Syllabus for B.Sc. FYUGP
Chemistry

Gauhati University

Guwahati::Assam

NEP –FYUGP
Course Distribution
Department of Chemistry
Gauhati University

Department /Centre	Subject / Discipline	Course Title	Semester	Credit	Paper Type
Chemistry	Chemistry	Chemistry I	Semester 1	4	Compulsory
Chemistry	Chemistry	Chemistry II	Semester 2	4	Compulsory
Chemistry	Chemistry	Chemistry III	Semester 3	4	Compulsory
Chemistry	Chemistry	Inorganic Chemistry - I	Semester 4	4	Compulsory
Chemistry	Chemistry	Organic Chemistry - I	Semester 4	4	Compulsory
Chemistry	Chemistry	Theoretical Chemistry	Semester 4	4	Compulsory/Elective
Chemistry	Chemistry	Magnetic Resonance Spectroscopy and Analytical Technqiues	Semester 4	4	Compulsory/Elective
Chemistry	Chemistry	Inorganic Chemistry-II	Semester 5	4	Compulsory/Elective
Chemistry	Chemistry	Organic Chemistry-II	Semester 5	4	Compulsory/Elective
Chemistry	Chemistry	Reaction Dynamics	Semester 5	4	Compulsory/Elective
Chemistry	Chemistry	Light-Matter Interaction	Semester 5	4	Compulsory
Chemistry	Chemistry	Inorganic Chemistry - III	Semester 6	4	Compulsory/Elective
Chemistry	Chemistry	Organic Chemistry - III	Semester 6	4	Compulsory/Elective
Chemistry	Chemistry	Equllibria and Electrochemistry	Semester 6	4	Compulsory/Elective
Chemistry	Chemistry	Industrial Chemistry	Semester 6	4	Compulsory

Prerequisites:

- For Major in Chemistry a student must pass in Chemistry and Mathematics at XII level.
- For Minor in Chemistry a student must pass in Chemistry at XII level.

Semester-I: Chemistry I (3L- 0T-1P)

Graduate Attributes

i. ***Course Objective:***

This course aims at giving students insight into the fundamental aspects of atoms, ions and molecules in terms of their electronic structure and reactivity. Structure and bonding in/of these are to be dealt with basic quantum chemistry treatment. Further, periodic classification of elements to illustrate the changes in properties along the periods and groups to be emphasized upon. Properties of the gases and liquids are to be introduced.

Accompanying laboratory course is designed to introduce students to various laboratory apparatus, preparation of standard solutions, measurement of physical properties, and laboratory safety.

ii. ***Learning outcome:***

On successful completion, students would have clear understanding of the concepts related to atomic and molecular structure, chemical bonding, periodicity and states of matter. Students will be able to work in a chemical laboratory following standard safety protocols.

No. of Required Classes: 45 (Theory) + 30 (Practical)

No. of Contact Classes: 45 (Theory) + 30 (Practical)

No. of Non-Contact Classes:

iii. ***Particulars of Course Designer*** (Name, Institution, email id):

1) Dr. Sonit Kumar Gogoi, Gauhati University, skgogoi@gauhati.ac.in

2) Dr. Dhriti Mahanta, Gauhati University, mdhriti@gauhati.ac.in

Semester-I: Chemistry I (3L- 0T-1P)

Unit	Content	Contact Hours
Unit I: Atomic structure	Historical development on structure of atom; Bohr's model, H-atom spectrum; black body radiation; photoelectric effect (qualitative treatment only); The dual behaviour and uncertainty. Quantum mechanical approach to atomic structure: concept of wave function, well behaved function, operator, normalised and orthogonal wave function, Schrodinger wave equation, eigenfunction, Significance of Ψ and Ψ^2, Particle in a 1-D box; Schrodinger equation of hydrogen atom (no derivation), radial and angular wave functions for hydrogen atom, probability distribution, quantum numbers, Pauli's Exclusion Principle, Hund's rule of maximum multiplicity, Aufbau's principle and its limitations.	8
Unit II: Periodicity and chemical behaviour	Effective nuclear charge; Slater's Rule; covalent and ionic radii, ionization energies, electronegativity (various scales), electron affinities	3
Unit III: Chemical bonding I (ionic interaction)	General characteristics of ionic compounds; lattice and solvation energy; Born Lande equation; Kapustinski equation, Madelung constant, Born Haber cycle for lattice energy calculation	4
Unit IV: Structure of organic molecules	Nature of bonding: hybridisation of atomic orbitals (qualitative VB and MO approach); effect of hybridization on bond properties.	4
Unit V: Stereochemistry of organic molecules	Representation of organic molecules in 2D and 3D (Fischer, Newman and Sawhorse projection formulae and their interconversions); geometrical isomerism (cis-trans, syn-anti, E/Z notations); concept of chirality (enantiomers and diastereomers); configuration and conformation, barriers to rotation, conformational analysis (ethane, butane, cyclohexane)	8
Unit VI: Electronic effects in organic molecules	Concept of electrophiles and nucleophiles; inductive effects; resonance, conjugation and delocalisation.	3

