
TOTAL	**60**	**91**
Maximum marks for the paper (Including bonus question) = 91		

Practical II

CH $2P_1$ – Practical II

(11sessions 3hr/week)

1. Errors & Standard Deviation.
2. Introduction to Volumetric Analysis-Estimation of NaOH using standard HCl.
3. Introduction to RBPT: Estimation of HCl using Std. Na_2CO_3.
4. Redox Titration: $KMnO_4$ <> Oxalic acid. Define RBPT problem.
5. Complexometric titration: Zn^{2+} <> EDTA.
6. Preparation of RBPT CHARTS. Presentation of the charts by each group. Discussion of materials required.
7. Prepare solutions. Standardize / check solutions.
8. Do the main experiments individually.
9. Preparation of poster. Preparation of results through posters.
10. Repetition.
11. Viva

Course Outcomes: At the end of the course, the student should be able to

CO1	Knowledge	Recall the mole concept and define errors, accuracy, precision, significant figures, standard deviation and relate these to the concept of volumetric analysis.
CO2	Understand	Compare various ways of expressing concentration and explain the differences in them.
CO3	Apply	Identify the number of significant figures and solve numerical problems based on mole concept and chemical equations.
CO4	Analyze	Apply the theoretical concepts to develop experimental skills in carrying out volumetric analysis independently and draw inference/suggest a solution
CO5	Evaluate	Assess the errors in and calibrate the glassware used for experiments and estimate the amount of chemical substance present in a solution of unknown concentration.
CO6	Create	Propose a research problem based on volumetric analysis, design an experiment and develop a method, discuss in a group and improvise the methodology, carryout independent work and create a personalized mode of presentation of results