Unit VII: Gaseous state	Causes of deviation from ideal gas behaviour, compressibility factor, Z, and its variation with pressure and temperature for different gases. State variables and equation of states for real gases; van der Waals equation of state, its derivation and application in explaining real gas behaviour. Reasons and examples of failure of van der Waal equation of state and interpretation of van der Waals pressure-volume isotherm. Critical state and phenomena, mathematical definition and interpretation of critical point, relation between critical constants and van der Waals constants: along with their thermodynamic interpretation. Introduction to virial equation and virial coefficients, derivation of Boyle temperature.	8
Unit VIII: Liquid state	Qualitative treatment of the structure of the liquid state. Physical properties of liquids: vapour pressure, surface tension coefficient of viscosity, and their determination. Temperature variation of viscosity of liquids and comparison with that of gases. Effect of addition of various solutes on surface tension and viscosity. Explanation of cleansing action of detergents (micelle formation and critical micelle concentration).	7

Laboratory Course I	1. Introduction to laboratory apparatus and safety measures in laboratory, 2. Calibration of apparatus (volumetric flask, thermometer, melting point apparatus etc.) **Group A** (a) Preparation of normal and molar solution, for example KCl, $Na_2C_2O_4$, HCl, H_2SO_4 etc. (Verification by conductometric measurement). (b) Determination of solubility of a given salt at different temperature and plot solubility curve. (c) Determination of water of crystallisation of hydrated salt by ignition and weighing. **Group B** (a) Determination of the melting points of organic compounds (here, the student is required to learn about thermometer calibration before performing the experiment). (b) Effect of impurities on the melting point – mixed melting point of two unknown organic compounds. (c) Purification of organic compounds by crystallization using the following solvents: (a) water, (b) alcohol, (c) alcohol-water mixture. **Group C** (a) Evaluating the compressibility factor using standard packages such as Excel/Origin/Python/Fortran. (b) Simulating an ideal gas using programming. (c) Simulation of a real gas using programming. (d) To determine the partial molar volume of ethanol-water mixture at a given composition. (e) Determine the surface tension of a given liquid at room temperature using stalagmometer by drop number method. (f) Determine the surface tension of a given liquid by means of stalagmometer using drop weight method. (g) Determine the composition of a given mixture by surface tension method. (h) Study the variation of surface tension of detergent solutions with concentration. (*Students are required to perform Exp. 1, 2 and a minimum of two experiments from each group*)	30

Text Book /Reference Book	1. University Chemistry, P. Siska, O. K. Medhi, 2nd edition, Pearson Education 2. General and Inorganic Chemistry, R.P. Sarkar (part 1) 3rd edition, NCBA 3. Concise Inorganic Chemistry, J. D. Lee, 5th Edition, Pearson Education 4. Inorganic Chemistry (Principles of Structure and Reactivity), J. E. Huheey, E. A. Keiter, R. L. Keiter, O. K. Medhi, 5th edition, Pearson Education 5. Principles of Physical Chemistry, Puri, Sharma, Pathania, 48th Edition, Vishal Publishing Com. 6. Atkins Physical Chemistry, Atkins, de Paula and Keeler, 11th Edition, Oxford University Press. 7. Stereochemistry of Organic Compounds, D. Nasipuri, 4th Edition. 8. Reaction Mechanism in Organic Chemistry, S. M. Mukherji, S. P. Singh,3rd Edition. 9. Organic Reactions and their Mechanisms, P. S. Kalsi, 5th Edition. Solomons' Organic Chemistry, T. W. G. Solomons, C. B. Fryhle, S. A. Snyder.

Semester-II: Chemistry II (3L- 0T-1P)

Graduate Attributes

i. ***Course Objective:***

This course extends the concepts of chemical bonding and introduces to coordination chemistry. The students will be familiarized with the organic reactive intermediates. Elementary concepts of acidity, basicity and thermodynamics are to be deliberated. Laboratory experiments relevant to the topics in the theory are included for the students to appreciate the concepts and to hone the experimental skills.

ii. ***Learning outcome:***

Students shall understand and apply the concepts of chemical bonding, coordination chemistry, acids and bases and the reactive intermediates. They shall also understand the chemistry from a thermodynamic point of view. Students will acquire preliminary training on quantitative analysis, synthesis of coordination compounds, qualitative analysis of organic compounds and measurement of a few basic thermodynamic parameters.

No. of Required Classes: 45 (Theory) + 30 (Practical)

No. of Contact Classes: 45 (Theory) + 30 (Practical)

No. of Non-Contact Classes:

iii. ***Particulars of Course Designer*** (Name, Institution, email id):

1) Prof. Anup Kumar Talukdar, Gauhati University, aktalukdar@gauhati.ac.in

2) Dr. Arabinda Baruah, Gauhati University, arb@gauhati.ac.in

Semester-II: Chemistry-II (3L- 0T-1P)

Unit I: Chemical bonding II (covalent bond and chemical forces)	Valence bond theory (Heitler-London approach), energetics of hybridization, equivalent and non-equivalent hybrid orbitals. Bent's rule, resonance and resonance energy, molecular orbital theory (MOT). Molecular orbital diagrams of homonuclear (N_2, O_2) and heteronuclear diatomic (CO, NO, CN^-), bonding in BeF_2 and HCl (idea of s-p mixing and orbital interaction). Valence shell electron pair repulsion theory (VSEPR). Covalent character in ionic compounds, polarising power and polarizability. Fajan's rules and consequences of polarisation. Ionic character in covalent compounds: Bond moment and dipole moment. Percentage ionic character from dipole moment and electronegativity difference. Weak chemical forces (van der Waals forces, ion-dipole forces, dipole-dipole interactions, induced dipole interactions, instantaneous dipole-induced dipole interactions and hydrogen bonding) and their effects on melting and boiling points, solubility and hydration energy.	10
Unit II: Coordination chemistry-I (structure and isomerism)	Introduction to coordination complexes (Werner theory, types of ligands) IUPAC nomenclature, isomerism in coordination complexes, stereochemistry of complexes with coordination numbers 4, 5, and 6. Berry pseudorotation.	5
Unit III: Reactive intermediates in organic reactions	Formation, structure and stability of reactive intermediates: carbocations, carbanions, radicals, carbenes, nitrenes, benzyne (brief mechanistic perspective using concepts of substitution, addition, elimination and rearrangements reactions).	12
Unit IV: Acidity, basicity, and pK_a	The definition of pK_a; Lewis acids and bases; organic acids and bases (factors affecting relative strength); substituents affect the pK_a (carbon acids).	3

Unit V: Thermodynamics	Mathematical treatment: exact and inexact differentials, partial derivatives, Euler's reciprocity, cyclic rules. Intensive and extensive variables. Isolated, closed and open systems. Cyclic, reversible and irreversible processes. Zeroth law of thermodynamics. First law of thermodynamics, concept of heat (q) and work (w), internal energy(U) and enthalpy (H) in differential forms: their molecular interpretation. Calculation of w, q, ΔU and ΔH for expansion of ideal gas under isothermal and adiabatic conditions for reversible and irreversible processes. Derivation of Joule-Thomson coefficient and inversion temperature. Application of first law of thermodynamics: standard state, standard enthalpy changes of physical and chemical transformations: fusion, sublimation, vaporization, solution, dilution, neutralization, ionization. Bond-dissociation energy Kirchhoff's equation, relation between ΔH and ΔU of a reaction. Difference between enthalpy and standard enthalpy. Second law of thermodynamics, entropy (S) as a state function, molecular interpretation of entropy. Residual Entropy. Free energy: Gibbs function (G) and Helmholtz function (A) and their molecular interpretation. Difference between free energy and standard free energy. Gibbs-Helmholtz equation, criteria for thermodynamic equilibrium and spontaneity of a process. Maxwell's Relations and their physical significance.	15

Laboratory Course II	1. Preparation of buffer solution and measurement of pH using pH-meter (acetic acid-sodium acetate buffer) **Group A:** (a) Determination of total hardness of water by titration against standardised EDTA solution. (b) Synthesis of coordination compounds i) Potassium tris(oxalato)chromate(III), ii) $[Ni(DMG)_2]$ **Group B:** (a) Qualitative organic analysis for N, S and halogenin a given organic compounds. (b) Detection of presence of unsaturation and aromaticity in an organic sample. (c) Identify acidic functional groups of a given organic sample (Acetic acid, Lactic acid, Tartaric acid and Phthalic acid) and determine the pKa by titrametric methods. **Group C:** (a) Determination of heat capacity of a calorimeter and enthalpy of neutralisation (eg. hydrochloric acid with sodium hydroxide). (b) Determine the enthalpy of solution of oxalic acid from solubility measurements. (c) Determination of heat capacity of a calorimeter for different volumes using change of enthalpy data of a known system (method of back calculation of heat capacity of calorimeter from known enthalpy of solution or enthalpy of neutralization). (d) Calculation of ionization enthalpy of ethanoic acid. (e) Determination of enthalpy of hydration of copper sulphate. (*Students are required to perform Exp. 1 and minimum of two from each group*)	30
Text Book /Reference Book	1. General and Inorganic Chemistry, R.P. Sarkar (part 1) 3rd edition, NCBA 2. Concise Coordination Chemistry, R. Gopalan, V. Ramalingam, 1st edition, Vikash Publishing House 3. Inorganic Chemistry (Principles of Structure and Reactivity), J. E. Huheey, E. A. Keiter, R. L. Keiter, O. K. Medhi, 5th edition, Pearson Education 4. Principles of Physical Chemistry, Puri, Sharma, Pathania, 48th edition, Vishal Publishing Com. 5. Atkins Physical Chemistry, Atkins, de Paula and Keeler, 11th edition, Oxford University Press. 6. March's Advanced Organic Chemistry: Reactions, Mechanisms, and Structure, Michael B. Smith 7th edition (Wiley). 7. Organic Chemistry, G. M. Loudon, 4th edition. 8. Mechanism and Theory in Organic Chemistry, Sachin Kumar Ghosh, New Central Book Agency.	

Semester-III: Chemistry III (3L- 0T-1P)

Graduate Attributes

i. ***Course Objective:***

This course extends the concepts of acids/bases and coordination chemistry as well as gives introductions to the redox reactions, ideal solutions and colligative properties. Further, the course is intended to apprise students about different classes of organic compounds, such as halogenated hydrocarbons, alcohols, phenols, thiols, epoxides and carbonyls.

Through the accompanying laboratory experiments on volumetric analysis, identification and preparation of derivatives and determination of physical properties of liquids, this course intends to make students learn about the qualitative and quantitative aspects of the analysis.

ii. ***Learning outcome:***

On successful completion of the course students will have significant knowledge of acids/bases as well as an overview of bonding in coordination compounds, principles of redox chemistry, solutions and their properties. Students will also be able to describe and classify organic compounds in terms of their functional groups and reactivity. Further experiments on acid/base and redox titrations will enable the students to consolidate their skills on quantitative analysis. In addition, qualitative analysis of organic compounds having common functional groups will give the students an idea about functional groups and their reactivities. Physical chemistry experiments will introduce the students to physical property measurements and kinetics of chemical reactions.

No. of Required Classes: 45 (Theory) + 30 (Practical)

No. of Contact Classes: 45 (Theory) + 30 (Practical)

No. of Non-Contact Classes:

iii. ***Particulars of Course Designer*** (Name, Institution, email id):

1) Dr. Sanfaori Brahma, Gauhati University, sanfaori@gauhati.ac.in

2) Dr. Tridib Kumar Goswami, Gauhati University, tridib@gauhati.ac.in

Semester III: Chemistry-III (3 L-0 T-1 P)

Unit	Content	Contact Hrs
Unit I: Acid and Bases	Acid-base concepts, measure of acid and base strength, proton affinity, acidity and basicity of binary hydrogen compounds, inductive effect and strength of oxyacids, acidity of aqua ions, steric effect, proton sponge, solvation and acid base strength, non-aqueous solvents and acid base strength, levelling effect, superacids and superbases. Hard and soft acids and bases (HSAB), application of HSAB principle and symbiosis.	7
Unit II: Oxidation and reduction -I	Reduction potentials: Redox half-reactions, standard potentials and spontaneity, trends in standard potentials, the electrochemical series, Nernst equation (Influence of pH and concentration on electrode potential). Principles of redox titration and choice of redox indicators.	4
Unit III: Coordination chemistry-II	Valence bond theory (VBT), inner and outer orbital complexes, electroneutrality principle and back bonding, effects of hybridization in metal ligand bond strength and stability of complexes, choice of metal d-orbital(s) in hybridization in different coordination geometries, magnetic properties of complexes, drawback of VBT.	4
Unit IV: Aromaticity	Concepts of aromatic, anti-aromatic and non-aromatic compounds (including examples of cyclic carbocations, carbanions and heterocyclic compounds); Hückel's rule.	3
Unit V: Hydrocarbons and halogenated compounds	Methods of preparation, properties and relative reactivity of alkyl and aryl halides; Selectivity in electrophilic and nucleophilic substitution reactions (S_NAr), Preparation and reactions of diazonium salts; Benzyne mechanism.	4
Unit VI: Alcohols, phenols, thiols and related compounds	Preparation, properties and relative reactivity of 1°, 2°, and 3°-alcohols, ethers, epoxides (preparation and reactions with alcohols, ammonia derivatives and $LiAlH_4$). Thiols and sulfides; phenols (preparation, properties and reactivity; Reimer-Tiemann and Kolbe's-Schmidt Reactions)	4
Unit VII: Carbonyl compounds	Structure, reactivity and preparation; oxidations and reductions (Jones reagent, PCC and PDC, Oppenauer, Clemmensen, Wolff-Kishner, $NaBH_4$, $LiAlH_4$, MPV), Baeyer Villiger oxidation.	4

Unit VIII: Solution	Vapour pressure of solution. Ideal solutions, ideally diluted solutions and colligative properties. Raoult's law & Henry's Law. Thermodynamic derivation of colligative properties of solution (using chemical potentials) and their inter-relationships. Abnormal colligative properties.	7
Unit IX: Partial molar quantities	Fugacity, activity coefficients and concept of chemical potential: Gibbs Duhem equation and Duhem-Margules equation: their use and application, Enthalpy, free energy and entropy of mixing, excess thermodynamic functions.	8
Laboratory Course III	**Group A** (a) Acid-base titration: estimation of carbonate, bicarbonate and hydroxide. (b) Redox titration: estimation of Fe(II) using standardised $KMnO_4$ solution. (c) Determination of water of crystallisation of Mohr Salt using standardised $KMnO_4$ solution. (d) Estimation of Fe(II) with $K_2Cr_2O_7$ using internal indicator (diphenylamine). **Group B** (a) Identification of functional groups in a given organic sample: Simple functional groups such as alcohols, phenols, amines, nitro, carbonyl and carboxylic acid groups. (b) Prepare derivatives of a given organic sample containing single functional group (i.e. alcohols, phenols, amines, nitro, carbonyl and carboxylic acid group). **Group C** (a) Determine the surface tension of a given solution at room temperature using a stalagmometer. (b) Determine the viscosity of a liquid at a given concentration at laboratory temperature, by viscometer. (c) Determine the composition of a given liquid mixture by viscosity method. (d) Study the variation of viscosity of sucrose solution with the concentration of the solute. (e) Compare the strengths of HCl and H_2SO_4 by studying kinetics of hydrolysis of methylacetate. (*Students need to perform at least three experiments from Group A and C. Group B is compulsory.*)	30

Text/ Reference Books:	1. General and Inorganic Chemistry, R.P. Sarkar (part 1), 3rd edition, NCBA. 2. Concise Coordination Chemistry, R. Gopalan, V. Ramalingam, 1st edition, Vikash Publishing House. 3. Inorganic Chemistry (Principles of Structure and Reactivity), J. E. Huheey, E. A. Keiter, R. L. Keiter, O. K. Medhi, 5th edition, Pearson Education. 4. Principles of Physical Chemistry, Puri, Sharma, Pathania, 48th edition, Vishal Publishing House. 5. Atkins Physical Chemistry, Atkins, de Paula and Keeler, 11th edition, Oxford University Press. 6. March's Advanced Organic Chemistry: Reactions, Mechanisms, and Structure, Michael B. Smith 7th edition (Wiley). 7. Organic Chemistry, Volume 1, I. L. Finar, 5th edition. 8. Organic Chemistry, L. G. Wade Jr., Maya Shankar Singh, 6th edition. 9. Organic Chemistry, P. Y. Bruice, 8th edition, Pearson Eduacation.	